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DEPARTMENT OF CIVIL ENGINEERING

OPTION: CONSTRUCTION TECHNOLOGY

FINAL YEAR PROJECT

STRUCTURAL DESIGN OF G+2 BUILDING APARTMENT CASE STUDY AT KICUKIRO DISTRICT RWANDA

Submitted in partial fulfillment of the requirement of the award of Advanced Diploma in Construction Technology.

Submitted By:

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Kigali, October, 2024

DECLARATION

I, Niyitegeka Elyse, hereby declare that this project report entitled "Structural Design of G+2 Building Apartment: Case Study of Kicukiro District, Rwanda" is my original work and has not been submitted previously for any degree or diploma at any other institution. All sources of information have been duly acknowledged.

APPROVAL

This is to certify that the project report entitled "Structural Design of G+2 Building Apartment: Case Study of Kicukiro District, Rwanda" submitted by Niyitegeka Elyse in partial fulfillment of the requirements for the degree of Advanced Diploma has been approved by the undersigned.

Supervisor's name: Mr. Emmanuel Nsengiyumva

Signature ……………………

Date ………………… ………

DEDICATION

This project is dedicated to my beloved family, whose unwavering support and encouragement have been my greatest source of strength. To my friends and mentors, thank you for your guidance and inspiration throughout this journey.

May God bless you all.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my supervisor, Mr. Emmanuel Nsengiyumva, for his invaluable guidance, support, and encouragement throughout the course of this project. His expertise and insights have been instrumental in shaping the direction and outcome of my work.

I am also grateful to the faculty and staff of ULK (Université Libre de Kigali) for providing the necessary resources and a conducive environment for my research. Special thanks to my family and friends for their unwavering support and understanding during this challenging period.

Lastly, I extend my appreciation to all those who have directly or indirectly contributed to the successful completion of this project.

ABSTRACT

This project presents the structural design of a G+2 building apartment located in Kicukiro District, Rwanda. The design process involves site analysis, conceptual design, detailed architectural planning, and structural analysis using advanced software tools such as ArchiCAD 2024and Prokon. The project aims to create a functional and aesthetically pleasing residential building that adheres to local building codes and regulations. Key aspects of the design include load calculations, material selection. The outcome of this project provides a comprehensive blueprint for the construction of a sustainable and efficient residential building.

LIST OF SYMBOLS AND 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 transmitted 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

Δbalancing shear force

Φ: Diameter of steel reinforcement expressed in (mm)

y: unite weight

λ: Ratio chooses the type of panel

λ: Slenderness ratio

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

ξR: the maximum value of ξ

φ: Coefficient used to consider the column slenderness and the constructioninaccuracies.

ULK: Université Libre de Kigali

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CHAPTER ONE: GENERAL INTRODUCTION

1.1. Introduction

This chapter comprises the background of the study, problem statement, research objectives, significance of the research, scope of the research and, finally the structure of the research

1.2. Background of the study

Kicukiro District, located in the vibrant city of Kigali, Rwanda, is experiencing significant growth due to its strategic position and increasing population, which has resulted from urban migration. This surge has created a pressing demand for housing, prompting both local authorities and the government to implement various initiatives aimed at increasing housing supply to meet the needs of the community. As the architectural landscape of Kicukiro evolves, existing residential designs reflect a blend of traditional and modern styles, underscoring the necessity for culturally relevant and sustainable architecture in urban planning. This project aims to design a G+2 apartment building that addresses the urgent need for affordable housing, enhances community living, and integrates sustainable design practices. By contributing to housing solutions in Kicukiro, the project seeks to foster economic growth, promote social cohesion, and minimize environmental impact. Key research questions will explore the specific challenges the design aims to overcome and how it can encourage sustainability and community engagement.

1.3. Problem statement

The Kicukiro District of Kigali City is undergoing rapid urbanization, resulting in a significant increase in the demand for modern and sustainable housing. Despite this growth, there is a noticeable shortage of high-quality residential buildings that meet the needs of the urban population. Existing housing options often lack essential amenities, energy-efficient systems, and sustainable design practices, which are crucial for enhancing the quality of life and promoting environmental sustainability. This project aims to address these challenges by focusing on the structural design of a contemporary apartment building. The goal is to create a functional, aesthetically pleasing, and environmentally friendly living space that meets the diverse needs of residents. By integrating innovative design solutions and sustainable practices, this project seeks to provide a high- quality living environment that contributes positively to the urban landscape of Kicukiro District

1.4. Research objective

This research pursues the following objectives:

1.4.1. Main objective

The main objective is to do the structural design of G+2 building apartment in Kicukiro

1.4.2. Specific objectives

The specific objectives of this project were:

1. To prepare floor plans, sections, elevations, site plans and perspectives
2. To design the columns, beams, slab and stairs
3. To fill the gap by implementing a G+2 building apartment.

1.5. Significance of the research

1.5.1. Personal benefits

It is a normal practice for the final year students at ULK Polytechnic institute to work on a project related to our studies. The personal interest of the student in the subject of this research is also our devotion to participate in the sustainable development of our country.

This project allowed me to be familiarized with planning, design and analysis of structures for civil engineering software like ArchiCAD 24 and Prokon

1.5.2. Academic benefits

Practical Application of Knowledge: This project allows you to apply theoretical knowledge from your coursework to a real-world scenario, enhancing your understanding of architectural and structural principles.

Skill Development: You'll develop essential skills such as project management, problem-solving, critical thinking, and technical skills in design software like ArchiCAD, Prokon, or SketchUp.

1.5.3. Social benefits

- Community Building: Well-designed apartment buildings can foster a sense of community among residents. Shared spaces like gardens, playgrounds, and community halls encourage social interaction and community activities.
- Improved Living Standards: Providing modern, safe, and comfortable living spaces can significantly improve the quality of life for residents. This includes better sanitation, access to clean water, and reliable electric.

1.6. Scope of the research

This project deals with:

Super structural (upper aground lever structure) safety especially by doing architectural design and reinforced concrete structure design of vulnerable structure elements (columns, beams).

About architectural plans this project will only focus on apartment building it means that the planning of plans this project will only focus on apartment building, it means that the planning of outside will not be done. The other points also like, electricity, building cost estimate will not appear.

Limitations of the research

- Budget constraints might limit the scope of your research, particularly in terms of conducting extensive fieldwork or experiments Excessive printing and communication costs.
- Lack of availability of required literature.
- Unavailability of permission to do research in specific area.
- Limited time for research.

1.7. Structure of the research

The study will be structured in five main sections to clarify and coherently address all of the Honeycomb block tests.

CHAPTER ONE: General introduction that comprises Introduction, problem statement, research objectives, significance of the research, scope of the research and, finally the structure of the research

CHAPTER TWO: Literature review will talk about all the details and theories concerning elements and materials with their design formulas.

CHAPTER THREE: Methodology of the study which consists of the methods, procedures, the definitions of the instruments that will be used for the investigations and with the methods and techniques used to collect all the data required.

CHAPTER FOUR: Results and discussion which deals with the presentation, analysis, and interpretation of the findings.

CHAPTER FIVE: Conclusion and recommendations which is the last, presents conclusions, recommendation to state the output of the research.

CHAPTER TWO: LITERATURE REVIEW

2.1. Defnition

An apartment is a set of rooms forming an individual residence within a larger building. Typically, an apartment includes essential living spaces such as a kitchen, bathroom, living room, and one or more bedrooms. Apartments are designed to provide private living quarters for individuals or families within a shared structure.

2.1. Architectural Drawings

An architectural drawing is a technical illustration of a building or structure that visually communicates the design, layout, and construction details. These drawings are essential for architects, engineers, and builders to understand and execute the design accurately.

Architectural drawings are made according to a set of conventions, which include the following particular views:

2.1.1 Floor plan

In architecture and building engineering, a floor plan is a drawing to scale, showing a view from above, of the relationships between rooms, spaces, traffic patterns, and other physical features at one level of a structure. Dimensions are usually drawn between the walls to specify room sizes and wall lengths.

2.1.2 Sections

The term section typically describes a cut through the body of a building, perpendicular to the horizon line. A section drawing is one that shows a vertical cut transecting, typically along a primary axis, an object or building.

2.1.3 Elevations

Elevation drawings tend to flatten an object that has three dimensions by cutting or separating by cutting a representation of a portion of a building or object exposed when cut by an imaginary vertical plane so as to show its construction and interior. Architects also use the word elevation as a synonym for façade, so the north elevation is literally the north-facing wall of the building.

2.2. Structural Design

Structural engineering is a science and arts of planning, designing, and constructing safe economical structures that will serve their intended purposes. The structure engineering is concerned with the behaviors of structures such as buildings, roads, bridges, retaining walls, dams, and others are composed by gathered of designed elements intended to receive and support load. In a framed structure the load is transferred from slab to beam, from beam to column and then to the foundation and soil below it.

2.2.1 The aim of design

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during design period. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and resistance to the effects of loads of misuse.

2.2.2 Column

A column or pillar in architecture and structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member.

2.2.3 Beam

A beam is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending. Beams are characterized by their manner of support, profile (shape of cross-section), length, and their material.

2.2.4 Slab

Slabs are horizontal structural elements in building floors and roof. They may carry gravity loads as well as lateral loads. The depth of the slab is usually very small relatively to its length and width.A concrete slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 100 and 500 millimeters thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving.

2.2.5 Foundation

A foundation (or more commonly, a base) is the element of structural structures, which connects it to the ground, and transfers loads from the structure to the ground. Foundations are generally considered either shallow or deep.

2.2.6 Footing

A concrete support under a foundation that rests in solid ground and is wider than the structure supported is called a footing. Footings distribute the weight of the structure over the ground.

2.3. Design Load Acting on the Structure

The types of loads acting on structures for buildings and other structures can be broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load and impact load. The horizontal loads comprise of wind load and earthquake load. The longitudinal loads i.e. tractive and braking forces are considered in special case of design of bridges, gantry girders etc. but also in our project we will consider the Service loads because are actual loads that the structure is designed to carry. The characteristic loads used in the design are the flowing: Dead load, imposed load and wind load which are provided by BS8110: Part1.

1.Types of Load

Dead load (gk)

The first vertical load that is considered is dead load. Dead loads are permanent or stationary loads which are transferred to structure throughout the life span. Dead load is primarily due to self-weight of structural members, permanent partition walls, fixed permanent equipment and weight of different materials. It majorly consists of the weight of roofs, beams, walls and column etc. which are otherwise the permanent parts of the building. The calculation of dead loads of each structure are calculated by the volume of each section and multiplied with the unit weight. The unit weights of some of the common materials are provided. (BS 6399 Part 1, 1996)

Imposed load or live load (qk)

The second vertical load that is considered in design of a structure is imposed loads or live loads. Live loads are either movable or moving loads without any acceleration or impact. These loads are assumed to be produced by the intended use or occupancy of the building including weights of movable partitions or furniture etc. Live loads keep on changing from time to time. The minimum values of live loads to be assumed it depends upon the intended use of the building. (BS 6399 Part 1, 1996)

Wind loads (wk)

Wind load is primarily horizontal load caused by the movement of air relative to earth. Wind load is required to be considered in structural design especially when the heath of the building exceeds two times the dimension transverse to the exposed wind surface. For low rise building say up to four to five stories, the wind load is not critical because the moment of resistance provided by the continuity of floor system to column connection and walls provided between columns are sufficient to accommodate the effect of these forces. The calculation of wind loads depends on the two factors, namely velocity of wind and size of the building. Complete details of calculating wind load on structures are provided by

Load combinations for the ultimate state

Various combinations of the characteristic values of dead load Gk imposed load Qk, wind load Wk and their partial factors of safety must be considered for the loading of the structure. The partial factors of safety specified by BS 8110. Also, are in table 2.2 of Partial factors of safety for loadings from (W.H Mosley, J.H. Bungey, 1987)

for the ultimate limit state, the loading combinations to be considered are as follows:

- Dead and imposed load l.4 Gk + 1.6 Qk
- Dead and wind load 1.0Gk + l.4Wk
- Dead, imposed and wind load 1.2Gk + 1.2Qk + 1.2Wk

2.3.1. Reinforced Concrete Properties

Concrete is arguably the most important building material, playing a part in all building structures. Its virtue is its versatility, i.e. its ability to be molded to take up the shapes required for the various structural forms. It is also very durable and fire resistant when specification and construction procedures are correct. Concrete can be used for all standard buildings both single story and multistory and for containment and retaining structures and bridges.

There are two main materials that make concrete strong such as concrete and steel, consider some of the widely differing properties of these two materials that are listed in table below:

Reinforced Concrete Slab

Reinforced concrete slabs are used in floors, roofs and walls of buildings and as the decks of bridges. The floor system of a structure can takes many forms such as in situ solid slabs, ribbed slabs or precast units. Slabs may span in one direction or in two directions and they may be supported on monolithic concrete beams, steel beams, walls or directly by the structure's columns. (W.H Mosley, J.H.Bungey, 1987)

a) One-way slab

The slab is called one way when $\frac{Ly}{Lx} > 2$ where ly is length of longer side s and lx is length of shorter side $\frac{Ly}{Lx} > 2$ is delivered from BS 8110, part 1997.

The one-way slab can be designed in two ways such as:

1. Single span one-way slab is simply in designing.

2. Continuous one-way spanning slabs should in principle be designed to withstand the most unfavorable arrangements of loads, in the same manner as beams.

