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DEPARTMENT OF CIVIL ENGINEERING

OPTION: CONSTRUCTION TECHNOLOGY

STRUCTURE DESIGN OF G + 3 COMMERCIAL BUILDING IN NYABUGOGO STATION KIGALI NYARUGENGE DISTRICT

Submitted in partial fulfillment of the requirement for the advanced diploma in construction technology

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Kigali, September 2024

DECLARATION

I, **RUKERATABARO Carmel Carmel,** declare that This research study is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Learning". No part of this research should be reproduced without the authors' consent or that of ULK Polytechnic Institute.

Student name: RUKERATABARO Carmel Carmel

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CERTIFICATION

I hereby certify that the research work for this project has been carried out under my supervision. I have gone through the final submission, and hereby approve it to be submitted in accordance with the requirements of ULK Polytechnic Institute.

Supervisor name: Eng. Bonaventure NKIRANUYE

Signature: ……………………………………………….

Date: ……………………………………………….

DEDICATION

I dedicate my work

To the almighty and eternal God.

To my dear parents, **MASHAVU Brigitte, RUKERATABARO Jean marcel,** who have supported and encouraged me throughout my academic journey, I dedicate this work to you. Your unconditional love and constant support have been my strength and motivation. To my brothers and sisters, who have always been there for me, I dedicate this project to you. Your support and encouragement helped me persevere and achieves my goals. To my Friends, who are an important part of my family, I dedicate this work to you. Your support and friendship have been invaluable to me

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ABSTRACT

This dissertation presents a detailed study titled **"Architectural and Structural Design of a G+3 commercial Building: Case Study of nyarungenge district"** The study focuses on a G+3 commercial building at nyabugogo station that measure 207,775m x 158,64m, comprising essential features like balconies, agency office, restaurant, shops, bus parking, kitchens, bathroom, offices. Each floor stands at a height of 4 m.

The structural analysis employed fundamental civil engineering principles to meticulously design key elements, including beams, slabs, columns, foundations, and stairs. Longitudinal beams, with a depth of 500 mm, width of 200 mm, and a flange width of 907 mm, utilized Ø16 mm reinforcement bars at both top and bottom. Slabs were diversified into three types (continuous and discontinuous), each with a 25 cm thickness and reinforced with Ø12 mm bars. Columns incorporated Ø25 mm bars with Ø8 mm links at 144 mm center to center.

Foundation design adhered to a bearing capacity (Pb= 350 KN/m^2), resulting in foundations measuring 1500*1500*500 mm, reinforced primarily with Ø20 mm bars. Stairs facilitating inter-floor access were crafted with a 265 mm going, 180 mm riser, 200 cm flight height, and a pitch of 32.53^0. Reinforcement comprised Ø16 mm bars at the bottom and Ø8 mm bars at the top.

This dissertation offers a comprehensive exploration of the structural intricacies involved in designing a G+3 commercial building. Through meticulous analysis and design, it provides valuable insights into construction practices, particularly within the unique context of nyarungenge district.

Keywords: Structural design, G+3 commercial building, nyabugogo station, Beams, Slabs, Columns, Foundations, Stairs, Reinforcement bars, Civil engineering principles, architectural

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LIST OF SYMBOLS AND ABBREVIATIONS

βsx and βsy: moment coefficients shown in Table 3.13 in BS 8110-1:1997

βsx and βsy: moment coefficients shown in Table 3.14 in 8110-1:1997

βvx and βvy: shear force coefficients shown in Table 3.15 in 8110-1:1997

As_{max}: maximum area of steel.

As_{min}: minimum area of steel.

As_{prov}: area of steel provided.

As req: area of steel required

BRC – British Reinforced Concrete

ULS – Ultimate Limit State

SLS – Serviceability Limit State

ACI – American Concrete Institute

Msx: bending moment in x direction

Msy: bending moment in y direction

Asc: area of steel in compression

Asv: area of steel in vertical links

G+3 – Ground plus three floors

Max: maximum

W/C – Water-Cement Ratio

fcu: characteristic strength of concrete.

Mx: moment on the column in x direction

My: moment on the column in y direction

RC – Reinforced Concrete

LL – Live Load

DL – Dead Load

BS – British Standards

Fy – Yield Strength of Steel

Fc – Compressive Strength of Concrete

Ec – Modulus of Elasticity of Concrete

As – Area of Steel Reinforcement

Qk: characteristic imposed load.

Gk: characteristic dead load.

VC: Shear capacity.

Ac: total area of concrete

As: minimum recommended area of reinforcement.

bw: average web width of a flanged beam

βb: the ratio of redistributed moment over elastic analysis moment

γm: partial safety factor for the strength of material

fy: characteristic strength of reinforcement.

γf: partial safety factor for load

lx: length of shorter side.

ly: length of longer side

hf: thickness of the flange.

M: design ultimate moment at the section considered.

N: design axial force.

W: Design shear force due to ultimate loads.

Z: lever arm

W: Design shear force due to ultimate loads.

Z: lever arm

V: Shear stress

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

d: effective depth of the tension reinforcement.

ф: diameter of steel.

l: span of the beam.

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

LIST OF APPENDICES

CHAPTER 1: GENERAL INTRODUCTION

1.0. Introduction of the study

This Chapter provides a comprehensive background of the study, the problem statement, the main objective, the specific objectives, the significance of the study, scope and limitations and the organization study.

1.1 Background of the study

Bus stations are one part of the global travel circuit. In large parts of the world, buses are part of public transport in many countries, especially in developing countries where rail and air transport is less available in the rapid process of urbanization across the globe, the demand for functionality, ecological consideration, and appropriate designing of bus terminals to meet the higher passenger traffic is on the rise. The bus stations of these days are combined with smart technologies, displaying real-time information along with enhanced security. In the world nowadays, there is an increasing demand for greener transport solutions. This calls for the need to use public transport as a way to reduce carbon emissions and congestion in cities. This can be done by constructing bus terminals or stations. (Aggarwal,2004).

In Africa, buses are the major source of public transportation. Most of these modes of transport are prominent in Sub-Saharan Africa. The bus stations are normally centering of economic activities since this helps in trade and daily travel to and from work. Most bus stations across the continent face challenges characterized with overcrowding, inadequate facilities, and poor maintenance. However, a growing development in the process of modernizing the facilities proxy's investments of some of the cities in BRT systems and terminal upgrades. These bus terminals are also important in developing projects of regional integration like the African Continental Free Trade Area, as they allow for transboundary movement of goods and people. (African Union2015)

The East Africa region relies greatly on the bus station for its inter-city and cross-border travel. Major bus terminals in cities like Nairobi, Dar es Salaam, and Kampala connect travelers to other parts of the region. Bus stations contribute to the local economy by providing business opportunities to small-scale operators and a source of employment. Transportation infrastructure is being developed and improved, including but not limited to upgrading bus stations and facilities, to cater for rapidly growing urban centers within the region. The two Bus terminals in Rwanda form part of a key nodal point in the transport network, linking Kigali with the rest of the country and the neighbors. (EAC Secretarial 2021)

The government of Rwanda has been embarking on improvements in infrastructure related to public transport, upgrading bus stations to meet the increasing demand by passengers and raising the service quality. In Rwanda, with its development, the concept of the bus station is increasingly becoming central to broader urban planning strategies focusing on mitigation of congestion, sustainable mobility, and in general enhancing the urban experience. Nyabugogo Station in Kigali is one of the busiest bus terminals in Rwanda; it acts as an interchange for the citizens within the country, other local travelers, and even international ones. It connects Kigali with various parts of Rwanda to other neighboring countries like Uganda and Tanzania. (Rwanda vision2020)

Nyabugogo Station faces some key issues with overcrowding, shortage of amenities, and traffic congestion. The redevelopment project will ensure that building a modern multi-purpose commercial building with integrated transportation and commercial activities takes care of the challenges for efficiency while passengers experience it. The redevelopment of Nyabugogo Station represents an extendable dimension in the bigger positive efforts of Kigali to improve its urban mobility, reduce congestion, and promote more public transport as a sustainable alternative to using private cars. (city of Kigali 2020)

1.2 Problem statement

Urban public transportation infrastructure in Kigali, particularly at Nyabugogo Station, faces significant challenges in terms of efficiency and service delivery. Nyabugogo is a key transportation hub, serving both intercity and local commuters; however, its outdated infrastructure is no longer adequate to support the increasing volume of passengers. The station’s current design results in overcrowding, inefficient traffic flow, and insufficient passenger amenities, which contribute to long waiting times, discomfort, and safety concerns for travelers. Additionally, the surrounding swampy area exacerbates the problem by posing challenges to both infrastructure stability and expansion. The absence of modern facilities, such as digital ticketing systems, organized parking, and accessible commercial spaces, further limits the station's ability to meet growing demands. Without a strategic redevelopment plan, Nyabugogo Station will continue to face these operational inefficiencies, negatively affecting the city's transportation system and economic growth. Therefore, addressing these structural and design limitations is crucial for improving urban mobility, passenger satisfaction, and overall infrastructure sustainability.

1.3. Objectives of the study

1.3.1. Main objective

The main objectives of this project were and structural design of G + 3 commercial building in Nyabugogo station.

1.3.2. Specific objectives

- To provide the plan view, perspectives, elevations, cross sections of building;
- To design the critical building members in order to check if the building is safe;
- To calculate loads taken down on the column
- To prepare structural plan and structural details for structural elements.

1.4. Significance of the study

The redevelopment of the Nyabugogo Station in Kigali is a critical infrastructure project aimed at improving the functionality, aesthetics, and overall efficiency of one of the city's busiest transit hubs. This study will explore how modern design principles, particularly in commercial buildings and reinforced concrete structures, can contribute to urban renewal and economic growth. By incorporating sustainable design practices, this project will also address environmental concerns. The use of reinforced concrete with sustainable materials and energy-efficient designs can significantly reduce the carbon footprint of the new structures, setting a benchmark for future projects in Kigali and beyond.

1.5. Personal Benefits

Engaging in this project will enhance your technical and professional skills, particularly in architectural design and civil engineering. You will gain hands-on experience in designing commercial buildings and working with reinforced concrete, which are essential skills in the construction industry.

Successfully completing this study will position you as an expert in urban redevelopment projects, potentially opening doors to career opportunities in both the public and private sectors. It will also build your portfolio, showcasing your ability to handle complex construction projects.

1.5.1. Academic Benefits

This study will contribute to the academic community by providing a comprehensive case study on the redevelopment of a major urban transit hub. It will offer valuable insights into the challenges and solutions associated with such projects, particularly in the context of a developing city like Kigali.

Your work will serve as a foundation for further research in the fields of architecture, civil engineering, and urban planning. It will encourage innovation in the design and construction of commercial buildings, promoting the use of advanced materials and techniques.

1.5.2 Socio-Economic Benefits

The redevelopment of Nyabugogo Station will stimulate economic activity in the area, creating jobs and attracting businesses. The new commercial buildings will provide spaces for retail, offices, and other commercial activities, boosting the local economy.

The project will enhance the quality of life for residents and visitors by providing a modern, efficient, and aesthetically pleasing environment. Improved infrastructure will lead to better transportation options, reducing traffic congestion and improving accessibility.