- Characteristic imposed load Qk may not exceed characteristic dead load Gk;
- Loads should be substantially uniformly distributed over three or more spans;
- Variations in span length should not exceed 15 % of longest.
- In a one-way slab, the area of each bay < 30 m^2

Procedures of designing a slab

- Determine a suitable depth of the slab
- Determination of load.
- Determination of moments
- Calculate main reinforcement and secondary reinforcement areas.
- Check critical shear stresses.
- Check detailing requirements.

1. Loadings

n= (1.4Gk +1.6Qk) x A Where A= width of slab ×span (A is influence area)

Moment (M) =(M) $= \frac{nL}{8}$ where M is the moment caused by applied load on the structure another hand is called applied moment.

Ultimate designed moment (Mu): is the ability of structure to resist to applied moment.

$Mu = 0.156fcu * b * d^2$ by having Mu and M we check if the member need Compression reinforcements

the following are how the check is done:

$M > 0.156fcu * b * d^2$ Compression reinforcements are required

$M < 0.156fcu * b * d^2$ Compression reinforcements are not required

Where b and d are width and effective depth of the member respectively.

- **formulas used to find Steel reinforcement**

$K = \frac{M}{f_{cu}bd^2}$; if K>0.156 Compression reinforcements are required and K<0.156 Compression reinforcements are not required

$Z = d\left[0.5 + \left(\sqrt{0.25 - \frac{K}{0.9}}\right)\right]$ where $0.775d < Z < 0.95d$ and the transverse reinforcement are calculated from this formula $A_S = \frac{M}{0.87fyZ}$ known as main steel bars. In the case where Compression reinforcements are required the flowing formula are used: $A'_S = \frac{(M - 0.156f_{cu} * b * d^2)}{0.87f_y(d - d')}$ (for compression reinforcement)

$A_S = \frac{0.156f_{cu}b * d^2}{0.87f_y * z} + A'_S$ (for tension reinforcements)

$\frac{0.13bh}{100} = \text{The minimum area of reinforcement for high yield steel.}$

$\frac{0.24bh}{100} = \text{The minimum area of reinforcement for mild yield steel.}$

if As < Asmin provide reinforcement corresponding to Asmin Provided by BS8110-1:1997, close 3.12.5

2. **Shear reinforcement formulas**

$v = \frac{V}{bd} < \text{The maximum allowable shear stress} = \text{Min}\left(\sqrt{0.8fcu} \text{ or } 5N/mm^2\right)$

and $\frac{100A_S}{bd}$ for calculation of **vc** **(**BS8110-1:1997, close 3.4.5.2)

To find shear reinforcement table 3.16 in BS8110-1:1997 is used and closes which are used in shear design are:3.4.5.8, 3.4.5.9 and 3.4.5.10 in BS8110-1:1997 (gupta, 2010)

3. **Deflection formulas**

Actual $\frac{\text{span}}{\text{effective depth}}$ and Steel service stress, fs is $fs = \frac{5}{8}fy\frac{\text{Area required}}{\text{Area provided}}$

$M.F = 0.55 + \frac{477 - fs}{120(0.9 + \frac{M}{bd^2})}$ and Hence permissible $\frac{\text{span}}{\text{effective depth}}$ = basic ratio × M.F

In checking deflection, the tables in BS8110-1:1997 are conducted: table 3.9, 3.10 and 3.11

b) Two-way slab:

The slab is called two way when $\frac{Ly}{Lx} < 2$.

Steps of designing two-way slab (BS 8110.)

1. Design Moments

The maximum design moments per unit width of rectangular slabs of shorter side Lx and longer side Ly are given below:

Shorter spanning side: Msx= Bsx×n×lx^2 and longer spanning side: Msy= Bsy × n × $lx^{2.}$

So, after getting moment on longer and shorter side to find reinforcement is the same as one-way slabs but in two way provide reinforcement along shorter and longer direction. The coefficient Bsx and Bsy are provided by BS 8110-1:1997 close:3.5.3.7 in table 3.14

2. Design for Shear

Shear is checked along both directions x and y

$$\mathrm{Vsx} = \beta \mathrm{vx} * \mathrm{n} * \mathrm{lx} \qquad \mathrm{Vsy} = \beta \mathrm{vy} * \mathrm{n} * \mathrm{lx}$$

The coefficient Bvx and Bvy (BS 8110-1:1997 close: 3.5.3.7 in table 3.15)

Shear reinforcements are designed in the following way and using these formulas:

$\mathrm{v} = \frac{\mathrm{v}}{\mathrm{bd}} < 0.8\sqrt{\mathrm{fcu}}$ And calculate $\frac{100\mathrm{As}}{\mathrm{bd}}$ (This ratio gives the value to be used while calculating of shear force in concrete (vc).

vc=$\sqrt[3]{\mathrm{fcu}}/25$*factor given by $\frac{100\mathrm{AS}}{\mathrm{bd}}$

Shear reinforcement are required when shear stress of the steel bars is greater than that of concrete vc <v and are not required if the shear stress in concrete is greater than that of steel reinforcements

3 Design of reinforcement bars

Assume diameter of main steel and secondary steel then provide effective depth (d) on both sides. Moment of resistance (Mu) =$0.156\mathrm{fcubd}^2$ where $\mathrm{k} = \frac{\mathrm{M}}{\mathrm{f_{cu}bd^2}}$;

$\mathrm{Z} = \mathrm{d}[0.5(\sqrt{0.25 - \mathrm{K}/0.9})]$And $\mathrm{A_S} = \frac{\mathrm{M}}{0.87\mathrm{fyZ}} \geq \mathrm{Asmin} = 0.13\%\mathrm{bh}.$

if As < Asmin provide reinforcement corresponding to Asmin

Provided by BS8110-1:1997, close 3.12.5

4. Design of steel for shear force

$$\mathrm{v} = \frac{\mathrm{V}}{\mathrm{bd}} < \text{The maximum allowable shear stress} = \mathrm{Mix}\left(\sqrt{0.8\mathrm{fcu}} \text{ or } 5\mathrm{N/mm^2}\right)$$

and $\frac{100\mathrm{A_S}}{\mathrm{bd}}$ for calculation of $\mathbf{vc}$

5. Deflection check

The deflection is found in the mid-span and is done by using bending moment.1/d = 26

$$\text{Actual} \frac{\text{span}}{\text{effective depth}}, \quad \mathrm{M.F} = 0.55 + \frac{477 - \mathrm{fs}}{120\left(0.9 + \frac{\mathrm{M}}{\mathrm{bd^2}}\right)} \mathrm{fs} = \frac{5}{8}\mathrm{fy}\frac{\text{Area required}}{\text{Area provided}}$$

And $\frac{\text{permissible span}}{\text{effective depth}}$ = basic ratio × MF

If M.F > 2 take 2 to calculate permissible ratio = (1/d) * 2 or M.F and if the permissible ratio is greater than the real ratio, the section of the slab is enough and adequate hence there is no deflection.

6. Crack check: The code of practice also states that the distance between the steel bars may be greater than 3d in order to prevent cracks in the slab. In general reinforcement spacing rules is given by close 3.12.11 in BS8110-1:1997

2.2.6.2 Reinforced Concrete Beam

Reinforced concrete beam is a typically a concrete beam that is reinforced by steel and supports large weight loads on a vertical scale.

Reinforced concrete beam design consists primarily of producing member details which will adequately resist the ultimate bending moments, shear forces and torsional moments. At the same time serviceability requirements must be considered to ensure that the member will behave satisfactorily under working loads. (W.H Mosley, J.H.Bungey, 1987)**.** According to (Chanakya Arya 1997**)**, beams in reinforced concrete structures can be defined according to:

1. Cross-section.

2. Position of reinforcement.

3. Support conditions.

The following are three basic design stages have to be considered (W.H Mosley, J.H.Bungey, 1987)

1. Preliminary analysis and member sizing.

2. Detailed analysis and design of reinforcement.

3. Serviceability calculations.

Types of beam section

The three common types of reinforced concrete beam section are

1. Rectangular section with tension steel only (this generally occurs as a beam section in a slab)

2. Rectangular section with tension and compression steel

3. Flanged sections of either T or L shape with tension steel and with or without compression

steel

A. Rectangular section with tension steel only

All beams may fail due to excessive bending or shear. In addition, excessive deflection of beams must be avoided otherwise the efficiency or appearance of the structure may become impaired.

1. Area of tension reinforcement (As)

The preliminary analysis need only provide the maximum moments and shears in order to ascertain reasonable dimensions. Beam dimensions required are

(1) Cover to the reinforcement.

(2) Breadth (b)

(3) Effective depth (d)

(4) Overall depth (h).

The overall depth of the beam is given by: h =d +Cover + t (W.H Mosley, J.H.Bungey, 1987)

Moment (M) =(M) $= \frac{\mathrm{nL}}{8}$

Ultimate designed moment (Mu): is the ability of structure to resist to applied moment.
$\mathrm{Mu} = 0.156\mathrm{fcu} * \mathrm{b} * \mathrm{d}^2$ by having Mu and M we check if the member need Compression reinforcements
the following are how the check is done:
$\mathrm{M} > 0.156\mathrm{fcu} * \mathrm{b} * \mathrm{d}^2$ Compression reinforcements are required
$\mathrm{M} < 0.156\mathrm{fcu} * \mathrm{b} * \mathrm{d}^2$ Compression reinforcements are not required
Where b and d are width and effective depth of the member respectively.

- **formulas used to find Steel reinforcement**

$\mathrm{K} = \frac{\mathrm{M}}{\mathrm{f_{cu}bd}^2}$; if K>0.156 Compression reinforcements are required and K<0.156 Compression reinforcements are not required

$\mathrm{Z} = \mathrm{d}\left[0.5 + \left(\sqrt{0.25 - \frac{\mathrm{K}}{0.9}}\right)\right]$ where $0.775\mathrm{d} < \mathrm{Z} < 0.95\mathrm{d}$

$\mathrm{A_S} = \frac{\mathrm{M}}{0.87\mathrm{fyZ}}$

B. Rectangular section with tension and compression steel

In the case where Compression reinforcements are required the flowing formula are used:

$A'_S = \frac{(M-0.156 f_{cu}*b*d^2)}{0.87 f_y (d-d\prime)}$ (for compression reinforcement)

$A_S = \frac{0.156 f_{cu} b*d^2}{0.87 f_y * z} + A'_S$ (For tension reinforcements)

By neutral axis lies in the flange

The following formulas are used in calculation of area of reinforcement:

$K = \frac{M}{f_{cu} bd^2}$, then the moment arm $Z = d[0.5 + (\sqrt{0.25 - K/0.9})] \leq 0.95d$, the deep of the neutral axis $x = \frac{1}{0.45}(d - z)$ and the deep of the compression block is a= 0.9x.

If a ≤ hf, the procedures of calculations are the same as rectangular beam design. Taking the width of the beam as $\mathbf{b_f}$.

If compression reinforcement is required, the flowing formula are critical:

If $a > hf$ when $M \leq \beta ffcubd^2$ and $hf \leq 0.45d$, then $As = \frac{M+0.1fcubd(0.45d-hf)}{0.87fy(d-0.5hf)}$ where

$Bf = 0.45\frac{hf}{d}(1 - \frac{bw}{b})(1 - \frac{bf}{2d}) + 0.15\frac{bw}{b}$

Otherwise the calculation has two parts. The first part is for balancing the compressive force from the flange, C_f, and the second part is for balancing the compressive force from the web, C_w. the ultimate resistance moment of the flange is given by: $Mf = 0.45fcu(bf - bw)hf(d - 0.5hf)$.The moment taken by the web is computed as: $Mw = M - Mf$and the normalized moment resisted by the web is given by: $Kw = Mw/fcubwd^2$.

If $Kw \leq 0.156$ the beam is designed as a singly reinforced concrete beam. The reinforcement is calculated as the sum of two parts, one to balance compression in the flange and one to balance compression in the web.

$As = \frac{Mf}{0.87fy(d-0.5hf)} + \frac{Mw}{0.87fyZ}$ Where $Z = d[0.5 + (\sqrt{0.25 - K/0.9})] \leq 0.95d$

If Kw > K', compression reinforcement is required. The ultimate moment of resistance of the web only is: $Muw = K'fcubwd^2$

The compression reinforcement is required to resist a moment of magnitude $Mw - Muw$. If compression reinforcement is required the following formula are used to find its area:

$As' = \frac{Mu-M_{uw}}{fs' - (\frac{0.67fcu}{\gamma c})(d-d')}$ Where, **d'** is the depth of the compression reinforcement from the concrete compression face and $\mathbf{f'_{s=0.87}} f_y$ if $\frac{d'}{d} \leq \frac{1}{2}\left[1 - \frac{f_y}{800}\right]$

$f'_{s=E_s\varepsilon_c}\left[1-\frac{2d'}{d}\right]$ If $\frac{d'}{d}>\frac{1}{2}\left[1-\frac{f_y}{800}\right]$

2. Shear reinforcement formulas

$v=\dfrac{V}{bd}<$ The maximum allowable shear stress $=$ Min$\left(\sqrt{0.8fcu}\text{ or }5N/mm^2\right)$

and $\frac{100A_S}{bd}$ for calculation of **vc** (Provided by BS8110-1:1997, close 3.4.5.2)

To find shear reinforcement table 3.16 in BS8110-1:1997 is used and closes which are used in shear design are: 3.4.5.8, 3.4.5.9 and 3.4.5.10 in BS8110-1:1997

5. Deflection check

The deflection is found in the mid-span and is done by using bending moment.1/d = 26

Actual $\frac{\text{span}}{\text{effective depth}}$, $\text{M.F} = 0.55 + \frac{477 - \text{fs}}{120\left(0.9 + \frac{\text{M}}{\text{bd}^2}\right)}$ $\text{fs} = \frac{5}{8}\text{fy}\frac{\text{Area required}}{\text{Area provided}}$

And $\frac{\text{permissible span}}{\text{d}}$ = basic ratio × MF

If M.F > 2 take 2 to calculate permissible ratio = (1/d) * 2 or M.F and if the permissible ratio is greater than the real ratio, the section of the slab is enough and adequate hence there is no deflection.