1.6 Scope and limitations of the study

This project will focus on the analysis of the structure safety of the building as well as doing of the following elements:

- Plans view
- Structural plans
- Foundation
- Slabs
- Beams
- Column and stairs

Has the conception of the building is large domain involving different spleen that cannot be covered within a limited time this project not treat that following:

- Soil analysis
- The electrical plumbing and internet installation works
- cost estimation of the project

1.7. Organization of the study

This report has five chapters:

Chapter 1: General Introduction

Guides the reader to get the idea of what the study is all about, it contains the background of the research problem and also clarifies the objectives of this study.

Chapter 2: Literature review

This chapter contains theoretical aspects and describe in detail different parts of the building to be studied in this research

Chapter 3: Materials and Methods

This chapter describe the study area and given the overview and describe the material and method in details of the drawings of the buildings

Chapter 4: Result and Discussions

This chapter is the main and the biggest chapter in this this dissertation, this chapter describe the structure analysis of different parts of the building slab, beams, column, foundation, stairs and ramp their respective reinforcement

Chapter 5: Conclusion and Recommendation

This chapter closes the report by providing a brief overview of the contains in this report and give the conclusion to the result obtained in chapter 4 and also giving me recommendation to those results

CHAPTER 2. LITERATURE REVIEW

2.0 Introduction

This chapter focuses on the review of the literature on design and concept of a commercial building of three storied and the related literature. In this particular research the literature mainly bases on what different authors have written about structural and architectural design of a commercial building. The purpose of this literature review is to identify gaps which were left out by different authors to widen the understanding of architectural and structural design of a commercial building.

2.1. Preliminary design

Load Estimation: Estimation of dead loads, being permanent or static loads that the building will carry, and live loads that can be described as temporary or movable. Other loads, and snow, depending on the location are also included. (Eurocode, 1991)

Material selection: The concrete, steel, wood, or composite can be selected based on the requirement that would be strength, durability. (ACI, 2019).

Structural System Selection: Determine the structural system type according to building height, function, and loads, such as framed structure, shear wall structure, or truss structure.

2.1.1. Dead Load

Self-weight of the structure includes the weight of all permanent components of the structure, such as beams, columns, slabs, walls, floors, and fixed equipment. (BS, 1996)

2.1.2. Live Load (LL)

It consists of the temporary or movable loads that the structure may be called upon to support: for example, people, furniture, vehicles, and other movable items. In a commercial building, live loads would involve the weight of occupants, office equipment, and possibly parking loads, if applicable. (BS, 1996)

2.1.3 .Concrete

Concrete is the homogenous mixture of binder (cement) fine aggregate coarse aggregate and water sometimes admixtures.

Fine aggregate (sand) are those aggregate which pass through a 4.55mm sieve opening.

Coarse aggregate (gravel) crushed stone coarse aggregate are those aggregate which are retained on 4.75mm sieve opening.

In order to achieve the desired compressive strength of concrete the quantity of water should be measured and respected, to get the quantity of water to be added, we should consider that the quantity of water is the product of the quantity of cement and water cement ratio (w/c).

(ACI, 1997)

Admixture is a material ingredient of concrete which is added in the concrete for specific reasons.

Requirement mix ratio

Ex: 1:1:2

In order to achieve the desired compressive strength, the same weighing batching tool should be used. (ASTM, 2019)

2.1.4. Design reinforcement

Reinforcement bars are found into 3 type

Hot rolled mild steel with characteristic strength (fy)=250N/mm² mild steel has smooth surface

Hot rolled or worked high yield steel with characteristic strength (fy) of 460N/mm² and young modulus (E) of 200 KN/mm²

Fabric mesh is made by steel which are jointed /welded together to form a mesh with characteristic strength (fy) of 460N/mm², (BS, 2005).

2.2. Foundations

Foundations are the foundation of any building and are essential to ensure the stability and durability of the structure, Foundation Design Steps: Soil Investigation, Analysis of soil properties in Nyabugogo to determine its bearing capacity. Foundation Types is Choice between shallow foundations (slab foundations or isolated footings) and deep foundations (piles) based on the results of the soil investigation, Pile foundations should be used when shallow foundations are inadequate to support the loads or when soil conditions pose challenges for stability and settlement control calculation of foundation dimensions to support the building loads based on local and international standards, Selection of appropriate construction materials (high strength concrete, reinforcing steel),(BS, 1986).

Foundation is the lowest part of the building that supports loads from upper part of the building and distribute them on the soil loads should be avoid failure of the building (unequal settlement of the building)

Deep foundation: is the foundation where by depth of foundation over base of the foundation must be greater than 2; total load on foundation = 1.0Gk +1.0QK+w

Area of the foundation =total load on foundation /bearing capacity of the soil

Bearing capacity of the soil is the ability of the soil to with stand upper applied loads; the bearing capacity of the soil < maximum pressure; the bearing capacity of the soil is determined using different method among those method, we have dynamic cone penetrometer test

Size of footing is determined as follows: for square footing the size of footing = square roots of area of the footing.

For rectangular footing, the size of the footing is obtained by dividing the assumed size into the area of footing.

If design stress > bearing capacity the foundation is note unsafe

If design stress< bearing capacity the foundation is safe. Ko

If the foundation is unsafe different decisions may be taken

Consider the depth where bearing capacity is maximum

Soil stabilization

Resizing footing

If Qf<Rb*Ab, the foundation is not safe with respect to punching shear

Conclusion: thickness of the footing should be increased, (Eurocode, 2004).

2.3 .Beams

Beams support the loads from the slabs and transfer them to the columns, beam design steps, Applied Loads Identification of dead loads and live loads, beam dimensions, Calculation of the cross-section required to support the applied loads, considering bending and shear stresses.

Reinforcement: Arrangement of reinforcing bars to resist bending moments and shear forces.

Type of beam according to load -bearing

Primary beams: primary beams are beams which are directly supported by columns; Great span: primary beam which has long span; support main structure /main element like floor slab and roof; load transfer: primary beams support load from floor and roof and distribute them on the columns.

Secondary beams: secondary beams are beams which are supported by primary beams; short span: secondary beams have short span compared to primary beam; support no structure element: secondary beam is designed to carry no load bearing structures live partition wall or no -load bearing wall at all; load transfer: secondary beam transfer load to primary beams.

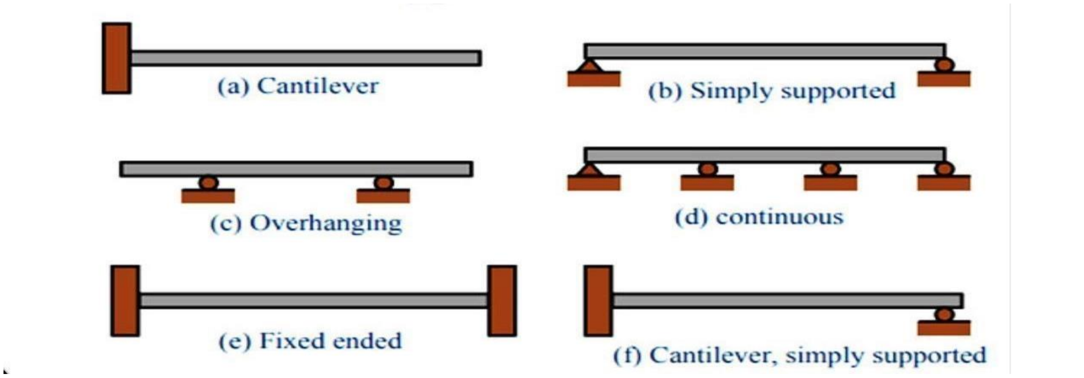


Figure 2.1: Types of beams according to load-bearing

Type of beams according to their supports

Type of beam according to amount of reinforcement

- Over reinforced beam
- Under reinforced beam
- Balance beam

Type of beam section

- Rectangular beam

Singly reinforced rectangular beam reinforcement parts are in the bottom of beam section (tension zone) only there are no reinforcement bars in the top of beam or there are minimum reinforcement bars to control cracking. (BS, 2004).

Doubly reinforced rectangular beam reinforcement bars in the bottom (tension zone) and in top (compression zone) of beams

Condition: MU>MRC; k>kbal

The intention /main goal of designing beam section is to find out the area of steel needed condition ASmin <AS<ASmax

If Mu <MRC, no compression bars required

If Mu>MRC, compression bars required

Where Mu = ultimate moment /maximum moment

MRC = moment of resistance of concrete

If k < kbal, no compression bars required

k>kbal, compression bars required

2.4 .Columns

Columns are the vertical members that transfer the loads from the beams and slabs to the foundations.

Column Design Steps: Vertical Loads: Calculation of the total vertical loads that each column must support.

Column Dimensions: Determination of the cross-section of the columns to avoid buckling and ensure stability.

Reinforcement: Placement of longitudinal reinforcement and stirrups to resist compressive and shear forces.

Code classifies column into two type:

- Short column
- Slender column

Short column is when lex/h and ley/b is less than 15 for braced column and less than 10 for unbraced column

lex=effective height with respect to major axis

ley=effective height with respect to minor axis

h= width of column

b= breadth of column

le=฿10, where ฿= coefficient that depend on end condition (0,75< ฿<1)

Table 19 and 3.20 shows the value of B for braced column and unbraced column respectively in order to control cracking in the column B should be depends to N/bhfcu This value is found in table 3 to 2 of the code

Asmin =0,4*Ac; Asmax=6*Ac/100

To make sure that Link should not be less than 6 mm or a quarter Of Maximum diameter of many bars; the spacing should not be greater than 12 times the maximum diameter of main bars. (ACI, 2019).

2.5. Slabs

Slabs form the floors and ceilings of the building.

Slab Design Steps

Applied Loads: Determination of dead loads (self-weight) and live loads.

Slab Thickness: Calculation of the minimum thickness required to avoid excessive bending and deformations.

Reinforcement: Placement of reinforcing bars to resist bending moments and shear forces.

That is, horizontal flat structures elements that are provided as a cover of flu or the building slab support different loads such as itself.

Type of slab

one-way slab= slab spanning in One Direction

two-way slab= slab spanning into directions

flat slab= a slab which is supported by column and beam without intermediate beam

Condition

if l y over LX< 2 the slab is it two-way slab

if l y over LX>2 this slab is the one-way slab

The thickness of this slab is running between LX over 20 and lx/40

2.6. Ramps stairs

Ramps are essential for vehicular and pedestrian access, especially in a commercial setting.

2.6.1. Ramp design steps

Ramp Slope: Determination of the slope based on safety and accessibility standards.

Ramp Dimensions: Calculation of the width and length to ensure smooth passage.

Reinforcement: Arrangement of reinforcements to support dynamic loads from vehicles and pedestrians.

For the design of stairs, focusing on reinforced concrete techniques, here are some key considerations:

2.6.2. Types of stairs

Straight Stairs: Common in buildings with limited space.

Spiral Stairs: Used for aesthetic purposes and in areas with restricted space.

Dog-Legged Stairs: Two flights of stairs running in opposite directions with no space between them.

Open-Well Stairs: Similar to dog-legged stairs but with space between the flights.

Components of Stairs

Tread: The horizontal part where the foot is placed.

Riser: The vertical part between the treads.

Stringer: The inclined member supporting the treads and risers.

Landing: The flat area between two flights of stairs.

Design Consideration

Tread-Riser Ratio: Typically, the sum of the tread and twice the riser should be between 600mm and 650mm.

Staircase Width: Depends on the type of building but generally not less than 1.0m for residential buildings and 1.5m for public buildings.

Headroom: Minimum headroom should be 2.1m to avoid discomfort.

Slope: The slope of stairs is generally between 25° and 40°.

2.6.3. Structural design elements

Load Consideration: Include dead load (self-weight of stairs) and live load (people using the stairs).

Reinforcement Detailing:

Main Reinforcement: Placed at the bottom of the staircase to resist tension. Use bars of adequate size depending on the load.

Distribution Bars: Placed at the top surface perpendicular to the main reinforcement.

Formulas for Structural Design:

Step Height (Riser) Calculation: h=Total Rise / Number of Risers

Tread Length Calculation: t=Total Going / Number of Treads

Reinforcement Calculation:

Bending moment for stair slab: $M=wL^2/8$

Area of steel reinforcement: $As=M/fy \times j \times d$

Shear Design: Ensure that the design shear force is within the permissible limits of concrete shear strength.

2.6.4. Construction details

Formwork: Should be properly supported to hold the concrete in place until it gains sufficient strength.

Concrete Mix: Usually, a mix ratio of 1:2:4 (cement: sand) is used for stairs, but this might vary based on specific project requirements.

Curing: Proper curing is essential to ensure the durability and strength of the staircase.

2.7. Architectural design

Form: The shape, appearance, and overall aesthetic of the building.

Function: Use of the building. Architects are responsible to provide spaces that meet needs and are useful to those who would be using it. (*IBC* **2021)**.

2.7.1. Spatial planning

This involves the organization of spaces within a building to ensure that space is utilized efficiently and movement between spaces is smooth.

This includes floor plan design, circulation routes-like hallways, stairs, and elevators-and the relations between areas, such as public versus private.

2.7.2. Lighting

Artificial and natural lighting is of great significance during architectural designing.

Daylighting strategies, the orientation of the building, and window placement for maximum interior light.

Artificial Lighting: Design enhances the mood, function, and aesthetic of spaces.

2.7.3. Sustainability

Incorporating ecological-friendly habits within a building, including energy-efficient systems, sustainable materials, and designing for minimal environmental impact.

Green architecture can feature solar panels, rainwater harvesting, and green roofs.

2.7.4. Structural Integrity

The design must be such that the building can carry its loads and resist various environmental forces like wind, earthquakes, and weather. It should look pleasing to the eye.

They are structural elements-beams, columns, foundations, among others-which must be designed to maintain the stability of the building safely.

2.7.5. Aesthetics

Architectural design also encompasses the artistic expression of the building in style, for instance, modern, classic, industrial; the proportions; and the overall visual harmony.

The design, inside and outside, is by the look and feel one wants to portray: sleek and modern, warm and traditional, bold and innovative.

2.7.6. User Experience

Design the spaces to be functional yet comfortable and pleasant for users.

Consider ergonomics, accessibility, and ambiance-ramps instead of stairs, wide doors for wheelchair access.

2.7.7. Regulations and codes

It has to meet the local building code, safety regulations, zoning laws, and accessibility standards. The designs should strictly adhere to the architects in all legal respects regarding permits that will be required for them to begin construction.

2.8. Design Process

2.8.1 Conceptual Design

This is the first stage where the architect provides a rough picture of the design he has in mind. It involves sketches, mood boards, and simple models.

2.8.2 Schematic Design

The architect creates more advanced drawings, like floor plans and elevations. Refine the design concept; study the project for feasibility.

2.8.3 Construction Documents

Construction drawings and specifications are created in detail. These documents direct the builders and ensure that the design is executed according to plan.

CHAPTER 3.MATERIALS AND METHODS

3.0 Description of the study area

The proposed site for this project was located in Nyarugenge district, Muhima sector,

Figure 3.1: Site location of proposed building station

3.1. Data Source

The architectural drawings and designs of the G+3 commercial building was obtained and studied in minute detail to understand the layout, dimensions, and specifications from the viewpoint of an architect. Detailed discussions with the architects and builders present on the project were held to understand the aesthetic requirements and unique design considerations.

Historical climate information, which included weather patterns and recorded wind speeds for Nyarugenge district, was also obtained from relevant meteorological sources. This information proved important in making realistic estimates of the wind loads, which are fundamental in the structural design process.

Besides site-specific information, a critical literature review was done to understand the best practices and new approaches towards the design of multi-story buildings. Various scholarly articles, research papers, and textbooks were studied in order to understand state-of-the-art developments in the field of structural engineering so that the design reflected modern approaches that were within accepted industrial standards and codes.

Consultations were also made with experts in the field, including seasoned structural engineers. This provided an excellent source of qualitative data through on-field insights and expert opinions on the issues and considerations involved in putting up multi-story buildings in the Nyarugenge district

This data formed the basis for designing the structure. Generally, attention to detail, follow-through with standards, and an integrated approach to data collection helped to ensure that the conclusions and recommendations of the dissertation were valid and scientifically sound.

3.1.1. Primary Data

The researcher has used primary data for this study as original data collected by the researcher from the population.

The main instrument used for the collection of data was the questionnaire, which was directly administered to the respondents by the researcher and the assistants. The kind of questions used in the questionnaire were mainly structured in nature; that is, closed-ended, for ease of administration and analysis. Field data obtained by the following tools:

- Direct interview and enquiries from the owner of the houses
- Carrying out site visits for on the spot observation and direct observation on existing facilities.
- Taking photographs of such visited existing facilities and producing diagrams for illustrative purposes of such.

3.1.2. Secondary data

Data sources may be either primary or secondary. In this case, the secondary source of data involves information obtained from research work already conducted that is relevant to the study. Information was sourced from textbooks, reports, journals, and electronically published maps, Google maps, Orthophotos. This data was obtained from already executed work in this field of studies. The sources of information included: Textbooks relevant to the research topic Past thesis and project works Sessional papers

- Newspapers and Journal
- Use of the internet for further information and data collection.

- Internationally recognized and accepted research encyclopedia

3.2. Design Considerations

The design of steel reinforcement is crucial to ensure the structural integrity and load-bearing capacity of the building. The following subsections provide a detailed explanation of the design considerations and calculations involved.

3.2.1 Bending Reinforcement

Moment of Resistance (Mr.): The moment of resistance for a reinforced concrete section can be calculated using the following formula

where: $Mr = As \cdot fy \cdot d(1 - (As \cdot fy)/(f^{\wedge\prime}\, c \cdot b \cdot d))$

As = area of steel reinforcement

fy = yield strength of steel

d = effective depth of the section

f'c = compressive strength of concrete

b = width of the section

Area of Steel (A_s): The required area of steel reinforcement can be calculated based on the bending, moment (M)and the moment arm (z):

$$As = M/(0.95 \cdot fy \cdot z)$$

Where:

M = ultimate moment

z = lever arm, typically taken as 0.95d for singly reinforced sections.

3.2.2 .Shear Reinforcement

Shear Capacity (Vr): The shear capacity of a reinforced concrete section is provided by both the concrete and the steel stirrups. The total shear capacity can be calculated using:

$$Vr = Vc + Vs$$

Where:

Vc = shear capacity of concrete

Vs = shear capacity of steel stirrups

Shear Capacity of Concrete (V_c):This is given by:

$$Vc = 2 \cdot \sqrt{(f^{\wedge\prime}\, c)} \cdot b \cdot d$$

Shear Capacity of Steel (V_s): The shear capacity provided by steel stirrups is: $Vs = (Av \cdot fy \cdot d)/s$

where:

Av = area of shear reinforcement (stirrup) per unit length

s = spacing of stirrups (in)

3.2.3 Column Design

- **Axial Load Capacity (P_u)**: The axial load capacity of a reinforced concrete column can be calculated as:

$$Pu = 0.95 \cdot f^{\wedge\prime}\, c(Ag - As) + fy \cdot As$$

  Where:

  Ag = gross area of the column

  As = area of steel reinforcement

- **Interaction Diagrams**: For combined axial and bending loads, interaction diagrams are used to determine the capacity of columns, considering both axial and moment capacities.

3.2.4 Beam Design

- **Flexural Design**: The flexural capacity of beams is determined using the moment of resistance formula mentioned above. The design ensures that the provided reinforcement can withstand the maximum moments experienced by the beam.
- **Shear Design**: Similar to columns, beams also require adequate shear reinforcement to resist shear forces. The design of stirrups is based on the calculated shear forces.

3.3. Detailing of Reinforcement

- **Rebar Placement**: Proper placement of rebar is essential to ensure the structural performance of concrete elements. This includes maintaining adequate cover, spacing, and alignment.
- **Splicing and Lapping**: Rebar's are often spliced or lapped to achieve the required lengths. The lap length (ls) can be calculate using

$$Ls = (db \cdot fy)/(4 \cdot \sqrt{}(f\text{^}' c))$$

Where:

db = diameter of the bar

fy = yield strength of steel

f'c = compressive strength of concrete

3.4. Aggregates

Aggregates are one of the essential constituents of concrete and occupy 60-75% of concrete volume; hence, they become very significant in determining the properties of concrete, which include strength, durability, and workability. This section provides an in-depth review of the sources, properties, quality control measures, and types that the aggregates to be used in the Nyabugogo Station redevelopment project are expected to have.

3.4.1. Types of Aggregates

Coarse Aggregates:

Description: Coarse aggregates are composed of either gravel, crushed stone, or recycled concrete. They are generally larger in diameter than 4.75 mm.

Types: In this work, a mixture of crushed stone and gravel has been utilized.

Crushed Stone: The stone is produced from hard, dense rocks such as granite or limestone.

Gravel: Naturally rounded particles, derived from riverbeds or quarries.

Size and Gradation: Aggregates are classified based on their sizes to offer the concrete mix proper packing and fewer voids. Common sizes are aggregates of 10 mm, 20 mm, and 40 mm.

Fine Aggregates:

Description: Fine aggregates are the one composed of natural sand or crushed stone dust, smaller than 4.75 mm diameter.

Types: In the present work, river sand and M-sand (manufactured sand) have been used.

River Sand: Naturally available sand, most often extracted from riverbeds; characterized by its smooth texture with rounded particles.

Manufactured Sand: Produced by crushing rocks, providing a rougher texture that improves bond with cement paste.

3.5 Additional Materials

There are other materials needed for the construction of the modern 3 + G commercial building at Nyabugogo Station, aside from the primary ones. These materials also play significant roles in ensuring that the structure is going to be durable, functional, and aesthetic.

3.6 Methods

3.6.1 Design Methodology

Design methodology adopted for the redevelopment of Nyabugogo Station involves a sequential approach to architectural and structural design. This section elaborates the various processes and tools employed to ensure a commercial building of functionality, aesthetically pleasing output and its structural soundness.

3.6.2 Architectural Design

Site Analysis

Contextual Study: Observe the environment, existing infrastructure, and socio-economic factors around.