Note about beam reinforcement

In accordance with BS8110: Part 1, clause 3.12.4.1, bars may be placed singly or in pairs or in bundles of three or four bars in contact. The minimum areas of reinforcement in a beam section to control cracking as well as resist tension or compression due to bending in different types of beam section are given in BS8110: Part 1, clause 3.12.5.3 and Table 3.2.7. The minimum spacing of bars is given in

2.2.6.3. Reinforced Concrete Column

Columns are structural members in buildings carrying roof and floor loads to the foundations. Columns primarily carry axial loads, but most columns are subjected to moment as well as axial load. the internal column is designed for axial load while edge columns and corner column are designed for axial load and moment. *(*T. J MacGinley &B.S. CHOO, 1997*)*

2.2.6.3.1 Classification of column

A column may be considered as a short when the ratios $\frac{\text{lex}}{\text{h}}$and $\frac{\text{ley}}{\text{b}}$ are less than 15(braced) and 10 (un braced). It should otherwise be considered as slender. Where

lex = effective height of the column in respect of the major axis (i.e. x-x axis).

ley = effective height of the column in respect of the major axis (i.e. y-y axis).

b: width of the column cross-section.

h: depth of the column cross-section.

The effective height (l_e) of a column in a given plane may be obtained from the flowing equation: $l_e=\beta l_o$, the value of β are given in table 3.19 and table 3.20 for braced and un braced columns respectively as a function of end conditions of the column and l_o is clear distance between end restrains, should not exceed 60 times the minimum thickness of a column.

(BS 8110-1:1997 clause: 3.8.1.6)

Practical design provisions

Columns with rectangular cross-sections should be reinforced with a minimum of four longitudinal bars, columns with circular cross-sections should be reinforced with a minimum of six longitudinal bars. Each of the bars should not be less than 12 mm in diameter. Where **Asc** the area of steel in compression and **Acc** is the area of concrete in compression. **(BS 8110-1:1997 clause: 3.12.5.4)**

1. **Area of reinforcement**

The code recommends that for columns with a gross cross-sectional area **Acol**, the area of longitudinal reinforcement (**Asc**) should lie within the following limits: 0.4%Acol ≤ Asc ≤ 6%Acol in a vertically cast column and 0.4%Acol ≤ Asc ≤ 8%Acol in a horizontally cast column. At laps the maximum area of longitudinal reinforcement may be increased to 10 per cent of the gross cross-sectional area of the column for both types of columns **(**BS 8110-1:1997 clause: 3.12.5)

2. **Design for links**

The diameter of links should not be less than 6 mm or one-quarter of the diameter of the largest longitudinal bar; or 0.25 times the largest bar diameter, the maximum spacing is to be 12 times the diameter of the smallest longitudinal bar in column.

Design of the column according to loading condition

Short columns are divided into three categories according to the degree of eccentricity of the loading as described in the flowing sections:

1. Columns resisting axial loads only;
2. Columns supporting an approximately symmetrical arrangement of beams
3. Columns resisting axial loads and uniaxial or biaxial bending.

- **Short Braced Axially Loaded Columns**

This type of column can occur in precast concrete construction when there is no continuity between the members. When the load is perfectly axial the ultimate axial resistance is N=O.45fcuAc +O.87fyAsc. Perfect conditions never exist and to allow for a small eccentricity the ultimate load should be calculated from: N=O.4fcuAc +O.75fyAsc

- **Short Braced Columns Supporting an Approximately Symmetrically Arrangement of Beams**

The moments on these columns will be small and due primarily to unsymmetrical Arrangements of the live load. The ultimate load that can be supported should then be taken as

N= 0.35fcuAc + 0.67fyAsc

- **Short Columns Resisting Moments and Axial Forces**

The area of longitudinal steel for these columns is determined by:

(1) Using design charts or constructing M-N interaction diagrams

(2) A solution of the basic design equations,

(3) An approximate method.

- **Biaxial Bending of Short Columns**

For most columns, biaxial bending will not govern the design. The loading patterns necessary to cause biaxial bending in a building's internal and edge columns will not usually cause large moments in both directions. Corner columns may have to resist Significant bending about both axes, but the axial loads are usually small and a design similar to the adjacent edge columns is generally adequate. In case the column is subjected to the bending in two directions, it is said to be biaxial bending **so** the following equations may be used.

1) $\text{for}\,\frac{\text{Mx}}{\text{h}'} \geq \frac{\text{My}}{\text{b}'}\ \text{thus Mx}' = \text{Mx} + \beta\frac{\text{h}'}{\text{b}'} * \text{My}$

2) $\text{for}\,\frac{\text{Mx}}{\text{h}'} < \frac{\text{My}}{\text{b}'}\ \text{thus My}' = \text{My} + \beta\frac{\text{h}'}{\text{b}'} * \text{Mx}$

Where: h′: effecteve depth

b′: Effective width

β: Coefficient obtained from table 3.22 in BS 8110-1:1997

(W.H Mosley, J.H.Bungey, 1987)**,** (BS 8110-1:1997 clause: 3.8.4.5)

2.2.6.4. Reinforced Concrete Stair

Stair is a set of steps which leads from one level of building to another. Stair provides means of movement from one floor to another in a structure. Staircases consist of a number of steps with landings at suitable intervals to provide comfort and safety for the users. Stairs are other types of slabs whose use is to connect the different floors of the structure. They are designed in the same way as beams by considering a unit width of the slabs. The stairs have main three parties that are: (1) Tread, (2) Riser and (3) Waist

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

1. Those spanning horizontally in the transverse direction.

2. Those spanning longitudinally.

The design of the stairs is the same as for one-way slab. The following information is required during designing the reinforced concrete stair:

- Waist, tread, riser, concrete cover and bar diameter.
- Vertical desistance from landing up to top slab (vertical distance).
- The part above the landing up to the slab (horizontal distance)
- Slop distance of the stair must be calculated
- The moment is calculated by $M = \frac{Fl}{8}$
- $N = 1.4Gk + 1.6Qk$ where Imposed loading on the stair is given in BS 6399, Part 1, table 1
- $Z = d[0.5 + (\sqrt{0.25 - K/0.9})]$ and $A_S = \frac{M}{0.87f_{y*z}}$

2.2.6.5. Reinforced Concrete Foundation Design

Foundations are required primarily to carry the dead and imposed loads due to the structure's floors, beams, walls, columns, etc. and transmit and distribute the loads safely to the ground. The purpose of distributing the load is to avoid the safe bearing capacity of the soil being exceeded otherwise excessive settlement of the structure may occur. There are many types of foundations which are commonly used, namely strip, pad and raft

Pad footing design

The general procedure to be adopted for the design of pad footings is as follows:

1. Calculate the plan area of the footing using serviceability loads.

2. Determine the reinforcement areas required for bending using ultimate loads.

3. Check for punching, face and transverse shear failures.

- **Plan area**

Plan Area $= \frac{\text{N}}{\text{Soil bearing capacity}}$ Where N=1.0GK+1.0QK (serviceability load).

- **Design for reinforcement**

Earth pressure Ps $= \frac{\text{N}}{\text{Plan area}}$ where $\text{M} = \frac{\text{Ps}*\text{l}^2}{2}$ and N=1.4GK++1.6QK

Ultimate design moment Mu $= 0.156\text{fcubd}^2 \geq \text{M} = \frac{\text{Ps}*\text{l}^2}{2}$

$\text{K} = \frac{\text{M}}{\text{fcubd2}}$ And $\text{Z} = \text{d}\,[0.5 + (\sqrt{}\,(0.25 - \text{K}/0.9)] \leq 0.95\text{d}$ then $\textbf{AS} = \frac{\mathbf{M}}{\mathbf{0.87fyz}}$

The reinforcements are provided in footing according to BS 8110-1:1997, clause 3.11.3.2.

- **Design for shear**
  - **Punching shear**

Critical perimeter, pcrit, is= column perimeter + 8 × 1.5d

Area within perimeter is= $(c + 3d)^2$ where c is side of column

Ultimate punching force, V, is V = load on shaded area

Design punching shear stress,v=$\frac{\text{V}}{\text{Pcrit}*\text{d}}$ and design concrete shear stress= $\frac{100\text{As}}{\text{bd}}$

vc is shear resistance where $\text{vc} = \sqrt[3]{}\,(\text{fcu}/25)$ × value of design concrete shear stress.

The footing is satisfactory if vc ≥ v, if shear reinforcement is required refer to BS8110-1:1997 clause 3.7.7.5.

  - **Face shear**

Maximum shear stress (υmax) occurs at face of column. Hence Vmax $= \frac{\text{W}}{\text{columnperimeter}\times\text{d}}$

The footing is satisfactory if Vmax< permissible (0.8×√fcu).

  - **Transverse shear**

Ultimate shear force (V) = load on shaded area = Ps ×area and design shear stress

$\text{v} = \frac{\text{V}}{\text{bd}} \leq$ vc, (BS8110-1:1997), (Chanakya Arya, 2008).

- **Cracking check**

The rules for slabs in BS8110-1:1997 clause 3.12.11.2.7. The bar spacing is not to exceed 3d or 750 mm. The minimum grade of concrete to be used in foundations is grade 35. (BS8110-1:1997, Clause 3.3.1.4) states that the minimum cover should be 75 mm if the concrete is cast directly against the earth or 40 mm if cast against adequate blinding. Table 3.2 of the code classes non-aggressive soil as a moderate exposure condition.

CHAPTER THREE: METHODOLOGY

In this chapter, I will outline the methodology devised to achieve the specific objectives of my project, which involves the architectural and structural design of a G+2 apartment building in the Kicukiro district of Rwanda. The methodology is crucial as it provides a systematic approach to the research and design processes, ensuring that the project objectives are met efficiently and effectively. The chapter will cover the research design, data collection methods, data analysis techniques, and the design methodology for both architectural and structural aspects. By following this structured approach, I aim to produce a comprehensive and well-supported design that meets the required standards and addresses the project's goals.

3.1. Choice of methodology

For this project, the chosen methodology involves several key steps: conducting a comprehensive literature review on sustainable architectural practices and structural design principles, performing a detailed site analysis of the Kicukiro district, and developing architectural and structural designs using software tools like AutoCAD and Revit. Data will be collected through surveys and interviews to understand community needs, and the designs will be evaluated for feasibility and sustainability. An implementation plan will be created, followed by seeking feedback from experts and stakeholders to refine the final design.

3.2. Techniques and methods used for data collection

3.2.1. Techniques

3.2.1.1. Documentation

Documentation is a crucial data collection technique. It involves systematically recording all relevant information, such as field notes from site visits, photographs, design drawings, and meeting minutes. This method ensures a comprehensive and detailed record of the research process, enhancing the credibility and reliability of the findings. By organizing and analyzing these documents, you can extract meaningful insights and maintain transparency throughout the architectural and structural design of the apartment building in Kicukiro.

3.2.1.2. Observation

observation is a key data collection technique. It involves systematically watching and recording the site conditions, construction activities, and community interactions. By directly observing these elements, you can gather firsthand, accurate data that provides deep insights into the practical aspects of the architectural and structural design of the apartment building in Kicukiro.

3.2.2. Methods

In general, quantitative and qualitative methods are used in research project. In this project we use quantitative method.

3.2.2.1. Quantitative methods

Quantitative research involves the systematic and scientific examination of numerical properties, phenomena, and their interrelationships. Its primary goal is to develop and utilize mathematical models, theories, and hypotheses related to natural phenomena. Measurement plays a crucial role in quantitative research as it bridges the gap between empirical observations and the mathematical representation of quantitative relationships.

3.3. Site survey

Different methods are used in site survey:

3.3.1. Geotechnical survey

The structural design of reinforced concrete structures includes an analysis of bearing capacity. In certain situations, bearing capacity is particularly relevant, necessitating data on soil properties, especially soil strength. These properties are typically determined during the site investigation process and can be confirmed through laboratory testing of the soil.

3.3.2. Environment survey

In this type of surveying, different techniques are used in order to collect information:

- Observation;
- Interview.

The environmental survey aimed to assess the potential impacts of the G+2 apartment building in Kicukiro. A structured questionnaire was developed and pilot tested to ensure clarity. The survey targeted local residents using random sampling to ensure representativeness. Data was collected both online and in-person over two weeks. Quantitative data was analyzed statistically, while qualitative responses were thematically analyzed. Ethical considerations included informed consent and confidentiality. The findings were compiled into a report to inform sustainable design practices.

3.4. Software used

- Microsoft office:The Microsoft word and excel are of great help within this project in the writing of this research.
- AutoCAD 2010: AutoCAD and ArchiCAD are Computer-Aided Design (CAD) software applications used for 2D and 3D design and drafting. Developed and sold by Autodesk, these tools have been utilized to create various figures and drawings for this project

CHAPTER FOUR: RESULTS AND DISCUSION

4.1 Introduction

This chapter deals with interpretation according to the findings in the design of the structure. The main consideration in this design is to ensure against the failure of super-structure and to check if it has the ability to carry the anticipated loading with an adequate margin of safety, so that it does not deform excessively within service.