Zoning and Regulations: Check municipal zoning ordinances, building codes, and environmental regulations for restrictions on the proposed development.

Conceptual Design

Vision and Objectives: Establish the overall vision of the project, defining its functional, aesthetic, and sustainable objectives.

Sketches and Models: Initial sketches will be done along with physical or digital models of the design concepts to start looking at the design work.

Consultation with Stakeholders: Consult all stakeholders, be it local authorities, future tenants of the building, or the community where the development is to be located, to seek their feedback on the design.

Preliminary Design

Space Planning: Detailed floor plans that indicate space allocations for different functional areas. Then, elevation and section drawings that define vertical dimensions and architectural features. Next, durable, aesthetic materials will be selected for the construction process, considering sustainability.

Final Design Development

Detailed Drawings: Full architectural drawings on floor plans, elevations, sections, detailed views.

3D Modeling: Development of detailed 3D models using Revit or Sketch Up for enhanced visualization and presentation.

Interior Design: Designing interior spaces to include furniture layouts, lighting, and finishes for a cohesive and functional environment.

d standards specific to Rwanda.

3.7 Structural Design

3.7.1 Load Calculations

Dead Loads: Calculation of the weight of the building components, which includes the structural elements, finishes, and fixed equipment

$$dead\ load = 1.4 \cdot GK$$

Live Loads: The loads that result from occupancy, furniture, equipment, and dynamic forces. Live load = $1.6 \cdot imposed\ load\ from\ table\ 1 of\ BS\ 6399{:}\ 1\ 1996$

wind Loads: Calculate the effects of wind, seismic action, and other environmental factors on the structure wind load=$1.4 \cdot WK$

Design Codes and Standards

International Standards: The design shall be done in accordance with international design codes, such as Euro code or ACI, for safety and reliability.

Local Regulations: The design shall adhere to local building codes an

Structural Analysis

Software Tools: ArchiCAD shall be the used software tools to model and analyze the building's structural elements.

Run finite element analysis to determine the stress distribution, deformation, and stability in response to various load conditions. Manual

Calculations: The results should be checked against manual calculations for critical elements.

3.7.2 Design of foundation

Foundations: Detailed design of the foundation system with respect to soil conditions, bearing capacity, and appropriate load transfer mechanisms

classification of the foundation

Shallow foundation: is the foundation where: $df/B \leq 2.0\ \ where$

df =depth of the foundation

B =base of the foundation/footing

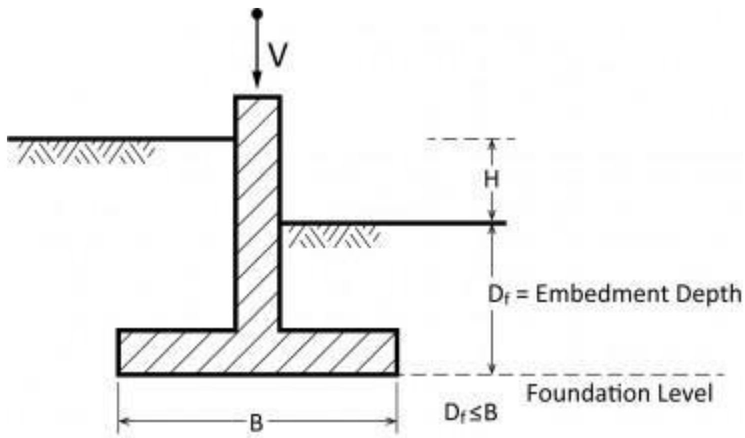


Figure 3.2: Deep foundation

Deep foundation: is the foundation where by $df/B > 2$

Ex pile foundation

Load calculation of foundation

Characteristic dead load =by considering the load from the column

Characteristic live load =by considering the load from the column

Characteristic load on foundation

w=5%-10% of the total characteristic load from the column

$$total\ load\ on\ the\ foundation = 1.0Gk + 1.0Qk + w$$

Area of foundation $= (total\ loard\ on\ foundation\ )/(bearing\ capacity\ of\ the\ soil)$

Bearing capacity of the soil is the ability of the soil to withstand upper applied load.

Bearing capacity of the soil $\nless$ Maximum pressure

Bearing capacity of the soil is determined using different method among those methods we have dynamic cone penetrometer test

Size of footing; for square footing, the size of footing is calculated $\sqrt{(Area\ of\ the\ footing)}$

For rectangular footing the size of footing is obtained by dividing the assumed side into the area of footing.

$$If\ the\ design\ stress > Bearing\ Capacity, the\ footing\ is\ unsafe$$

$$If\ the\ design\ stress < Bearing\ Capacity, the\ footing\ is\ safe$$

If the foundation is unsafe different decisions may be taken

- Consider the depth where bearing capacity is maximum
- Soil stabilization
- Resizing footing

$$Q \leq 0.54 \cdot Rb \cdot af \cdot t$$

$Q = p \cdot af \cdot s$, t = depth of the footing

p= pressure/design stress

Punching shear checks

$$Qf = Nf - \Delta q \leq Rb \cdot Ab,$$

$$where\ Nf = design\ load$$

$$\Delta q = p \cdot (ac + 2t)(bc + 2t)$$

Where μm= is the perimeter

$$\mu m = 2(ac + bc + 2t)$$

$Q > Rb \cdot Ab$, the foundation is not safe with respect to punching shear.

Conclusion the thickness of the footing should be increased

Moment

$$Mmax = (P \cdot af/2) \cdot ((bf - bc)/2)^{\wedge}2$$

Spacing of bar

$spacing = (b - 2cove - n\emptyset main\ bar)/(n - 1)$ where b=width of foundation

n=number of steel bars

Eccentrically loaded pad foundation

$$e = (M + h)/(P + w\ )\ where\ e = eccentricity$$

$M + h = momemt\ on\ the\ foundation$

$P + w =\ load\ on\ the\ column$

Condition : $L/6 > e, where\ = L = size\ of\ foundatin$

$Pmax = (P + w)/A + (M + h)/Z$ > bearing capacity

Where A= Area

$$Z = sectionial\ modulus = bL\epsilon/6$$

Condition, $Pmax > bearing\ capacity\ of\ the\ soil$

$Pmin = (p + w)/A - (M + h)/Z$ < 0 KN/m²

3.7.3. Design column

Columns and Beams: Determine the size and spacing and reinforcement details for columns and beams, respectively, for adequate strength and stiffness.

They are two type of column

- short column
- Slender column

Short column is when $lex/h \; and \;\; ley/b$ is less than 15 for braced columns and less than 10 for unbraced columns.

lex= effective height with respect to major axis

ley= effective height with respect to manor axis

h= width of column

b= breadth of column

le= B10, where n= coefficient that depend on end condition $(0{,}75 < B < 1$

Table 19 and 3.20 shows the value of B for braced column and unbraced column respectively in order to control cracking in the in the column B should be depend

$N/(b \cdot h \cdot fcu)$ this value is found in table 3.22 of the code

Minimum reinforcement

$$Asmin = 0.4 \cdot Ac$$

Maximum reinforcement

$$Asmax = (6 \times Ac)/100$$

Link

- The diameter of link should not be less than 6mmor a quarter of maximum diameter of main bars
- The spacing of links should not be greater than 12time the maximum diameter of main bar

  Design of short column

  Design of short column subjected to axial lord $N = 0.45fcuAc + 0.95fyAsc$

  Design of short column subjected to axial load moment on one axis

$$on\ y\ axis\ = N/bh$$

$$on\ x\ axis = M/bh\epsilon$$

$$100Asc/bh = the\ value\ from\ chart$$

$$d = cover - (\phi main\ bar)/2$$

Moment

$Mx/h^{\wedge\prime} > My/b^{\wedge\prime}$ The increase moment is Mx

$$Mx = mx + \beta\ h^{\wedge\prime}/(b^{\wedge\prime}\ my)$$

If $Mx/h^{\wedge\prime}\ > My/(h^{\wedge\prime}\ MY) =\ My + \beta\ b^{\wedge\prime}/h^{\wedge\prime}\ \ Mx$

$$My = my + B + b^{\wedge\prime}/(h^{\wedge\prime}\ mMx)$$

The increase moment is

$Mx = mx + \beta \cdot h^{\wedge\prime}/(b^{\wedge\prime}\ My)$

β is coefficient which is dependent on $N/bhfcu$ from the table 3.22

Load calculation

Requirement:

- Influence area
- Beam length
- Wall length
- Wall height = Height of column – Height of beam
- Height of the wall finishes = height of the column – Thickness of the slab

Calculation load

Dead loads

- Self-weight of the column = $1.4 \times width\ of\ the\ column \times breadth\ of\ column \times height\ of\ the\ column \times weight\ of\ concrete$
- Load from slab =$Design\ load\ of\ slab\ per\ unit\ area \times influence\ area$
- Load from beam = $1.4 \times Breadth\ of\ Beam \times Thickness\ of\ Beam \times Length\ of\ Beam \times Unit\ of\ Concrete$
- Load from wall masonry= $1.4 \times width\ of\ wall \times heigth\ of\ wall \times wall\ length \times Unit\ weight\ of\ masonry$
- Load from wall finishes= $1.4 \times thickness\ of\ wall\ finishes \times height\ of\ wall \times wall\ length \times 2 \times unit\ weight\ of\ finishes$
- Live load= $1.6 \times live\ load\ from\ the\ table\ 1\ of\ bs\ 6399 \times influence\ area$
- Load on column of ground floor

$$N\_1 = (load\ from\ slab + load\ from\ beam + load\ from\ wall\ finishes + live\ load) \times n^\circ\ of\ storeys + (self - weight\ of\ the\ column) \times n^\circ\ of\ floor + load\ from\ roof$$

- Load from roof= $load\ from\ beam + load\ from\ slab + live\ load$
- Load on column of first floor

$$N\_2 = (load\ from\ slab + load\ from\ beam + load\ from\ wall\ finishes + live\ load) \times n° \ of\ storeys - 1 + (self - weight\ of\ the\ column) \times n° \ of\ floor - 1 + load\ from\ the\ roof$$

- Load on column of last floor
- $N\_3 = self - weight\ of\ the\ column + load\ from\ the\ roof$

Calculate fixed end moment of column

$$KAB = 1/2 \times (bh\^3)/12LaB$$

$$KBC = 1/2 \times (bh\^3)/12LBC$$

$$KBD = Kcol = (bh\^3)/12LBD$$

εK= $KAB + KBC + Kcol$

Distribution factor= $kcol/\varepsilon K$

Fixed end moment at point B

FEMBA=$(ql\^2)/12$

FEMBC=$(ql\^2)/12$

Different of moment=$FEMBA - FEMBC$

Design moment=Different of moment$\times$ $Distribution\ factor$

If $Mx/h\^{\prime}\ \geq My/b\^{\prime}$

The increase moment

$$Mx = Mx + \beta\ h\^{\prime}/(b\^{\prime}\ My)$$

$$Mx/h\^{\prime}\ < My/b\^{\prime}\ ;\ My = My + \beta\ b\^{\prime}/(h\^{\prime}\ Mx)$$