4.2 Analysis and interpretation

4.2.1. Structural drawing

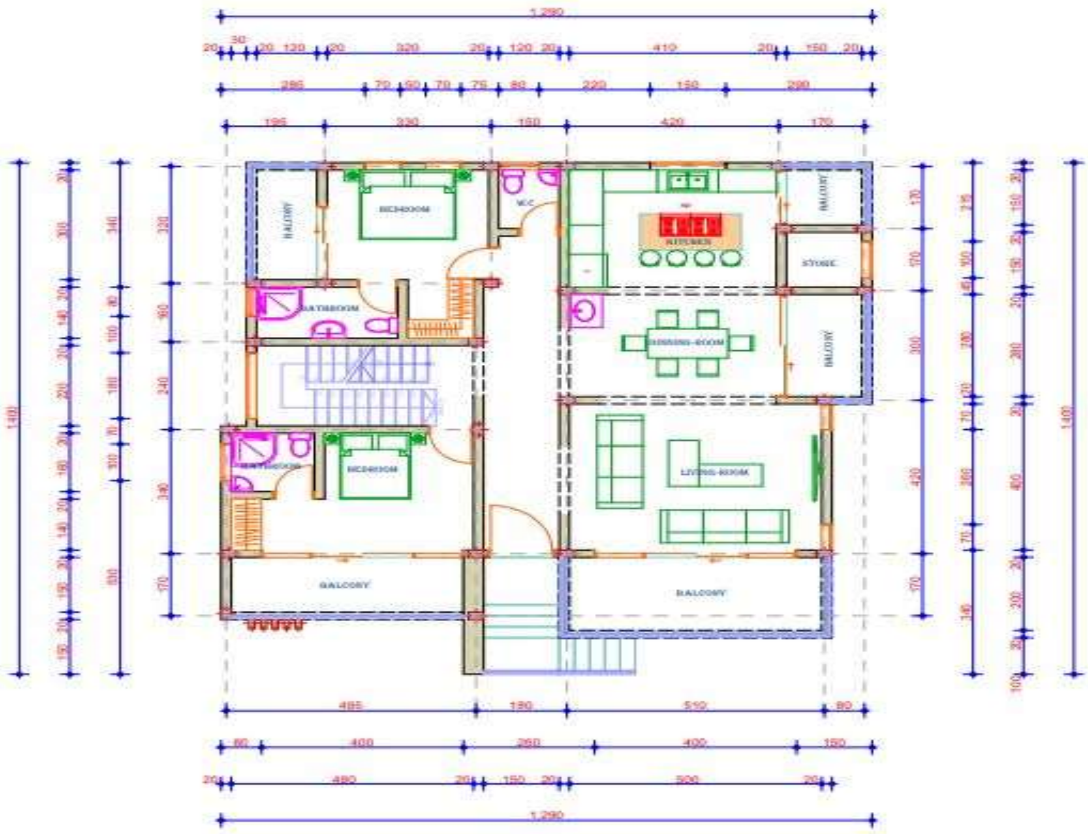


Figure 4. 1:Ground floor

4.2.2. Structure elements design

4.2.2.1. Slab design

Slab is designed by considering :

- critical panel from figure of structural plan.

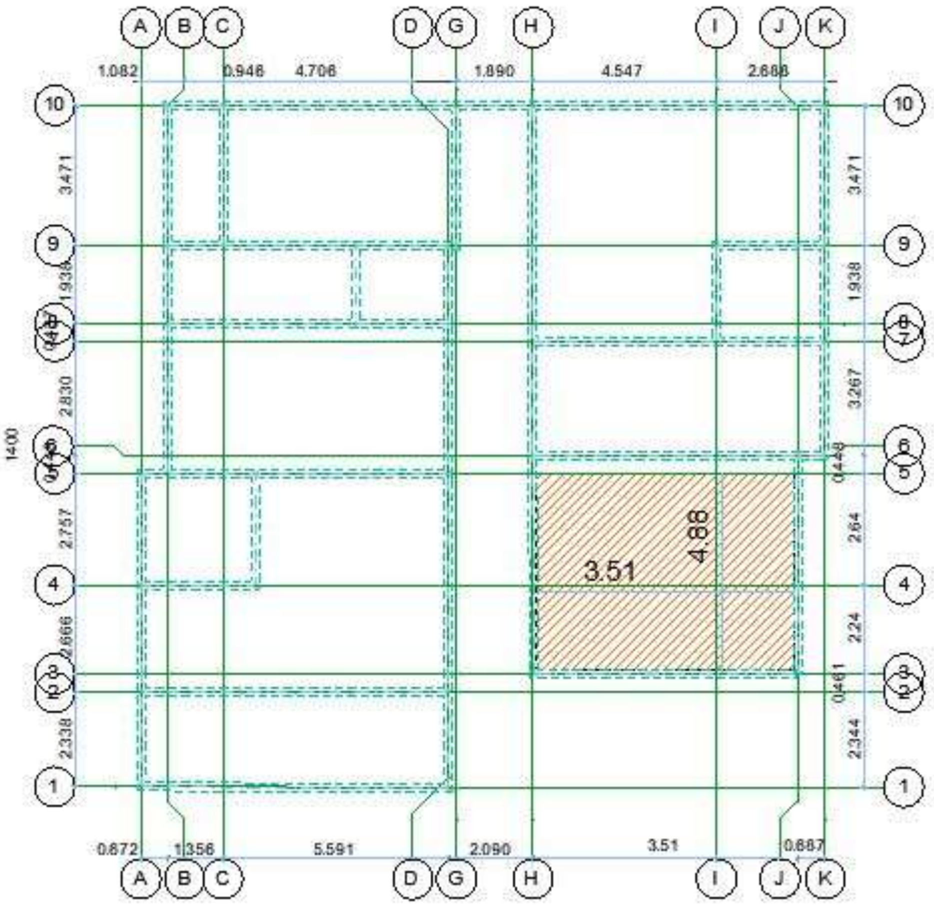
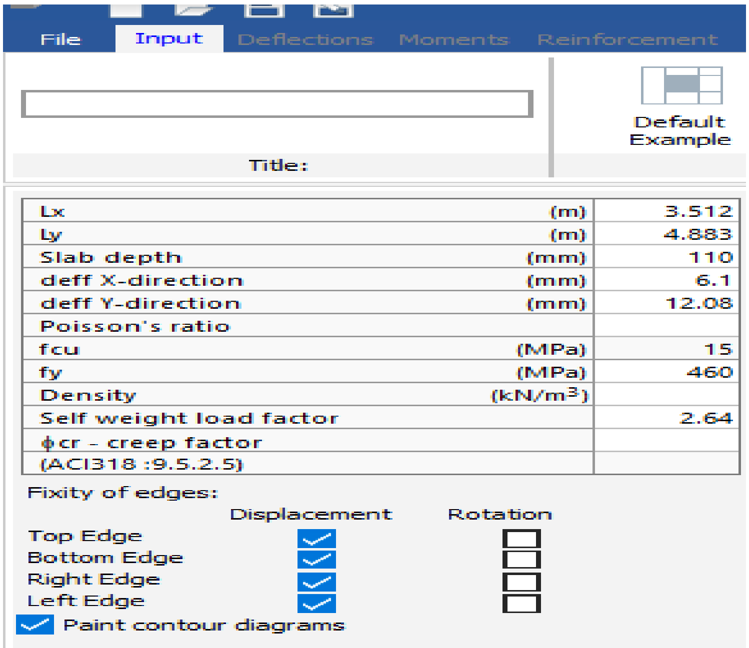


Figure 4. 2:Critical Panel from grid element

- Design parameters



File | Input | Deflections | Moments | Reinforcement

Title:

Default Example

Lx	(m)	3.512
Ly	(m)	4.883
Slab depth	(mm)	110
deff X-direction	(mm)	6.1
deff Y-direction	(mm)	12.08
Poisson's ratio		
fcu	(MPa)	15
fy	(MPa)	460
Density	(kN/m³)	
Self weight load factor		2.64
ϕcr - creep factor (ACI318 :9.5.2.5)		

Fixity of edges:

	Displacement	Rotation
Top Edge	☑	☐
Bottom Edge	☑	☐
Right Edge	☑	☐
Left Edge	☑	☐

☑ Paint contour diagrams

Table 4. 1:Design Parameters

- In design, British Standards should be followed. Here are the values from BS: 8110-1997
- The self-weight of the concrete: 24KN/m^3
- Unit weight of the wall: 18KN/m^3 (with burnt bricks made in clay
- The load due to the finishes: 1.5KN/m^2
- The live loads for the studio building: 2KN/m^2 (BS 8110, 1997).

During design, the ultimate design load is the combination of the live load and dead load. To get the dead load the following member dimensions are very useful.

For the slab:

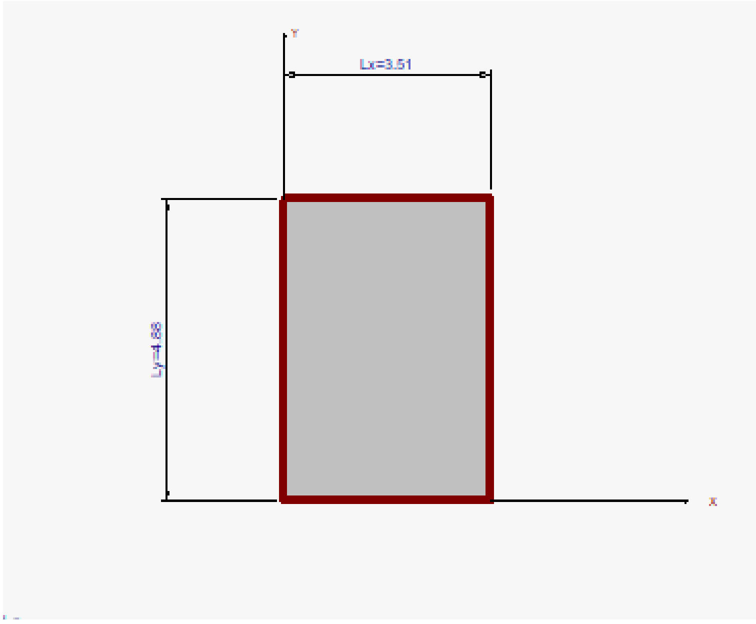


Figure 4. 3:Critical Panel

For all the reinforced concrete members, the cover to be consider is 25mm slab design

- **Data to be used**

Imposed loads (QK) = 2.0 KN/m2

fy= 460N/mm2

Depth of slab = 150mm = 15cm

Concrete cover = 25 mm

Finishes = 1.5KN/m2

f_{cu}= 30 N/mm2

- **Calculation of Loadings**

Self-weight of the slab= 24*1*1*0.15=3.6KNm^2

The total dead loads on the slab are the ∑of the self-weight of the slab and the finishes,

Total dead load (GK) =3.6+1.5=5.1KN/m^2

The ultimate design load due to the self-weight of the slab and the finishes, N=1.4Gk+1.6QK, N= (1.6*2) +(1.4*5.1) **=10.34KNm**

The total ultimate design load per 1m of width for the slab

N= 10.34KN/m^2 × 1m = 10.34KNm

N= 10.34KN/m^2 × 1m = 10.34KNm is two way spanning slab

$\frac{ly}{lx} = \frac{4.883}{3.512} = 1.4 < 2$, the slab is two way slab

Thickness of the slab lies in the range between

$\frac{lx}{40} \leq hf \leq \frac{lx}{20} \quad = \frac{3.512}{40} \leq hf \leq \frac{3.512}{20}$

8.78≤hf≤17.5, let take depth of slab =15cm

N= 10.34KN/m^2 × 1m = 10.34KNm

$\mathbf{M_{sXn}} = \boldsymbol{\beta}_{\mathbf{sXn}} \times \mathbf{n} \times \mathbf{l_x^2}$ negative moment in the direction of Lx at the support

$\mathbf{M_{syn}} = \boldsymbol{\beta}_{\mathbf{syn}} \times \mathbf{n} \times \mathbf{l_x^2}$ negative moment in the direction of Ly at the support

$\boldsymbol{M}\mathbf{s}_{\mathbf{xp}}$ **=** $\&_{sx}\boldsymbol{nl^2}\mathbf{x}$ positive moment in the direction of Lx at the mid span

$\boldsymbol{M}\mathbf{s}_{\mathbf{yp}}$ **=** $\&_{sy}\boldsymbol{nl^2}\mathbf{x}$ positive moment in the direction of Ly at the mid span

$\&_{sx}$**=0.099** $\&_{sy}$=0.051 βsx 0.050 βsy=0.032

Among all these moments exerting on the slabs, the moments to be used is that exerting on this Panel because it is the greatest and its details will be apply to all slab:

Then, for the support

$\boldsymbol{M}$**s**$_{\mathbf{xn}}$**=**0.050***10.34***3.512*3.512=6.34KNm

$\boldsymbol{M}$**s**$_{\mathbf{yn}}$=0.032***10.34***3.512*3.512=4.08KNm

For the mid span

$\boldsymbol{M}$**s**$_{\mathbf{xp}}$=0.099***10.34***3,512*3.512=12.62KNm

$\boldsymbol{M}$**s**$_{\mathbf{yp}}$=0.051***10.34***3.512*3.512=6.5KNm

For the support

The moments near the support is the hogging moments which means that the tensile stresses are acting at the top of the slab, thus the tensile reinforcements should be at the upper.

Reinforcement in the small span (Lx direction)

M$_{\mathbf{x}}$ **=6.1KNm**

The effective depth d=h-cover- Φ/2 =150-25-12/2=**119mm**

Where Φ is assumed reinforcement to be at the bottom=**12mm.**

The effective width b=1m=1000m, let calculate the lever arm Z,

Mu =0.156 fcubd^2 = [0.156x30x1000*(150^2) x10-$^6 KNm$

Mu =105.3KNm

$K = \frac{M}{Fcubd^2}$=$\frac{6.1*10^6}{30*1000*(150)^2}$=0.009

If (M=6.1KNm) <(Mu=105.3KNm) and K=0.009<0.156, thus no compression reinforcement required

The tensile reinforcement

$z = d(0.5 + \left(\sqrt{(0.25} - \frac{k}{0.9}\right)$ not greater than 0.95d

$z = (0.5 + (\sqrt{0.25 - \frac{0.009}{0.9}}$ =0.98d>0.95d,

then z=0.95d=0.95*119=**113.05mm**

The lever arm=**113.05mm**

$As = \frac{Mx}{0.95 * fy * z}$ $As = \frac{6.1*10^6}{0.95*460*113.05}$=106.27mm^2

The minimum area of reinforcement for high yield steel, $\boldsymbol{As_{min}}$=0.13%BH.

$\boldsymbol{As_{min}=\frac{0.13bh}{100} = \frac{0.13*10^3*150}{100} = 195mm^2}$

As min >As $\Longleftrightarrow$ **195mm^2<106.27mm^2**, thus we provide the reinforcement from As.

The tensile bars provided are **T10@300mm** with $\mathbf{A_s}$ **=261mm^2**(at the top) **13bars**

Here steel of 10mm diameter are used at 300mm spacing

Reinforcement in long span (Ly direction)

For the mid span in ly direction

M_x =12.08KNm

The effective depth d=h-cover- Φ/2 =150-25-12/2=**119mm** $z = d(0.5 +$

let calculate the lever arm Z, d= 150mm

$K = \frac{M}{Fcubd^2} = \frac{12.08*10^6}{30*1000*(150)^2}$=0.0178

As K=0.0178< 0.156, thus no compression reinforcement required in Ly direction.

The tensile reinforcement:

The lever arm $z = d(0.5 + \left(\sqrt{(0.25} - \frac{k}{0.9}\right)$

$z = 119(0.5 + (\sqrt{0.25 - \frac{0.009}{0.9}}$ =0.98d>0.95d, then z=0.95d=0.95*119**=113.05mm**

If (M=12.08KNm) <(Mu=105.3KNm) and K=0.009<0.156, thus no compression reinforcement required

$As = \frac{12.08*10^6}{0.95*460*75.05}$=368.33mm^2/m

The minimum area of reinforcement for high yield steel,

A_{smin}=0.13%bh $\boldsymbol{As_{min}} = \frac{\mathbf{0.13bh}}{\mathbf{100}} = \frac{\mathbf{0.13*10^3*150}}{\mathbf{100}} = \mathbf{195mm^2/m}$

thus, we provide the reinforcement from$\boldsymbol{A_s}$**.** The

Tensile bars provided are **T12@250mm** with $\boldsymbol{A_s}$**=452mm^2**. **21bars of short span**

Here steel of 12mm diameter are used at 250mm spacing

- **Design for Shear**

From table. Bvx= 0.43 and βvy =0.33

Vsx = βvx×n×lx= 0.43×8.996×3.512= **13.58KN** (**most critical**) and

Vsy= βvy×n×lx=0.33*8.996*3.512=10.42KN

$V = (\frac{V}{bd})^{1/3} = \frac{14.95*10^3}{10^3*150} = 0.099 < \sqrt{0.8fcu}\ or\ \frac{4.8N}{mm^2}$

$V = (\frac{100As}{bd})^{\frac{1}{3}} = \frac{100*186}{10^3*150} = 0.124$ The corresponding value is 0.67

$\frac{400}{d} = (3.63)^{1/4} = 1.38$ $(\frac{fcu}{25})^{1/3}$=1.06

$vc = \frac{0.79}{1.25} * (100As/bvd)^{\frac{1}{3}} * (\frac{400}{d})^{\frac{1}{4}} * (\frac{fcu}{25})^{1/3} \quad vc = 0.52\, {}^{N}/_{mm^2}$

$v < vc, 0.135 < 0.52$ Therefore, the beam is satisfactory to shear, no shear reinforcements required.

- **Deflection check**

$\frac{actual\ span}{\boldsymbol{d}} = \frac{\mathbf{3512}}{\mathbf{150}} = \mathbf{23.41}$ **Basic span/d=26 from (**Table 3.9 of BS 8110 part**)**

$M.FforAS = 0.55 + \frac{477-fs}{120\left(0.9+\frac{M}{bd^2}\right)} =\leq 2.0$ and $fs = \frac{5}{8} fy \frac{Arearequired}{Areaprovided}$

$fs = \frac{\mathbf{2*460*186}}{3*261} = 218.5$ and $\frac{M}{bd^2} = \frac{6.1*10^6}{1000*150^2} = 0.271$

$M.F = 0.55 + \frac{477-218.5}{120(0.9+0.504)} = 2.08 > 2$ So MF=2

$\frac{Permissiblespan}{effectivedepth} = basicratio * M.F$

$= 26 * 2 = 54$; Thus 54> 31.92 , therefore the floor is safe about deflection

- **Crack control**

Within BS 8810 Part 1 clause 3.12.11.2.7, this clause; slab states that the clear distance bars should not exceed 3d or 360 mm. Our spacing =**250 mm<360 mm ok. So our slab is safe for cracks.**

4.2.2.2 Beam design

The most loaded beam is that has a large influence area on it.

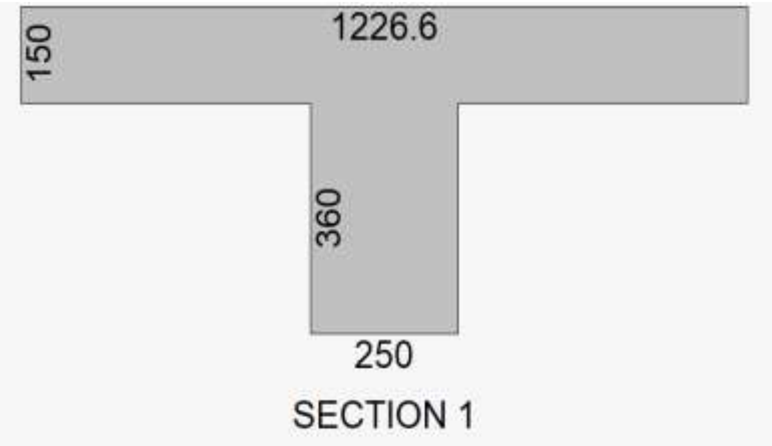


Figure 4. 4:Critical Beam A-B

For the first span

The length of the span L=3.551m

The self-weight of the beam=0.25×0.55×24=3.3KN/m

The self-weight of the slab= (0.11×24×6.35)/3.551=4.72KN/m

The self-weight of the wall= 0.2×2.4*2×18=17.28KN/m

The total finishes=1×6.35/3.551=1.788 KN/m

The total dead load per unit length g_k =3.3+4.72+17.28+1.788=27.08 KN/m

The live load per unit length q_k is = $Q_k \times \left(\frac{A}{L}\right) = 3 \times \left(\frac{6.35}{3.551}\right) = \frac{5.36\ KN}{m}$

Thus, the ultimate load exerting on the first span and fifth span is given by n=1.4g_k+1.6q_k

$$\boldsymbol{n} = (1.4 \times 27.08) + (1.6 \times 5.36) = \mathbf{46.488}\boldsymbol{KN/m}$$

For the second span

Influence area (A) is 9.94m^2

The length of the span L=4.566m

The self-weight of the beam=0.25 ×0.55×24=3.3KN/m

The self-weight of the slab= (0.11×24×9.94)/4.566=5.74 KN/m

The self-weight of the wall= 0.2×2.4*2×18=17.28KN/m

The total finishes=1×9.94/4.566=2.17KN/m

The total dead load per unit length g_k = 3.3+5.74+17.28+2.17=28.49KN/m

The live load per unit length q_k is = $Q_k \times \left(\frac{A}{L}\right) = 3 \times \left(\frac{9.94}{4.566}\right) = \frac{6.53KN}{m}$

Thus, the ultimate load exerting on the second span is given by n=1.4g_k+1.6q_k

$\boldsymbol{n} = (1.4 \times 28.49) + (1.6 \times 6.53) = \mathbf{50.334}\boldsymbol{KN/m}$

For the third span

Influence area (A) is 11.09m^2

The length of the span L=4.883 m

The self-weight of the beam=0.25 ×0.55×24=3.3KN/m

The self-weight of the slab= (0.11×24×11.09m^2)/4.883m= 6.41KN/m

The self-weight of the wall= 0.2×2.4*2×18=17.28KN/m

The total finishes=1× 11.09/4.883=2.27KN/m

The total dead load per unit length g_k = 3.3+6.41+17.38+2.27=29.26KN/m

The live load per unit length q_k is = $Q_k \times \left(\frac{A}{L}\right) = 3 \times \left(\frac{11.09}{4.883}\right) = \frac{6.81KN}{m}$

Thus, the ultimate load exerting span is given by n=1.4g_k+1.6q_k

$\boldsymbol{n} = (1.4 \times 29.26) + (1.6 \times 6.81) = \mathbf{51.72}\boldsymbol{KN/m}$

For the fourth span

Influence area (A) is 5.16m^2

The length of the span L=3.2m

The self-weight of the beam=0.25$*$ 1 $*$ 1 $*$0.55$*$24=3.3KN/m

The self-weight of the slab= (0.11×24× 5.16)/3.2 =4.257 KN/m

The self-weight of the wall= 0.2×24*2×18=17.28KN/m

The total finishes=1×5.16/3.2=1.61 KN/m

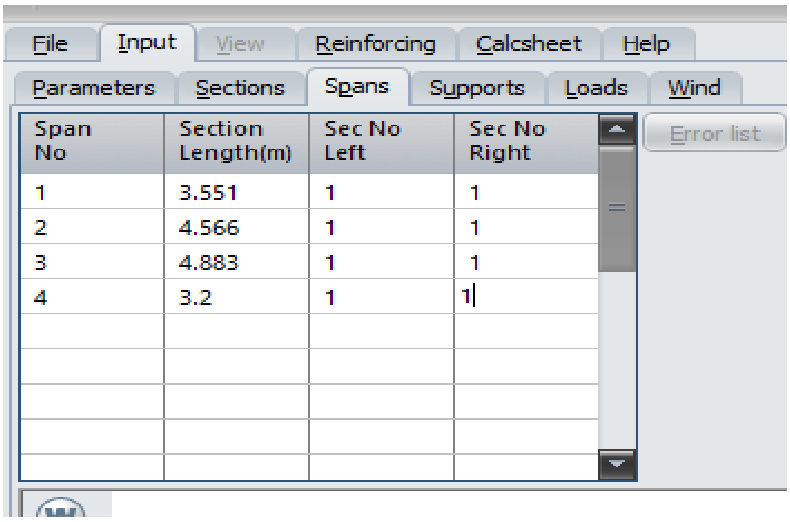
The total dead load per unit length g_k = 3.3+4.257 +17.28+1.61=26.447KN/m

The live load per unit length q_k is = $Q_k \times \left(\frac{A}{L}\right) = 3 \times \left(\frac{5.16}{3.2}\right) = \frac{4.83KN}{m}$

Thus, the ultimate load exerting on the second span and fourth span is given by n=1.4g_k+1.6q_k

$\boldsymbol{n} = (1.4 \times 26.447) + (1.6 \times 4.83\ ) = \mathbf{44.75}\boldsymbol{KN/m}$

Table 4. 2:Input parameters



File | Input | View | Reinforcing | Calcsheet | Help

Parameters | Sections | Spans | Supports | Loads | Wind

Span No	Section Length(m)	Sec No Left	Sec No Right
1	3.551	1	1
2	4.566	1	1
3	4.883	1	1
4	3.2	1	1

Error list

Design of the flanged beam

Lmax=516mm from fourth span

$$\frac{lmax}{15} \leq hf \leq \frac{lmax}{8}$$

$$\frac{516}{15} \leq hf \leq \frac{516}{8},$$

34.4 ≤h≤ 64.6, let take **h=400mm**

Hf=150mm span=4.883m

D=550mm

d=400mm bw=250mm

f_{cu}=30N/mm^2 f_y=460N/mm^2

D= h + cover + main bar/2=links

D=400-25-16/2+8=375mm

- **For the section of T bean**

1/3 of the beam span =1/3 (517) = 172.3mm

Bf= 1/2 of the distance between beams =1/2(4.57) =2290mm

12. $hf + bw\ (for\ \text{T}\ section)$ = (12*15) +25=2050mm

Mmax =$\frac{Wl^2}{8}$=$\frac{51.7^2}{8} = 334.11KNm$

MRC=0.156fcubd^2

MRC=0.156*30*10^6*172.3*375^2

MRC=1.133KNm

M<MRC,

K= $\frac{\text{M}}{\text{fcubd}^2}$=$\frac{51.6*10^6}{30*172.3*375^2}$ =0.071KNm

$\text{Z} = \text{d}\left(0.5 + \sqrt{0.25 - \frac{\text{k}}{0.9}}\right) = 375\left(0.5 + \sqrt{0.25 - 0.071/0.9}\right)$=376mm

Moment Applied(M)=90.38KNm (at the mid span

Breadth of flange=bw+$\frac{lz}{5}$= 250+$\frac{4883}{5}$=**1226.6mm**

Resisting Moment (MRC $_{\text{flange})}$ =$0.45\text{f}_{cu}\text{bh}_f(\text{d} - \frac{\text{h}_f}{2})$

MRC=$0.45 \times 30 \times 1226.6 \times 150(400 - \frac{150}{2})$

MRC =628417845Nmm

MRC =807.23KNm

M<MRC, hence NA lies in flange

Beam is designed as rectangular

K= $\frac{\text{M}}{\text{fcubd}^2}$= $\frac{90.38\times10^6}{30\times1226.6\times510^2}$=**0.009**

K<0,156, hence the beam is designed as singly reinforced rectangular beam

$Z = d\left(0.5 + \sqrt{0.25 - \frac{k}{0.9}}\right) = 550\left(0.5 + \sqrt{0.25 - 0.009/0.9}\right)$=**269.44mm**

level arm(Z)≥0.95d=380mm

Area of steel required=$\frac{M}{0.95fyZ}$=$\frac{90.38\times10^6}{0.95\times460\times269.44}$=**767.58mm^2**

Area of steel provided=791mm^2

the steel provided are 7T12

Here 7 steel of 12mm diameter are used.