If $Mx/h\^{\prime}\ < My/b\^{\prime}$

The increase moment

$$My\^{\prime} = My + \beta\ b\^{\prime}/(h\^{\prime}\ Mx)$$

$$N/bhfcu$$

3.7.4 Design of beam

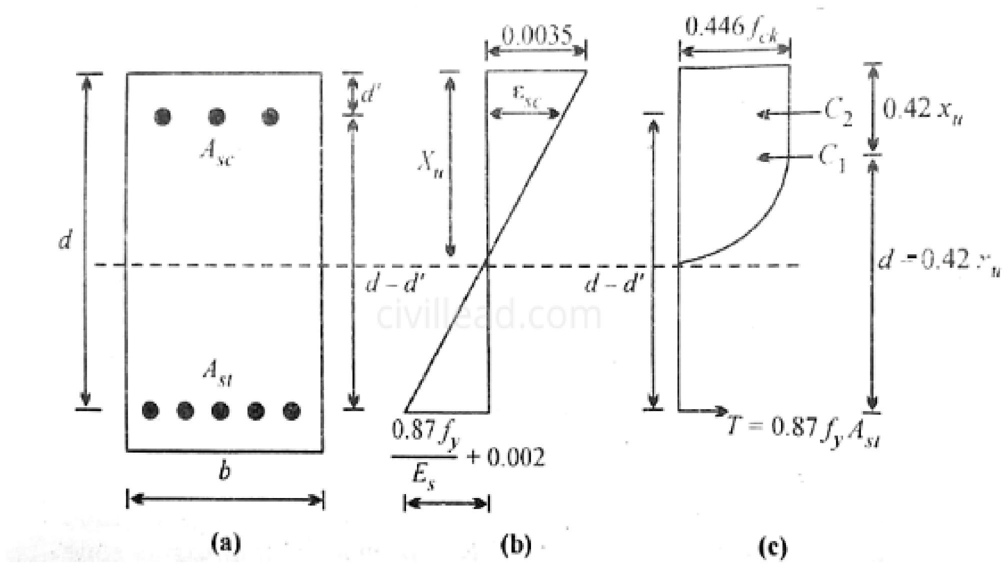


Figure 3.3 : Doubly reinforced beam

Condition: $Mu > MRC$; $K > KCol$

Flange beams: T beam

: L beam

T beam

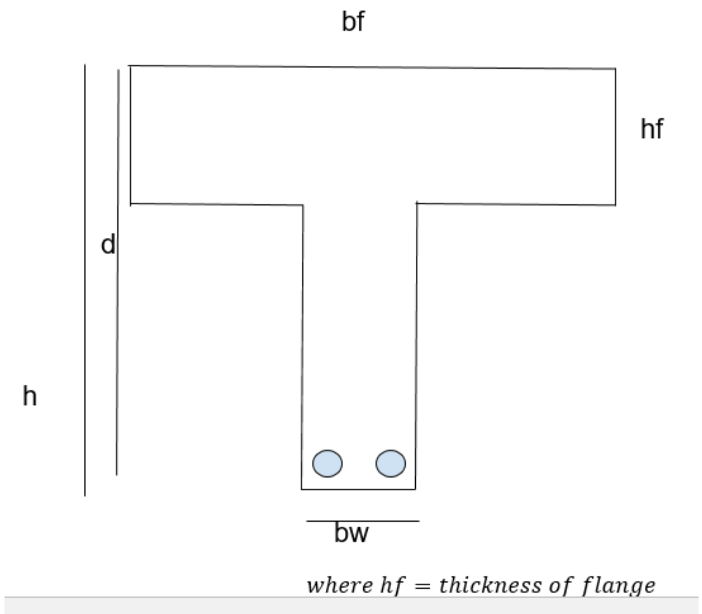


Figure 3.4: T Beam

L beam

The intention /main goal of designing beam section is to find out the area of steel needed condition

$$Asmin < As < Asmax$$

Where $As = Area\ of\ steel$

$$Asmin = Area\ of\ steel\ minimum$$
$$Asmax = Area\ of\ steel\ maximum$$

Table 3.1: Percentages of area of steel minimum

	percentage	Minimum 230N/mm²	maximum460N/mm²
Tension r/f rectangula beam Flange beam web in Tension $\frac{bw}{b} < 0.4$ $\frac{bw}{b} \geq 0.4$	$\frac{100As}{Ac}$ 100AS/bwh 100AS/bwh	0.24 0.32 0.24	0.13 0.18 0.13
compression r/f rectangula Beam Flange beam web in compression	100Asc/Ac 100ASc/bwhf	0.2 0.2	0.2 0.2

Where $As = Area\ of\ tension$

$Asc = Area\ compression$

$Ac = Area\ of\ concrete\ section = bh$

$$r/f = reinforcement$$

$$Asmax\ should\ not\ be\ greater\ than\ 4\%$$

Moment of resistance

Calculation of internal forces

$$force = J \times A$$

$$C = 0.201\ bd\ fcu$$

$$T = 0.95fy \times As$$

For equilibrium internal forces should be equal

$$c = T$$

$$As = (0.211 \cdot bd \cdot fcu)/fy$$

$$Z = 0.775d$$

Z=lever arm

Moment of resistance of steel

$$MRC = T \times Z = 0.95fyAs \qquad = 0.736dfyAs$$

Moment of resistance of concrete.

$$M = c \times Z = 0.201fcubd \times 0.775d$$

$$MRC = 0.156fcubd^\wedge 2$$

For equilibrium

$$MRS = MRC$$

$$0.736dfyAs = 0.156fcubd^\wedge 2$$

$$AS = MRC/0.736dfy \Rightarrow 0.212\ fcubd/fy$$

Percentage of reinforcement

$$p = 100As/bd$$

$$MRC = 0.156fcubd^\wedge 2$$

$$K = MRC/(fcubd^\wedge 2\ )\ where\ k\ is\ the\ factor\ ractor$$

$$Kbal = O.156$$

If $MU < MRC, no\ compression\ bar\ required$

$MU >, compression\ bars\ required$

Where Mu=ultimate moment bars required

MRC=moment of resistance of the concrete

Or

If K<Kbal,$no\ compression\ bar\ required$

K>Kbal,$compression\ bar\ required$

$Z = d[0.5 + \surd(0.25 - k/0.9)] \ngtr 0.95d$

If $Z > 0.95; take\ Z = 0.95d$

$$As = MRC/0.95fyz \Rightarrow Asmin = 0.13AC/100 \Rightarrow Ac = bh$$

$$Asmax = (4 \times Ac)/100 \Rightarrow (4 \times bd)/100$$

$$Asmin \nless As \nless Asmax$$

Calculated area of steel $As = MRC/0.95fyZ\ is\ called\ area\ of\ steel\ required \Leftrightarrow As\ reg = MRC/0.95fyZ$

As provided =AS provided is found in the table of groups of bars.

As provided: it is the area which is greater than as required but which is very close to it

As provided gives us number and size of steel bar and sometime spacing of bars

$$K = MRC/(fcubd^2)$$

For doubly reinforced beam concrete beam

For internal equilibrium

$$T = Cs + Cc \Rightarrow Cc = 0.45fcu \times 0.9x \times b$$

$$= 0.203fcubd$$

$$Cs = \delta \times A = 0.95fy \times As$$

$$T = 0.95fyAS$$

$$AS = AS - 0.203fcubd/0.95FY$$

Cs=$(M - MRC)/(d - d^{\prime})$

$$Cs = 0.95fy \times As$$

$$AS^{\prime} = Cs/0.95fy\ replace\ Cs\ by\ its\ value$$

$$As^{\prime} = (M - MRC)/((d - d^{\prime}) \times (0.95fy))$$

$$d^{\prime} \ngtr 0.214d \ngtr 0.43x$$

Flanged beam

If $MU < MRC, the\ netral\ axis\ is\ located\ in\ flange\ then\ the\ beam\ will\ be\ designed\ as\ rectangular\ beam\ if\ Mu > MRC\ , the\ neutral\ axis\ is\ located\ in\ web. then\ the\ beam\ will\ be\ designed\ as\ flanged\ beams.$

$$MRC = 0.45fcubhf(d - hf/2)$$

Neutral axis in web

Tension reinforcement only Mu<MRC

$$MRC = 0.95fyAs(d - hf/2) - 0.2fcubwb(0.225d - hf/2)$$

$$As = (M + 0.1fcubwb(0.45d - hf))/0.95fy(d - hf/2)$$

Tension reinforcement and compression reinforcement

$$MRC = fcubd^2\ [0.45\ hf/d\ (1 - bw/b)(1 - hf/2a) + 0.155\ bw/b]$$

$$As^{\prime} = (M - MRC)/0.95fy(d - d^{\prime})$$

$$As = 0.2fcubwd + 0.45fcuhf(bf - bw) + AS$$

$$d^{\prime}/x \ngtr 0.43 \Leftrightarrow d^{\prime} \ngtr 0.43x$$

$$b = bf$$

$$bf = bw + lz/5 \ for \ T \ beam$$

$$bf = bw + lz/10 \ for \ L \ beam$$

$$lz = distance \ between \ point \ of \ zero \ moment \ (effective \ span)$$

For continuous beam lz=0.7 $\times$ $effective \ span$

Shear reinforcement design

Shear stress= $v = w = v/bd$

$$v = maximum \ shear \ force$$

Shear capacity= $Vc = Wc$

$$Vc = (0.79(100As/bd) \ ((〖1/3〗 \ ^\wedge (400/d)1)/4(fcu/2s)1)/3)/1.25$$

$(100As/bd)$ 〖1/3〗 ^ $\ngtr 3$

$(400/d)1/4 \nless 1$

$(fcu/2s)1/3 \nless 1$

If $V < Vc \ no \ shear \ reinforcement \ required$

If $V > Vc$ shear reinforcement required

Deflection of beam

Deflection in a beam should be minimized the code (Bs 8110:part 2) in its clause 3.2.1 state that deflection should not be greater than $L/250$;where L is effective span deflection affects finishes in order to make that deflection should not affect finished the following limits are respected

$\frac{L}{350}$ for brittle finishes

$\frac{L}{500}$for non-brittle finishes

Span to effective depth

Basic span to effective depth ratio Basic span depends on the Beam sections rectangular beam or flanged beam the basic span/d is given in table 3.9 of the code

Table 3.2: Span to effective ratio table 3.9 of the code

Support condition	rectangular beam	Flanged beam bw/ b$\leq$ *0.3*
Cantiliver	7	5.6
simply supported	20	16.0

continuous	26	20.8

this value is applied to span up to 10 m if you have to close out of 3.4.6.4 for long span($> 10m$

Modification factor

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

fs=services stress

$$fs = 2/3 \ (fy \times As\ reg)/Asprouv \times 1/Bb$$

Bb=(moment after redustribution)/(momemt before redistribution)

When there is no moment redistribution. fs=$2/3\ fy$ table 3.10of the code highlights the values of Bb and in normal cases Bb is taken as 1

Asreq= Area of steel required at mid span to support ultimate loads

Asprouv=Area of steel provided at midspan

Compression renforcement

M.F=$1 + ((100As^{\prime}\ prouv)/bd)/(3 + (100As^{\prime}\ prou)/bd) \leq 1.5$

Allowable span to effective depth ratio

Basic span to effective depth ratio$\times\ M.F$ for tension reinforcement $\times\ M.F\ for\ compression\ rf$

Actual span to effective depth ratio= $(effective\ span)/d = span/d$

If allowable spend to effective death ratio is greater than actual spend to effective death ratio the beam is satisfactory with respect to deflections

if allowable spend/d is less than actual span/d beam is not satisfactory with respect to deflection

3.7.5 Design of slab

Slab is horizontal flat structure elements that is provided as a cover of floor of the building, slab support different loads such as its self-weight and imposed load

Type of slab

One-way slab=slab spanning in one direction

Two-way slab=slab spanning in two direction

Flat slab is a slab which is supported by columns and beam without intermediate beam

Condition

If $(ly)/lx \leq 2\ the\ slab\ is\ a\ two\ way\ slab$

If $ly/lx > the\ slab\ is\ a\ one\ way\ slab$

Where ly is long span

lx is short span

The thickness of slab is ranging between

$$lx/20 \text{ and } ly/40$$

Calculation loads

Dead load calculation.