- **Design for shear**

Ultimate shear force(v) =123.69KN

Shear stress(v_u)=$\frac{v}{bd} = \frac{123.69*10^3}{250*550} = 0.0036\, {}^{N}\!/_{mm^2}$**<4.8N/mm^2**

$$V_c = \frac{0.79}{\gamma_m}\left(\frac{100A_s}{db}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}\left(\frac{f_{cu}}{25}\right)^{1/3}$$

$\left(\frac{100*791}{250*510}\right)^{1/3}$=0.85 $\left(\frac{400}{510}\right)^{1/4}$=1 $\left(\frac{30}{25}\right)^{1/3} = 1.06$

$$V_c = \frac{0.79}{1,25} * 0.85 * 1 * 1,06 = 0.56N/mm^2$$

Sv (minimum spacing between links=$12 \times \emptyset bars = 12 \times 12 = \boldsymbol{144mm}$

$$\frac{\boldsymbol{ASv}}{\boldsymbol{Sv}} = \frac{0.4b}{0.95fyv} = \frac{0.4 \times 250}{0.95 \times 460} = \mathbf{0.228}$$

The spacing of links Sv should exceed 0.75d

$= 0.75 \times 144 = \boldsymbol{108mm}$

Using links of 8mm diameter

The area of two legs=$\pi r^2 = 3.14 \times 3^2 = \mathbf{56.52mm^2}$ $\quad \frac{\boldsymbol{Asv}}{\boldsymbol{Sv}} = \mathbf{0.228}$

$\boldsymbol{S_v} = \frac{\mathbf{56.52}}{\mathbf{0.228}} = \mathbf{247.89mm = 248mm}$

- **Check for deflection**

$\frac{actual\ span}{\boldsymbol{d}} = \frac{\mathbf{4883}}{\mathbf{550}} = \mathbf{8.878}$

Basic span/d=26 from (Table 3.9 of BS 8110 part**)**

$M.F\ for\ AS = 0.55 + \frac{477-fs}{120(0.9+\frac{M}{bd^2}}$ $\quad fs = \frac{2*fy*As\ required}{3*As\ provided}$

$fs = \frac{\mathbf{2*460*721.02}}{3*791} = 279.5$ and $\frac{M}{bd^2} = \frac{90.38*10^6}{250*550^2} = 12.4$

$M.F = 0.55 + \frac{477-279.5}{120(0.9+1.38)} = 1.28 < 2$

$\frac{permissible\ span}{effective\ depth} = basic\ ratio * M.F$

26*1.28=33.28; Thus 33.28> 9.58 , therefore the floor is safe about deflection

- **Crack control**

1.$S_{V=}248mm@interior\ nominal\ link < 3d(550 * 3)$

2.for fy = 460N/mm^2, d$\leq 200mm$ slab depth =150mm

Then our beam is satisfactory for cracks

4.2.2.3 Column Design

Effective column height

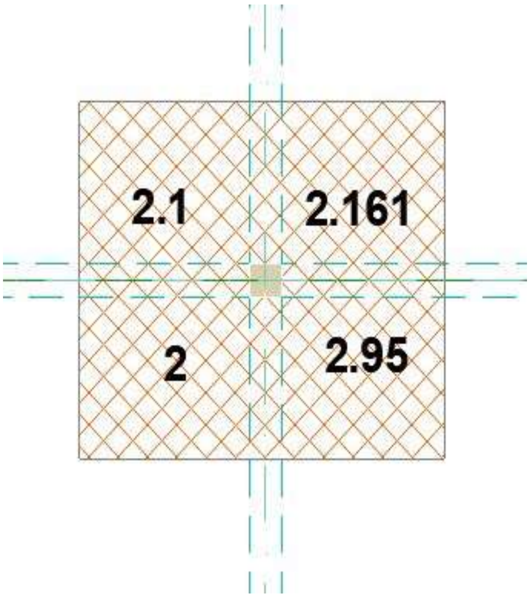


Figure 4. 5 :Influence Area of Critical Column

Design code: BS8110 - 1997

General design parameters:

Given: Column height= 3.5m Column section= (200*200) mm

Lx = Lex/h Ly=ley/b lex=βx.lo=0.7×3.5=2.45m

$\mathbf{Ley = \beta y.lo = 0.7 \times 3.5 = 2.45m}$ $\frac{ley}{b} = \frac{2.45}{0.2} = 12.25$

$\frac{lex}{h} = \frac{2.25}{0.2} = 11.25$

A column may be considered braced in a given plane if lateral stability to the structure as a whole is Provided by walls or bracing or buttressing designed to resist all lateral forces in that plane. It should otherwise be considered as unbraced

- **Check the slenderness of the column**

For the braced if the ratios$\frac{l_{ex}}{h}$, $\frac{l_{ey}}{b}$ are less than 15 the column is said to be short if not they are slender. For the unbraced if the ratios$\frac{l_{ex}}{h}$, $\frac{l_{ey}}{b}$ are less than 10 the column is said to be short if not it is slender.

l_{ex}effective height in respect major axis $= l_o\text{x} \times \beta = 3.5 \times 0.7 = 2.45m$ And b=200mm

l_{ey}effective height in minor axis $= l_{oy} \times \beta = 3 \times 0.7 = 2.45$ And h=220m

lo Clear height between end restraints

$\frac{l_{ex}}{h}$ and $\frac{l_{ey}}{b}$Are equal to 11.13 (lx = 11.25 < 15, ly = 12.25 < 15 and respectively both are less than 15 so they are short as the designed column is braced

Column is short braced

- **Determination of loads on column**

loading area of column=$\frac{1.141*1.844}{2} + \frac{1.141*1.756}{2} + \frac{1.172*1.844}{2} + \frac{1.756*1,172}{2} = 8.311m^2$

slab (permanent loads) = 1.4*0.15m*24KN/m^3*8.311m^2=41.88KN

live loads from the slab = 2KN/m^2*1.6*8.311m^2=26.59KN

load from beam=1.4*0.25*0.51*4.566m*24=20.08KN

load from the wall masonry=1.4*0.2*2.4*1*3.6*18=43.54KN

on floor of column=1.4*0.2*0.2*3.5*2.4=0.47KN

Load from slab roof=1.4*0.15m*24KN/m^3*8.311m^2=41.88KN

Ultimate loads(N)= (41.88 +26.59+20.08+43.54)2+(0.47*3) +41.88=307.47KN

Required steel reinforcement

N= $0.4fcu * Acc + 0.8fyASc$

Acc=b*h=200*200mm=40000mm^2

$$ASc = \frac{N - 0.4fcu * Acc}{0.8fy} = \frac{399000 - (0.4 * 0.3 * 40000)}{0.8 * 460} = 565mm^2$$

$ASc\ provided = 565mm^2$ 5T12 are provided

Here 5 T12mm diameter are used.

4.2.2.4. Foundation design

Clause 3.3.1.4 of the B.S code states that the minimum cover should be 75 mm if the concrete is cast directly against the earth and the minimum grade of concrete to be used in foundations is grade 35.The soil bearing capacity used has been related to who stated that the soil of But are region is hard clay (MININFRA, 2012) And it has the soil bearing capacity which varies between 300-600Kpa/mm^2

- The compressive strength is 35N/mm^2
- Bearing pressure of the soil is 145.2KN/m^2
- Total dead load from the 3 floors up to the foundation = 321.02KN
- The total live load from the 3 floors up to the foundation =77.98KN
- The ultimate axial load on the footing =423.933KN

- **Calculations**

The assumed the overall depth of footing (h) =800mm

Footing self-weight =one tenth of the total ultimate axial load on footing= 423.933/9=47.103KN

The total dead load including the self-weight of the footing = (229.3KN +47.103kN) =**276.403KN** exerting on the soil.

The total serviceability load=272.2KN +48.73KN =320.93**KN**

The required area of the footing is calculated by serviceability limit state,

$$\boldsymbol{A} = \frac{\mathbf{320.93}KN}{334.7} = \mathbf{0.96}\boldsymbol{m}^{\mathbf{2}}$$

The side of the footing is $= \sqrt{0.96} = 0.97m$

Side A=0.97

Side B=1.3

let us take 1.3m as area of 1.69m^2

For the ultimate axial loads = 423.933KN

The earth pressure = (423.933KN /1.69) = 256.17KN/m^2

Punching shear perimeter (critical perimeter) =Pcolumn+(8*1.5d) where **p** is the perimeter of the footing= $0.2 * 4 + (8 * 1.5 * 0.2) = 3.2m$

Area within perimeter = $(c + 3d)^2$ **C** is breadth of column and **d** is the effective depth of footing

=$(\mathbf{0.2} + \mathbf{3} * \mathbf{0.342})^{\mathbf{2}} = \mathbf{1.5}\boldsymbol{m}^{\mathbf{2}}$

Punching shear= earth pressure (l^2-area within perimeter)

= $256.17(1.3^2 - 1.5) = 48.67KN$

- **Check the shear stress at face of the column**.

Face shear

Shear stress v_c

$$v_c = \frac{\text{Axial load}}{\text{column perimeter} \times \text{d}} = \frac{423.933\text{KN } x10^3}{200 \times 4 \times 3200} = 0.165\text{N/mm}^2$$

As the maximum shear stress at face of the support is less than 5N/mm^2, no shear reinforcement required.Let check if the assumed thickness of the footing is adequate.

As the axial load from the column is acting as concentrated, it may cause the excessive punching shear force. To ensure if those punching shear stresses are within the allowable limit the thickness of the footing is sufficient.

Bending reinforcements

By considering the thickness of the footing to be 400mm and the assumed reinforcement to be T16, the effective depth d= $\text{h} - \text{C} - \frac{\Phi}{2}$, $d = 400 - 50 - \frac{16}{2} = 342mm$

Design moment(M)=$\frac{PS*L^2}{2}$

Where PS= punching shear

L= length of footing

$$M = \frac{375.03 * 1.3^2}{2} = 316.9KNm$$

Let check if the compression reinforcements if are needed,

$$K = \frac{M}{f_{cu}bd^2} = \frac{316.9 \times 10^6}{35 \times 1000 \times 342^2} = 0.077$$

No compression reinforcement required because K<0.156

The tensile reinforcement $\boldsymbol{A_s}$in the footing,

$Z = d[0.5 + (\sqrt{0.25 - K/0.9})] \leq 0.95d$

$Z = 342 \times [0.5 + (\sqrt{0.25 - 0.077/0.9})]$= 309.68 mm<0.95d

$$A_s = {}^{M}/_{0.87fy \times z} = \frac{316.9 \times 10^6}{0.95 \times 460 \text{ x } 309.68} = 2341.6mm^2$$

$T16@75mm$ for As provided=2680mm^2

Number of steel = $\frac{length-2cover}{spacing} + 1 = \frac{1.3-2*0.04}{0.075} + 1 = 18 bars\ and\ are\ put\ in\ two\ directions$

4.2.5. Design of reinforced concrete stairs case

a. size and loads calculation

The value of DL lies between ($\frac{1}{2} and\ \frac{1}{30} * 9$)

Where DL is the effective depth of stair, H is the of the stair

Dl values between $\frac{400}{20} = 20cm$ and $\frac{400}{30} = 13.33cm$,taken Dl=15cm

Height of riser (h) = 18cm Length of going (g) = 30cm

$\alpha = arctan\frac{18}{30}$=30^0

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

Hl=$\frac{d}{cos\alpha} + \frac{h}{2}$=$\frac{15}{cos30} + \frac{18}{2}$=26.32

Ho=hl-concrete cover =26.32cm-2.5cm=23.82cm

Dead loads=1.4*0.2382*1*1*24=8.003KN/m^2

Loads from finishes =1.4*1.7=2.38KN/m^2

Live load=1.6*5=8KN/m^2

Total load=8.003+2.38+8=18.383KN/m^2

Total loads from slab=16.232KN/m^2

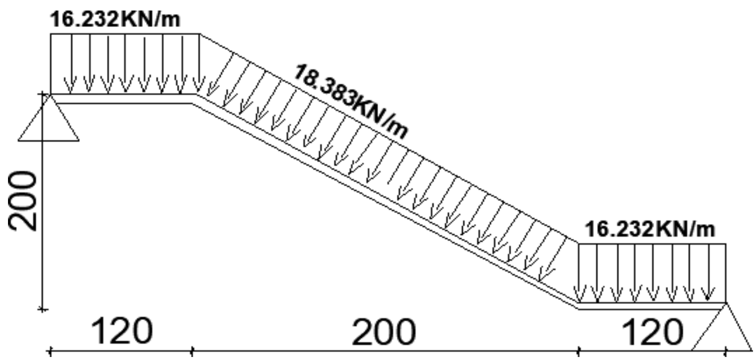


Figure 4. 6:Indicated Equivalent Uniform Distributed Loads

This Fig.4.7, shows how the load are distributed to the stairs according to their span, the span of 1.2m loading 10.44KN/span 3.6m loading 13.15KN/m and span of 1.2m loading 10.44KN/m.