Self-weigh of the slab=thickness of the slab*unite weight of concrete *breadth of slab (b=1m)

Finishes =1.4*unit weight of finishes*breadth of slab

Total = self-weight of the slab finishes

Imposed load calculation

imposed load/live load=1.6*imposed load from table 1of bs 6399:1-1996

design load =design dead load +design live load

calculation of moment

Msx= Bsx*n*$(lx)^2$

Msy= Bsy*n*$(ly)^2$ where Bsx and Bsy are moment coefficient from table 3.14 of the code (Bs 8110:1-1997) these coefficients depend on the type of panel and value of panel and value of ly/lx

n=design load

3.7.6 Design of Stair and Ramps

A stair is composed with landing and steps, where step= riser and going

Number of rises = number of going +1

Slope relationship 550<2R+G<700

dead load calculation out of landing

self-weight =1.4*thickness of stair slabs *length of flight*width of flight*unit weight of concrete.

Imposed load =1.6 *length of flight *width of flight*imposed load from table

Landing

Self-weight of landing =1.4 *width of landing *length of landing *thickness of landing

Total design load =self-weight f landing +imposed load

Design and Formwork: Detailed design of staircases and ramps includes rise and tread dimensions. Formwork is set up to shape the stairs and ramps.

Reinforcement: Reinforcing steel is laid in the formwork; with required overlaps and anchorage at landings.

Concrete Pouring: Concrete is poured in steps and compacted. Finishing consists of troweling to provide a smooth surface and non-slip treatments where necessary.
Curing: Adequate curing is necessary to prevent cracking and achieve the strength needed.

Electrical and Plumbing Installations: Conduits and pipes shall be embedded in walls and slabs. Connections shall be made according to safety standards and design specifications.

CHAPTER 4.RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results obtained from the structural design and analysis of the Nyabugogo Station redevelopment project. The outcomes of the geotechnical analysis, material selection, structural load analysis, and design decisions are discussed in detail. Furthermore, the challenges posed by the swampy site conditions and the methods implemented to overcome these obstacles will be examined in the context of the overall design's effectiveness, compliance with standards, and durability.

4.1Design of slab

For calculating the design of slab, we need to choose the critical panel.

The critical panel is the panel that are supposed to carry the biggest load and who has the biggest Ly and Lx where Ly is the long span and Ls is the short one. we can know that the panel are carried the biggest load if it loaded not from a stair.

Let consider that the critical panel is the panel 294

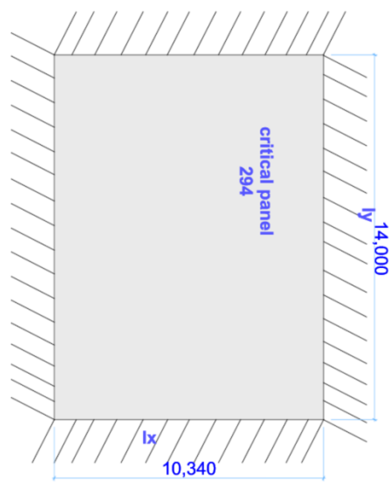


Figure 4.1: Slab Panel

Lx= 1400

Ly=1034

By consider the two types of slab to determine the types of slab.

If $\frac{Ly}{Lx} \leq 2$ the slab is two ways slab

If $\frac{Ly}{Lx} > 2$ the slab is a one-way slab

$\frac{Ly}{Lx} = \frac{1400}{1034} = 1.35$ the slab is 2 ways slab

The thickness of slab is ranging between

$\frac{Lx}{20}$ and $\frac{Lx}{40}$ n *

$\Rightarrow \frac{Lx}{20} = 70\ Cm$

$\Rightarrow \frac{Lx}{40} = 25.85\ Cm$

By considering that the thickness of slab is given as 25 Cm

Calculation load:

Self-weight of the slab = Thickness of slab * Unit Weight of concrete * 1.4 * Breadth of slab (b= 1m)

=0.25 * 1.4 * 25 * 1 = 8.75 kN/m

Finishes load = 1.4 * Unit weight of finishes * Breadth of slab

= 1.4 * 19 * 1 = 26.6 kN/m^2

Total = self-weight * Finishes =8.75 + 26.6 = 35.35 kNm^3

Imposed load

Live load = 16 * Imposed load from the table 1 of BS 6399:1996

We assume that, Imposed load from table = 3 kN/m^2

=1.6 * 3 = 4.8 kN

Calculation moments:

MSX^{-}= BSX * $(Lx)^2$ = MSy^{-} $\Rightarrow$ BSy * n * $(Ly)^2$

MSX^{+} = BSX * n * $(Lx)^2$ $\Rightarrow$ MSy^{+} = BSy * n * $(Ly)^2$

Where BSx and BSy are moment coefficient from table 3.14 of the code (BS * 110:1 – 1997)

The coefficient depends on the type of panel and value of $\frac{Ly}{Lx} = 1.35 \approx 1.4$

n = design load

MSx^{-}=0.0500*57.17*$(10.34)^2$=305.662kNm

MSy^{+}= 0.037 * 57.17 * $(10.34)^2$ =226.145 kNm

MSy^{-}= 0.032 * 57.17 * $(14)^2$ = 358.57 kNm

MSy^{+}= 0.024 * 57.17 * $(14)^2$ = 268.927 kNm

Shear Force

$$\frac{Ly}{Lx} = 1.35 \approx 1.4$$

VSx = BXx*n*Lx = 0.43*57.17*(10.34) = 254.18

VSy = BXy*n*Ly = 0.33*57.17*(14) = 254.12

Design for moments

MRC = 0.156

$$d = h - cover - \frac{\emptyset\ main\ bar}{2}$$

Let assume that Ø main bar 16 mm

$$d = h - cover - \frac{\emptyset\ main\ bar}{2}$$

$$h = 250 - 25 - \frac{16}{2} = 217mm$$

MRC = 0.156*30*1000*$(217)^2$

=220.376520

$$M < MRC$$

$$57.17 < 220.376520 \Rightarrow No\ cpompression$$

Bar required:

$$k = \frac{M}{fw\ bd^2} = \frac{57.17 * 10^6}{30 * 1000 * (217)^2} = \frac{57170000}{6310000} 0.040$$

$$k < k\ bal\ 0.028 < 0.156\ \Rightarrow No\ compression$$

$$Z = d\left[0.5 + \sqrt{0.25 - \frac{15}{0.9}}\ \right]$$

$$Z = 217\left[0.5 + \sqrt{0.25 - \frac{0.04}{0.9}}\ \right]$$

$$Z = 217\left[0.5 + \sqrt{0.25 - 0.044}\ \right]$$

$$Z = 217\left[0.5 + \sqrt{0.206}\ \right]$$

$$Z = 217[0.5 + 0.45]$$

$$Z = 206.99 \ngtr 0.957217$$

$$Z = 206.99 \ngtr 206.13$$

Let take Z = 206.15

$$Asreq = \frac{M}{0.95fyZ} = \frac{57.17 * 10^2}{0.95 * 460 * 206.15} = \frac{57170000}{9008755} = 634.6 \approx 635$$

$Asprov = 678 \quad 6T12$

$$ASmin = \frac{4 * AC}{100} = \frac{0.13 * B * h}{100} = \frac{0.13 * 1000 * 250}{100} = 325$$

$$ASmax = \frac{4 * AC}{100} = \frac{4 * b * h}{100} = \frac{4 * 1000 * 250}{100} = 10000$$

The condition is verified

ASmin $<$ AS $<$ ASmax $\Rightarrow 325 < 635 < 10000$

Design for shear

Shear at point x V=254.18

$$W = V = \frac{V}{bd} = \frac{254.18 * 10^3}{1000 * 217} = \frac{254180}{217000}$$

V=1.17 N/mm^2

$$Vc = Wc = \frac{0.79\left(\frac{100AsP}{bd}\right)^{1/3}\left(\frac{400}{d}\right)^{1/4}\left(\frac{fw}{25}\right)^{1/3}}{1.25}$$

$$\left(\frac{100AsP}{bd}\right)^{1/3} \ngtr\Leftrightarrow \left(\frac{100 * 678}{1000 * (217)}\right)^{1/3}$$

$$\left(\frac{67800}{217000}\right)^{0.333} = 0.68123$$

$$\left(\frac{400}{d}\right)^{1/4} \Leftrightarrow \left(\frac{400}{217}\right)^{0.25} = 1.16 > 10k$$

$$\left(\frac{fw}{25}\right)^{1/5} \nless 1\left(\frac{30}{25}\right)^{1/3} = 1.06 > 10k$$

$$Vc = \frac{0.79 * 0.681 * 1.16 * 1.06}{125} = 0.49\frac{N}{mm^2}$$

$$V < Vc; \frac{1.17N}{mm^2} > \frac{0.49N}{mm^2}$$

Shear reinforcement is required

Deflection check

Basic span to effective depth lotio from table 3.9 of the code basic span /d =26 for continuous slabs.

M.F for tension reinforcement

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

$$fs = \frac{2}{3} fy * \frac{Asreq}{Asprov} * \frac{1}{Bb}$$

$$fs = \frac{2}{3} * 460 * \frac{635}{678} * 1 = \frac{287.21N}{mm^2}$$

$$\frac{M}{bd^2} = 0.53 + \frac{477 - 287.21}{120(0.9 + 121)}$$

$$= 0.55 + \frac{189.7826941987}{253.6900762386}$$

$$= 1.36 + 0.55 = 121 < 2$$

Allowable span/d = basic span/d * MF

=26*1.91 = 49.66

Actual span/d=$\frac{10340mm}{217mm} = 47.6$

Allowable span/d>actual span/d the slab is satisfactory with respect to deflection.

Crack control

Spacing between bars should not be greater than 3d where d is effective depth 3d = 3*217 = 651mm

As calculated (consider spacing (160mm) is less than 3d = (651) there is no cracking.

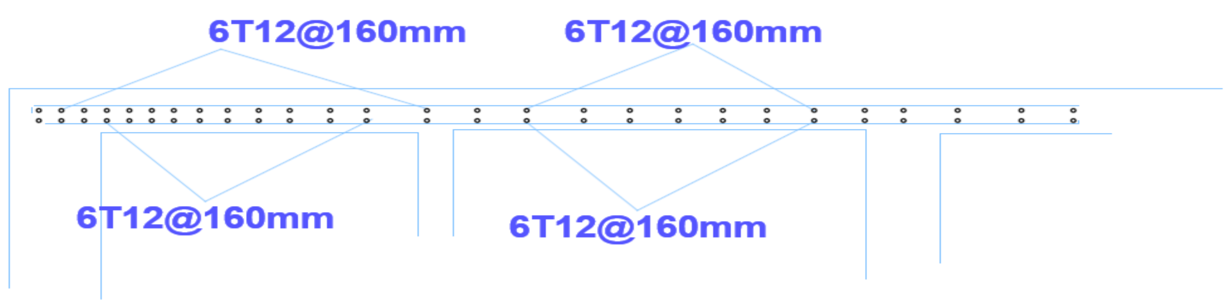


Figure 4.2: Slab reinforcement

4.2 Design of beam

For designing a beam, we need to follow this step

- Beam section
- Load on beam
- B.M and shear F

-Area of steel

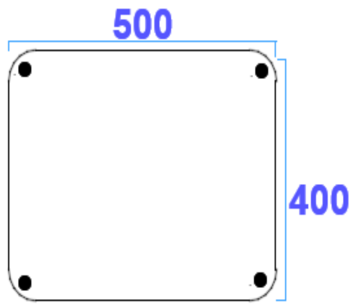


Figure 4.3: Reinforcement of beam

The intention / main goal of designing beam section is to find out the area of steel needed condition AS<AS<AS max

Where AS=Area of Steel

AS min = Area of steel minimum

AS max = Area of steel maximum

By considering the predesign we will start on it, thickness or depth of beam $\frac{lmax}{12} \leq \frac{lmax}{8}$ $where$ lmax =maximum span =1400

By knowing that our beam size is equal to 40*50cm breath of beam h/3 ≤ h/2 ⟹ $\frac{500}{3} \leq \frac{500}{2}$ 166.66 ≤ 250 load distribution from two-way slab to the beam

total self-weight of slab = w ⟹ $lx\ shorter\ side\ of\ the\ slab$

distribution of two-way slab for triangular load = w *$\frac{lx}{3}$ $self$ weight of the beam

beam size= 40*50cm

load on the span

fixed end moment for triangular section $\frac{0.25lx}{ly-0.5lx}$

for trapezoidal load w=w*$\frac{lx}{x}$ $(1\,\frac{1}{20})$

p1=$\frac{wlx}{3}$ $(\frac{3-m}{2})$ where m=$\frac{lx}{ly}$

fixed end moment for trapezoidal load

$$\frac{ly-lx}{ly-0{,}5\ lx} * w$$

M=$\frac{wl}{8}$ where w=design load from slab

$$M = \frac{57.17 * (1400)}{8}$$

D=effective depth⟹d= cover-h-$\frac{\phi main\ bar}{2}\phi link$

$$d = 500 - 25 - \frac{16}{2} - 8 = 459$$

Bf=b=400

Hf=thickness let us take 116mm

MRC=0,45*fcu*b*hf (d-$\frac{hf}{2}$)

MRC= 0.45*25*400*116(459-$\frac{116}{2}$)

MRC=13896,684000 N/mm

M <MRC ⟹307699.62 <138699.62

K=$\frac{MRC}{fcubd^2}$ =0,065

k>kbal,0,065>0,156

z=d$\left[0,5 + \sqrt{0.25 - \frac{k}{o,9}}\right] = 459\left[0.5 + \sqrt{0,25\frac{0,065}{0,9}}\right]$

z=423,15∢0,95d⇒0,95*459

423,15> 436.05

Let us take Z=423.15

AS=$\frac{MRC}{0,95fy\ z} = \frac{13896684}{0,95*460*423,15}$=751,51

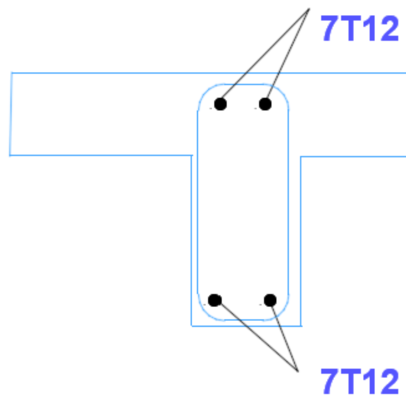
Asreq=751,51

Asprov=791 mm^2 7T12

Asmin =$\frac{0,13*Ac}{100} = \frac{0,13*400*116}{100} = 603$

Asmax =$\frac{4*Ac}{100} = \frac{4*400*116}{100} = 1856$

Figure 4.4: Reinforcement bars of beam



Asmin<As<Asmax the condition is already proved

4.3.Design of column

We will calculate total level on the column from the given structural by knowing the size of column =50*50

Thickness of beam = 50mm

Design load of beam = 57.17 KN

Live load = 3kN from the table

Weight of concrete =25 kN/m^2

Height of column = 4m

Calculation of loads

Dead loads*self – weight of the column = 14*width of column*breadth of column*height of column weight of concrete = 1.4*0.5*4*0.5*25 = 35 KN

Panel A= length*width

Influence area = A1+A2+A3+A4

A1=3*2.87= 8.61m^2

A2=3*7 = 21m^2

A3= 2.17*2.87 = 6.22m^2

A4= 2.17*7 = 15.19m^2

Influence area =8.61+21+6.22*15.19

=51.02 m^2

Beam length= (217+3) (7+2.87)-0.5 = 14.54

Wall length = (2.17+3)-0.5+(7+287)-0.5

=4.67+9.37 = 14.04m

Wall height = height of column – Height of beam = 4 - 0.5 = 3.5m

Height of wall finishes = Height of column thickness of slab = 4 – 0.25 = 3.75

Calculation of loads

Dead loads*Self – weight of the column = 1.4 * width of column*breath of column*Height of column weight of concrete = 1.4*0.5*0.5*4*24 kN/m^3 = 33.6 KN

Load from slab = Design load of slab per unit area*influence area = 57.17*51.62 = 2916.8134

Load from beam = 1.4*breadth of beam*Thickness of beam*Beam Length*Unit of Concrete

Consider

Breadth of beam = 40Cm

=1.4*0.4*0.5*3*24 = 20.16

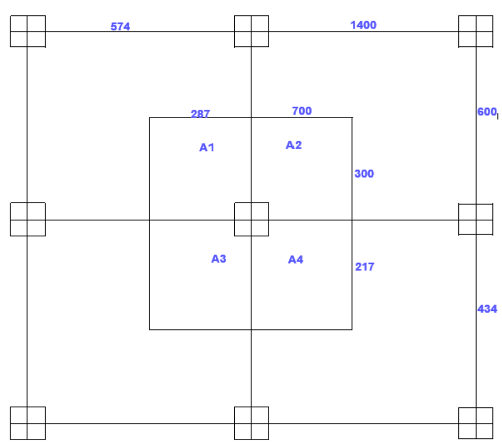


Figure 4.5: Influence area

Load from wall masonry = 1.4*Width of wall*Height of wall*Wall length*unit weight of masonry.

Width of wall = 20 Cm

= 1.4*0.2*3.5*19 = 111.72 KN

Load from finishes = 1.4*Thickness of finishes*height of wall*length of wall*2*Unit weight of finishes = 3

= 14*0.03m*3.5*6*2 = 33.516 KN

Live load = 1.6 live load from table 1 of BS 6399*influence area

=1.6*3*51.02 = 244.896

Load on column of ground floor

N1= (2919.81+20.16+111.72+33.51+244.896) *3+(336) *4 = 16489.74+134.4+5384.86

Load from roof = 2919.81+20.16+244.89 = 3184.86

N1 = 12.873.84 kN

N2 = (2919.81+20.16+111.72+33.51+244.896) *2+(33.6) *3+3184.86= 6660.18+3285.66= 9945.84 kN

N3 = (2919.81+20.16+111.72+33.51+244.896) *1+(33.6) *2+3184.86 = 3330.09+3252.06 = 6582.15 kN

N4 = (33.6) *1+3184.86 = 3218.46 kN

Calculate fixed end moment for the column which is subjected to axial load and biaxial load bending moment consider the size beam = 40 Cm

Height of column = 4m characteristic dead load

Consider dead load from column = 33.6

Consider live load from column = 244.896

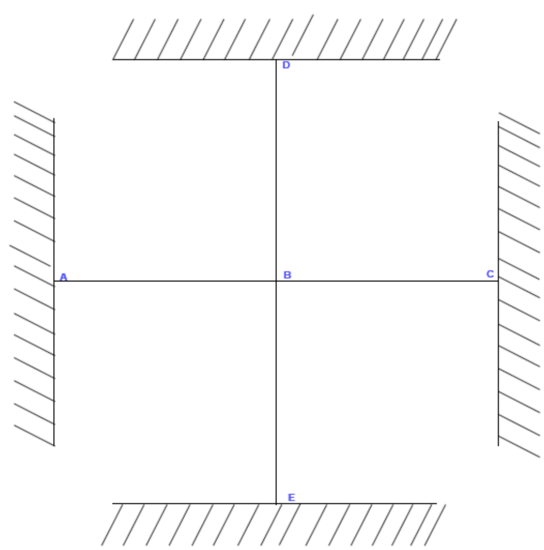


Figure 4.6: Direction of column

$$KAB = \frac{1}{2} * \frac{bh^3}{12LaB} = \frac{1}{2} * \frac{0.4 * (0.5)^3}{12 * 600}$$

$$=0.5 * \frac{0.4 * 0.25}{72} = 0.5 * \frac{0.1}{72} = 0.5 * 0.00138$$

$$=0.000694 \approx 694 * 10^{-6}$$

KBC = $\frac{1}{2} * \frac{bh^3}{12lBC} = \frac{1}{2} * \frac{0.4*(05)^3}{12*4.34}$

= 0.5*$\frac{0.1}{12*4.34} = 0.5 * \frac{0.1}{52.08}$

KBD = Kcd = $\frac{bh^3}{12LBD} = \frac{(0.4)^4}{12*1.4} = \frac{0.0256}{16.8} = 0.00015 \approx 15 * 10^{-5}$

$\varepsilon k = KAB + KBC + Kcd$

$$= 0.000694 + 0.00096 + 0.00015 = 0.001804 \approx 1804 * 10^{-6}$$

Distribution factor = $\frac{Kcd}{\varepsilon k} = \frac{0.00015}{0.001804} = 0.0831$