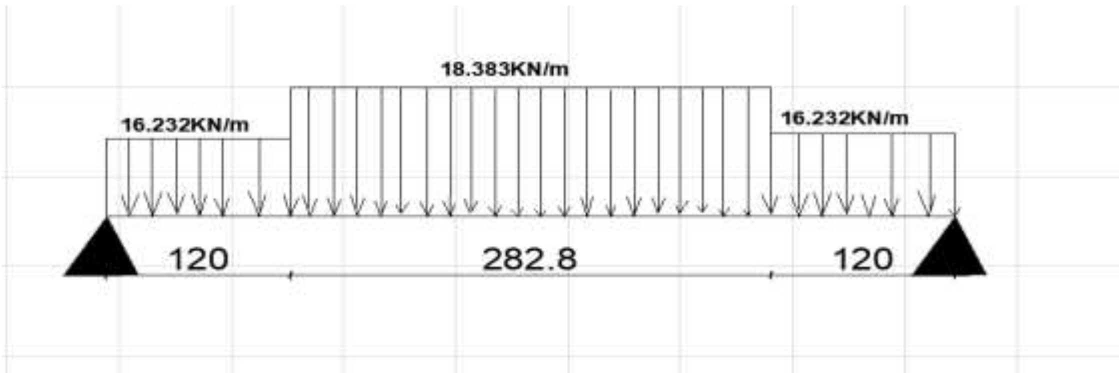


Figure 4. 7:Indicated Equivalent Uniform Distributed Loads

- **Calculation of support reaction**

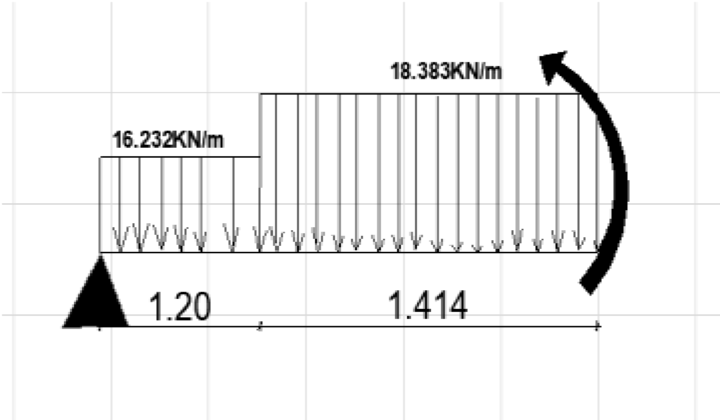
$\sum Fv$ =0;

Ay + By = (16.232*1.20) + (18.383*2.828) + (16.232*1.20) = 72.56KN

$\sum MA$= 0;(-16.232*1.20*0.6) - (18.383*2.828*3) - (16.232*1.20*5.8) + (5.4By) =280.62 KN

5.4 By = 280.62 KN

by $=\frac{280.62KN}{5.4}$= 51.96KNm



Ay = 20.6KNm

Figure 4. 8:Indicated Equivalent Uniform Distributed Loads

This fig4.9: it 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.

$\sum Mmax$ = 0;

M_{max} = (43.5*3) -(16.232*1.2*2.4) - (16.232*1.414*0.5) =72.27KN/m

Mmax = 72.27KNm

αm=Mmax/(Rb*〖ho〗^2*b)=(72.27*100)/(1.4*〖23.8〗^2 1.414)=0.090

αm = 0.090 which corresponds to ξ = 0.01; from the table of coefficients related to the design of members subjected to bending moment.

$\xi = 0.01$; $\xi < \xi_R = 0.950$ (case of singly reinforcements)

$\eta = 0.950$

$$As=\frac{M}{\eta * ho * Rs}$$

$$=\frac{72.27*100}{0.95*23.82*40}=7.984cm^2/m$$

As=7.984cm^2/m

With this cross section, we use the minimum steel cross section: 6Φ12mm/mWith **A_s =** 798.4mm^2/m

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

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

$$As=\frac{0.24*b*h}{100}=\frac{0.24*141.4*15}{100}=5.09cm^2/m$$

We provide 4Φ12mm/m with As =509.04 mm^2/m

Steel arrangement (Stair case)

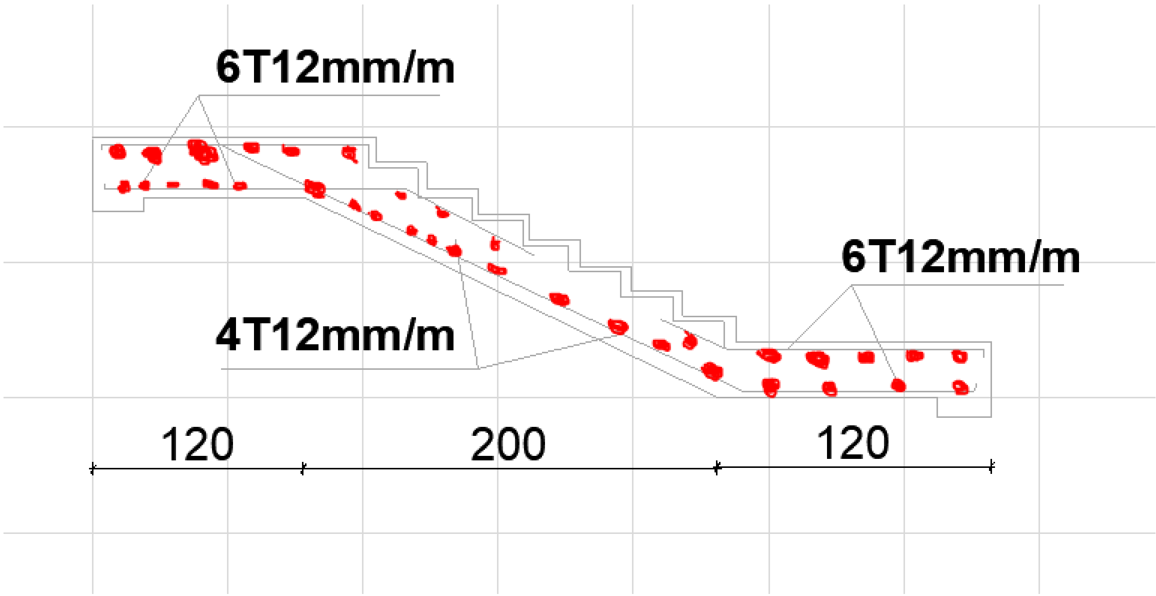


Figure 4. 9:Indicated Steel Arrangement (Stair Case)

CHAPTER FIVE: CONCLUSION AND RECOMMANDATIONS

5.1. Conclusion

In conclusion, this project on the structural design of a G+2 building apartment in Kicukiro District, Rwanda, has provided a comprehensive approach to creating a functional and aesthetically pleasing residential building. Through detailed site analysis, conceptual design, and structural planning, the project has addressed key aspects such as load calculations, material selection, and cost estimation.

The use of advanced software tools like ArchiCAD and Prokon has enabled precise and efficient design processes, ensuring that the building adheres to local building codes and regulations. The outcome of this project not only meets the requirements of modern residential architecture but also emphasizes sustainability and efficiency. This project has been a valuable learning experience, enhancing my understanding of both architectural and structural design principles. It has also highlighted the importance of interdisciplinary collaboration and the integration of various design elements to achieve a successful outcome.

I hope that this project will serve as a useful reference for future developments in the field of residential architecture and contribute to the ongoing efforts to improve the built environment in Rwanda.

5.2. Recommandations

Based on the findings and experiences gained from this project on structural design of a G+2 building apartment in Kicukiro District, Rwanda, the following recommendations are proposed:

- ✓ Sustainable Design Practices: Future projects should incorporate more sustainable design practices, such as the use of renewable energy sources, rainwater harvesting systems, and energy-efficient materials to reduce the environmental impact of residential buildings.
- ✓ Advanced Structural Analysis: It is recommended to utilize more advanced structural analysis tools and techniques to ensure the safety and stability of the building, especially in regions prone to seismic activity.

- ✓ Community Involvement: Engaging the local community in the design process can provide valuable insights and ensure that the building meets the needs and preferences of its future occupants.
- ✓ Regular Maintenance: Establishing a regular maintenance schedule for the building can help in prolonging its lifespan and maintaining its structural integrity.

REFERENCES

Ali, M. M., & Al-Kodmani, K. (2019). Tall buildings and urban habitat of the 21st century: A global perspective. *Buildings, 9*(2), 40.

Arya, C. (2019). The structural design of elements: Concrete, steelwork, masonry and timber designs to British Standard and Eurocodes (4th ed.). CRC Press.

Brock, L., & Brown, J. (2021). The architect's guide to the US National CAD Standard. Wiley.

Chatterton, M. (2020). The management of sustainable building services. Routledge.

City of Kigali. (2022). The Kigali master plan 2040.

Demkin, J. A. (Ed.). (2021). The architect's handbook of professional practice (16th ed.). John Wiley & Sons.

Hibbeler, R. C. (2018). Structural analysis (10th ed.).

Klimoski, E. (2020). Construction documents: Developing processes and procedures for effective processing. Routledge.

Levy, S. M. (2018). Project management for construction (7th ed.). McGraw-Hill Education.

Love, Peter E. D, Edwards, D. J. and Iran, Z. (2023). Emerging technologies and construction projects: A review regarding design creativity optimally in constructed space without containment and plagiaries. Construction Management and Economics.

McCormack, J. C. & Brown, R. H. (2020). Reinforced concrete design (10th ed.). Wiley.

McGuire, M. and Schaffer, W. (2021) The architecture reference & specification book: everything architects should know on a daily basis (2nd ed.). Rockport Publishers.

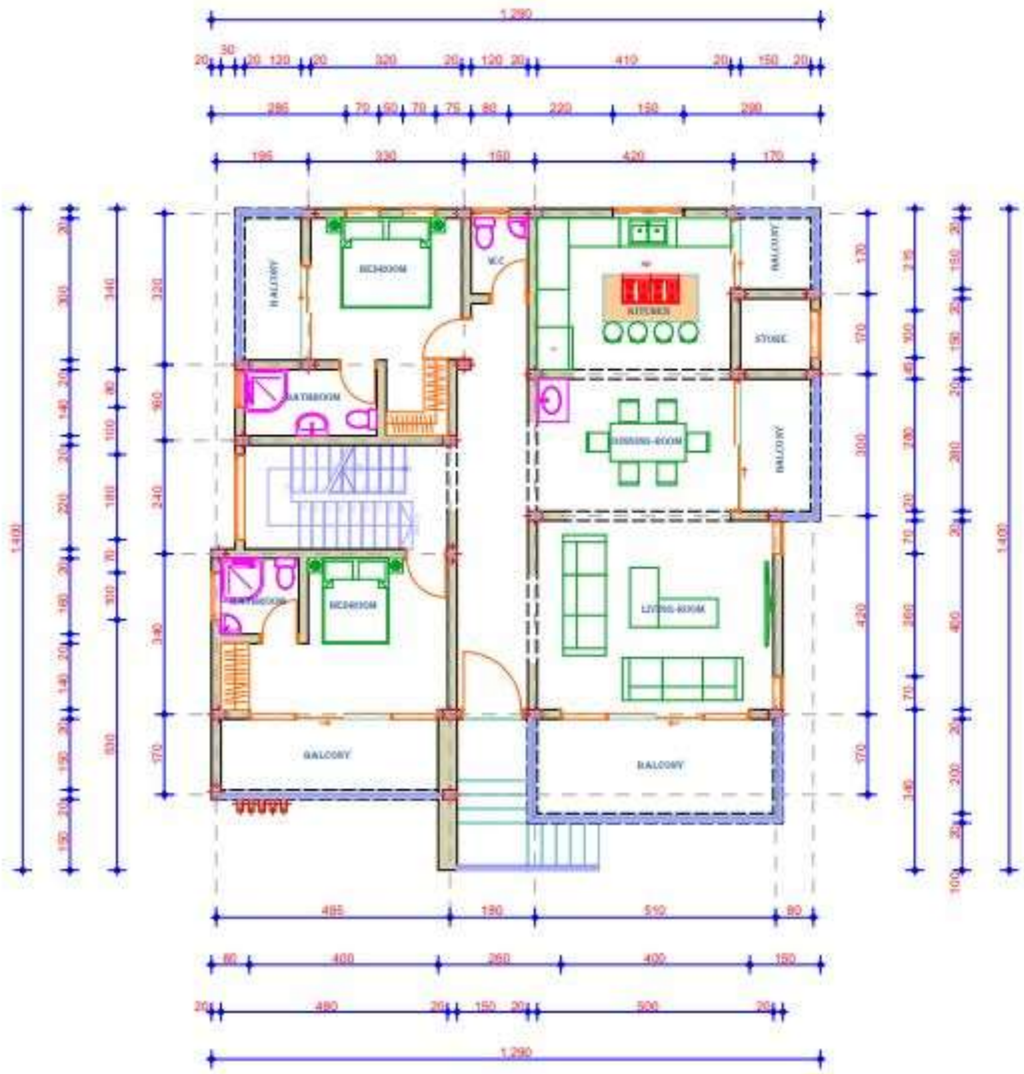
Nilsson, A. H., Darwin, D., & Dolan, C. W. (2021). Design of concrete structures (16th ed.). McGraw Hill.

Pressman, A. (2018). Designing architecture: The elements of process. Routledge.

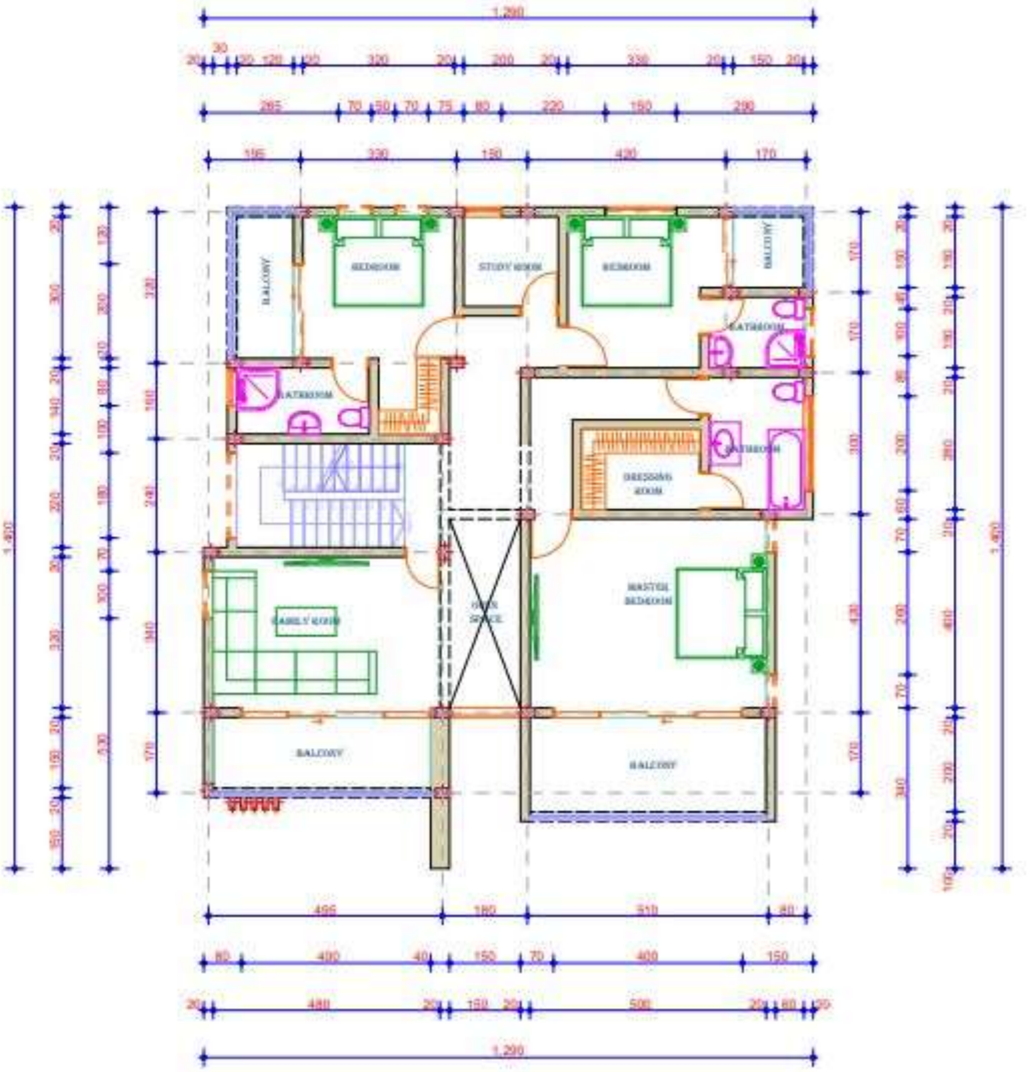
Satterthwaite, D. (2019). The new geography of poverty in

APPENDICES

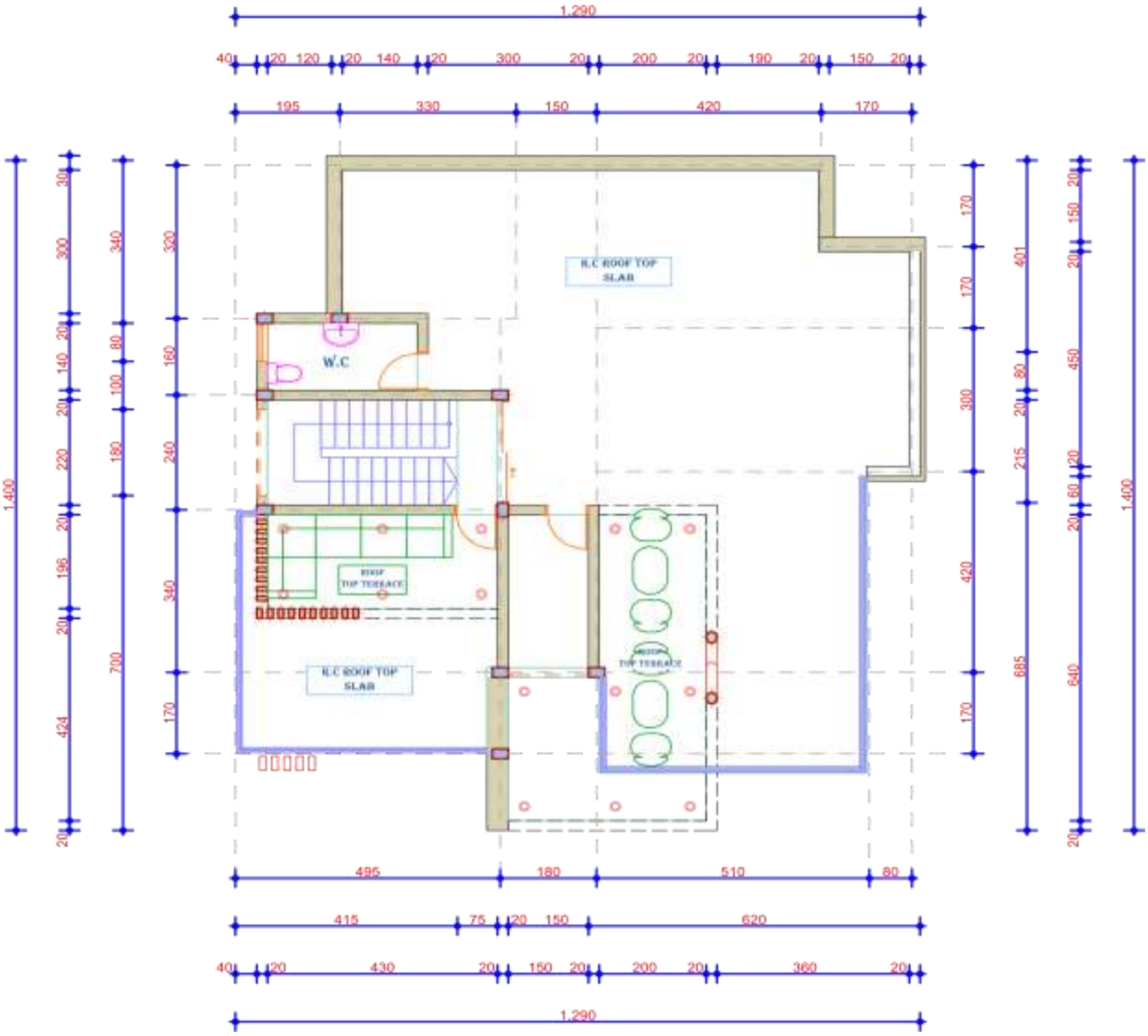
Appendix 1:Ground Floor plan



Appendix 2:First Floor

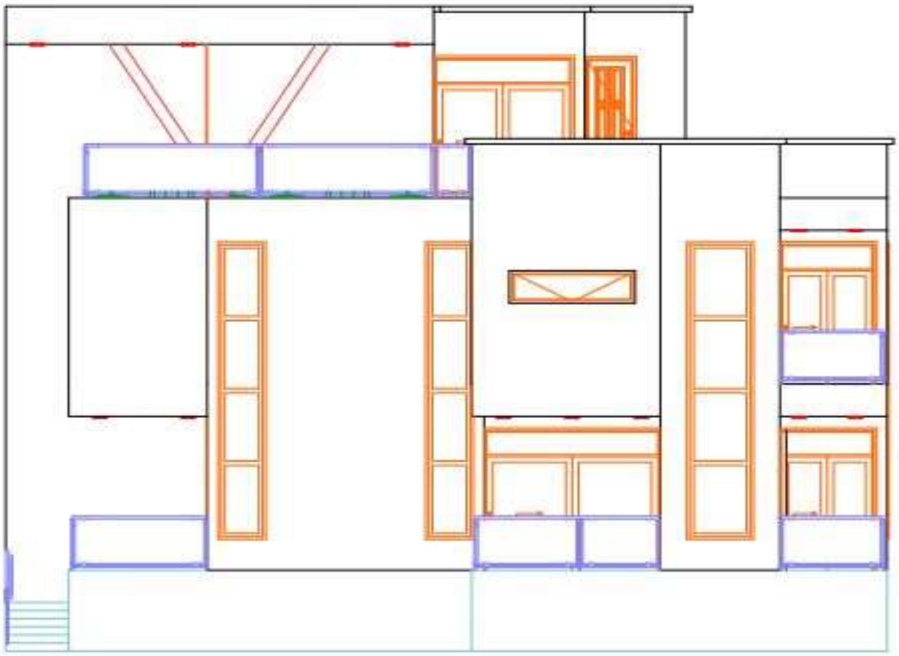


Appendix 3:Second Floor Plan

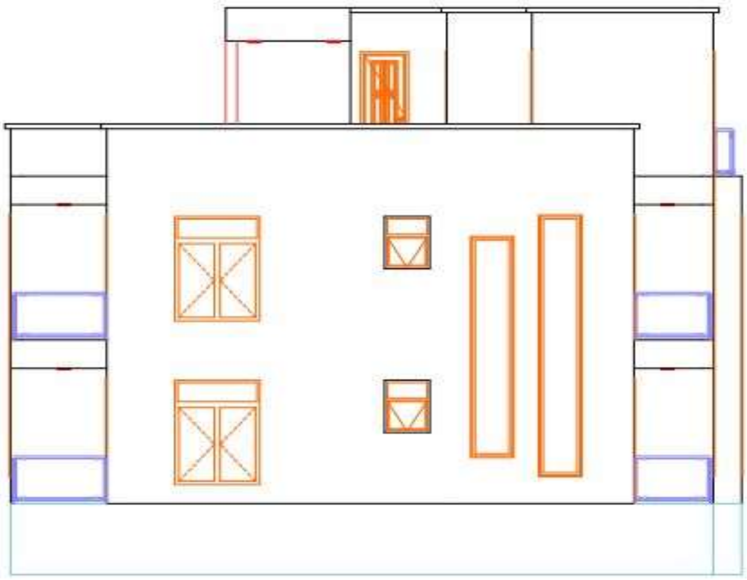


Appendix 4:Elevations

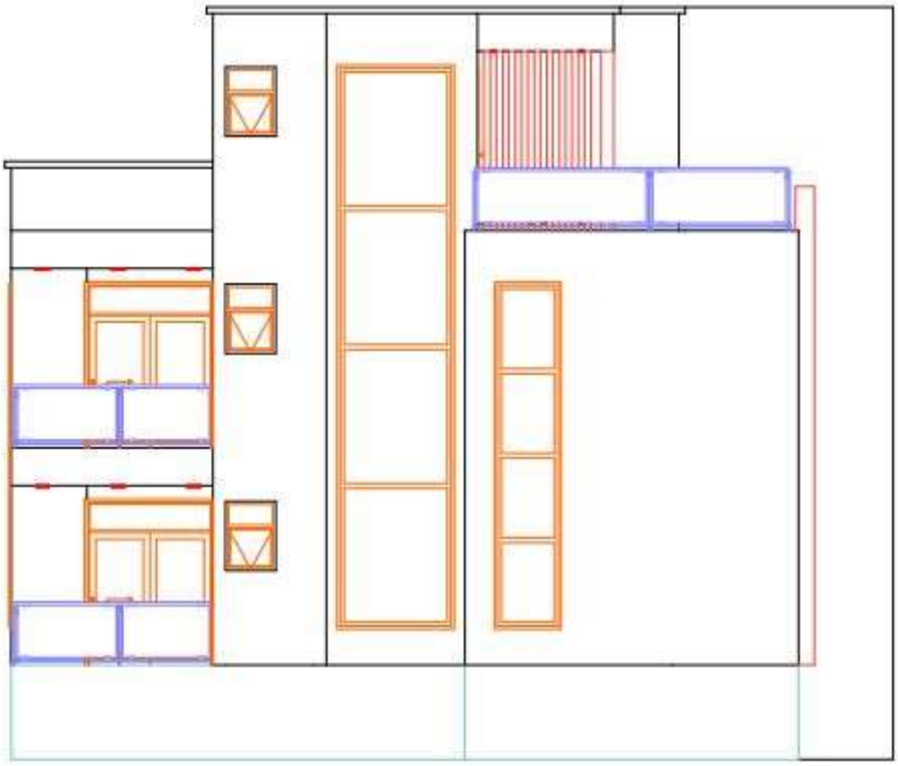
04. FRONT ELEVATION PLAN 1:60



05. RIGHT ELEVATION PLAN 1:60



06. BACK ELEVATION PLAN 1:60



07. LEFT ELEVATION PLAN 1:60

Appendix 5:Front View Perspective

Appendix 6:Back View Perspective

Appendix 7:Left View Perspective