Fixed end moment at point B

FEMBA =$\frac{qL^2}{12} = \frac{(14*33.6)+(1.6*244.8)(6)^2}{12}$

=$\frac{47.04+391.68)36}{12}$

=$\frac{15791.04}{12} = 1315.92kNM$

FEMBE =$\frac{qL^2}{12} = \frac{33.6*(4.34)^2}{12} = 52.739$

Difference of moments = FEMBA – FEMBC

1315.92 – 52.739 = 1263.19

Design moment = difference of moment*distribution factor = 1263.19*0.0831 = 104.971kNm

my = 104.971 kNm

$$KAB = \frac{1}{2} \times \frac{bh^3}{12 \times LAB} = \frac{1}{2} \times \frac{0.4 \times (0.5)^3}{12 \times 5.74} = 0.5 \frac{0.05}{68.88} = 0.00072 \times 0.5 = 0.00036$$

$$KBC = \frac{1}{2} \times \frac{bh^3}{12 \times LBC} = \frac{1}{2} \times \frac{0.4 \times (0.5)^3}{12 \times 14} = 0.5 \frac{0,05}{168}$$

$$KBD = Kcd = \frac{bh^3}{12 \times LBB} = \frac{(0.4)^4}{12 \times 4} = \frac{0.0256}{48} = 0.00053$$

$$\varepsilon k = KAB + KBC + Kcd = 0.00036 + 0.00014 + 0.00053 = 0.00103$$

Distribution factor k=$\frac{Kcd}{ck} = \frac{0.00053}{0,00103} = 0.514$

Fixed end moment at point B

FEMBA=$\frac{qL^2}{12}$ let us assume 14Gk + 1.6Qk

14Gk = 41.32

1.6Qk = 57.72kN

$$FEMBA = \frac{41.32 \times 3.74^2}{12} = 113.44kN$$

$$FEMBC = \frac{57.72 \times 14^2}{12} = 942.76\ kN$$

Difference of moment = 942.76 – 113.44 = 829.32

Design moment = Difference of moment * Distribution factor = 829.32 * 0.514 = 426.27 kN

Mx = 426.27

h’ = h – cover $\frac{\emptyset main\ bar}{2} - \emptyset links$

Let us assume cover = 25mm

$\emptyset main\ bar = 16mm$

$\emptyset links = 8mm$

h’=500m – 25mm - $\frac{16mm}{2} - 8mm = 459mm$

b’=500mm – 25mm - $\frac{16mm}{2} - 8mm = 459mm$

if $\frac{Mx}{h'} \geq \frac{My}{b'}$

The increase moment

$$Mx = Mx + B\frac{h'}{D'}\ My$$

$$\frac{Mx'}{h'} = \frac{426}{459} = 0.92$$

$$\frac{Mx}{h'} > \frac{My}{b'} Mx = Mx + B$$

B = 0.53

$$Mx' = 426 + 0.53 * \frac{459}{459} * 104.97$$

$$Mx' = 44359.12$$

If $\frac{Mx}{h'} < \frac{My}{b'}$

The increase moment

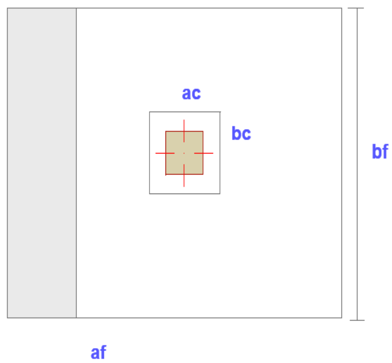
My’=My + $B\frac{b\prime}{h\prime}Mx$

$$\frac{My}{b'} = \frac{104.97}{459} 0.22$$

$$\frac{b'}{h'} My \frac{M}{bhf\omega} = \frac{12.87384 * 10}{500 * 500 * 30} = \frac{12.6734}{7500000} = 1.71$$

4.4. Design of foundation /footing

Figure 4.7: Footing sides



Classification of foundation

Shallow foundation: is the foundation where by $\frac{df}{B} \leq 2D$

where:

df = depth of foundation

B = Base of foundation/footing

Loads calculation

Dead load = consider the load from column = 35

Live load = consider the load from column = 244

Characteristic load on foundation

$\omega = 5\% - 10\%$ of the total characteristic load from the column

Total on foundation = 1.0 Gk + 1Qk + ω = service load for column + ω

Let us say $\omega = 10\%(10Gk + 1.0Gk)$

$$\omega = \frac{1.0 * 35 + 1.0 * 244.89 * 10}{100} = 27.989\ kN$$

16 loads on footing = 2798.9 + 27.989 = 2826.889 kN

Area of footing $= \frac{load\ on\ footing}{Bearing\ capacity}$

Let us assume the bearing capacity is equal to 350 kN/m^2

Area of the footing$= \frac{2826.889\ kN}{350\frac{kN}{m^2}} = 8.07m^2$

Square footing = $\sqrt{8.07m^2} = 2.84 * 2.84$

If design stress > bearing capacity the foundation is unsafe

If design stress < bearing capacity the foundation is safe

Consider design load $= \frac{2008}{2.84*2.84} = 249.1315$

Design stress < Bearing capacity

The foundation is safe

Let take the thickness of footing =80cm

T depth of footing

T=thickness of footing -cover -$\frac{\emptyset main\ bar}{2} \Longrightarrow 80 - 5 - \frac{16}{2} = 67cm$

P=249,13kn/m=0,024913

Af=150

S=25cm

Bf=150

Ac=50

Bc=50

0,54Rb*af*t=0,54*0,09*150*67=48843

Q=P*af*s=93,423

Q<0,54Rb*af*t, the condition is verified punching shear check

Where d is effective depth of the footing

Qf=nf -c

should be less or equal to Rb*Ab where nf=design load

$\Delta q = p *$(ac+2t) (bc+2t)

Rb=0,09

Ab=um*t

Um=2(ac+bc+2t) =perimeter

Using design load of column

Ac=50

Bc=50

T=67

P=0,024913KN/cm

$$\Delta q = 0{,}024913 * (50 + 2 * 67)(50 + 2 * 67)$$

Nf 2008KN

Qf =2008-843.45=1164,55

Um=2(50+50+2*67) =468m^2

Qf <Rb*Ab the foundation is not safe with respect to punching shear

Conclusion: the thickness should be increased.

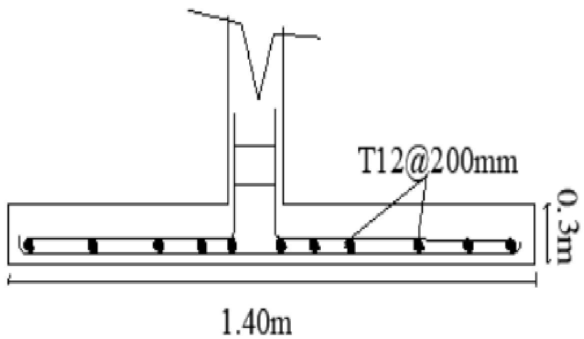


Figure 4.8: Footing reinforcements

4.5. Design of stairs

Stair is composed with landing and steps: Risers and goings.

Number of rises = Number of going + 1

Slop relationships.

550 < 2R + G < 700

Numbers of riser

Size of goings

Size of riser

Size of landing

Length of going of flight

Length of flight = Slope length

Height of floor to floor =

Slope = pitch

Thickness of waist

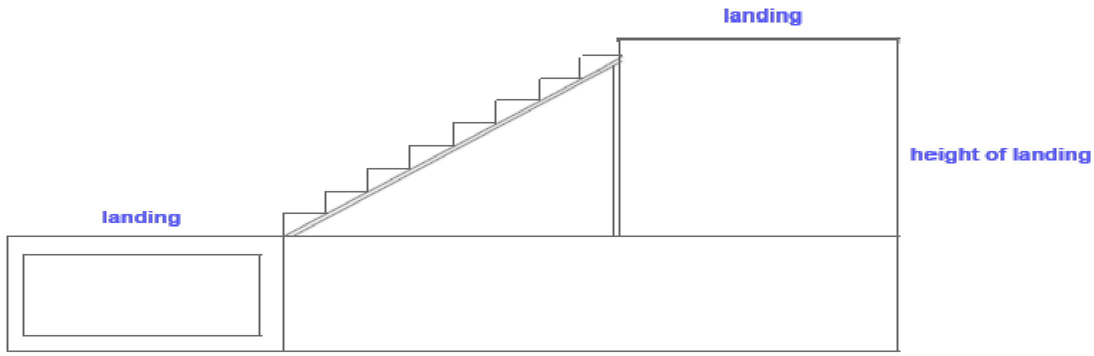


Figure 4.9: Stair sections

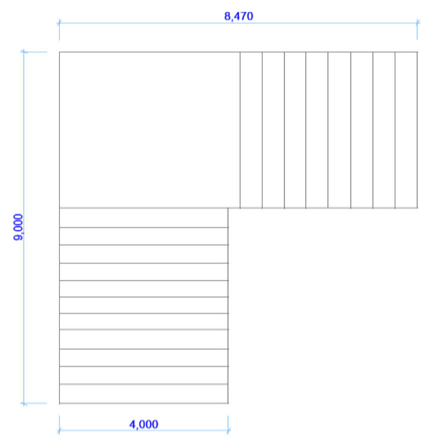


Figure 4.10: Stair measurements

Design load

Moment

Height of floor to floor = 4m

Width of beam / width of column = 40

Numbers of going = 10 goings

Numbers of riser = 10 + 1 =11

Size of riser = $\frac{1980}{11} =$ = 180 mm

2R + G = (700mm + 550mm)/2 = 625mm

G = 625 - 2R = 625 - 2. (180)

G = 625 - 360 = 265

Effective horizontal length = La + 0.3 (Lb1 + Lb2)

Where La = Is the length of stair including landing

Lb1 and Lab = width of supports (width of beam)

$$= 8.47 + 0.5(0.4 + 0.4) = 7.176\, m$$

$$\approx 7176\, mm$$

Length of going of flight = Number of goings * Size of going

$$= 10 * 265 = 2650 mm$$

Centre to center length of going of flight =

$$2650 + 0.5\,(400 + 400) = 3050$$

Length of $flight = \sqrt{(1980)^{2} + (3050)^{2}}$

$$= 3920400 + 9302500 = 13222900$$

$$= 3636.33$$

$$\approx 3.63\, m$$

Slope = $\tan^{-1}\alpha$= (Riser of flight): (horizontal distance)

$\tan^{-1}\alpha$ = ($\frac{1980}{3050}$) = 0.6491

α = 32.9°

Minimum pitch = 25° and maximum pitch = 45°

Depth of waist = $(Effective\ horizontal\ distance)/\ (26\ )$

=117.30 mm

=120mm

Thickness = effective depth + (main bar/2) + cover

=120mm+(16/2)+25mm

=153=150 mm

Dead load calculation

Out of landing

Self - weight=1.4 thickness of stair slab ……

Sinα=(ac/262) = ac = 265 sinα

=265 sin32 = 143.94 mm

Thickness of stair including finishes=Thickness of waist calculated thickness of step+tthickness of finishes

$$= 150 + (143.9/2) + 3$$

$$= 224.95\,mm$$

Self - Weight = 1.4* width of landing *Thickness of landing* unit of concrete) *0.5

= 1.4*4*2.06*25) *0.5

=144.2 KN

Impose load =

= (1.6*4*2.06*3) *0.5

=19.776

Total design load= 163.976

Total load on Span length = 163.97+184.006

Self-weight = 1,4 *0,22495*3,63*4*25kn/m^3

=114,31kN

Imposed load =1,6* length of flight*width of flight*imposed load from the table 1of BS 6399:1-1997

Imposed load = 1,6 *3,63*4*3=69,696

Total design loads on stairs slab =design dead load +design live load

$$114{,}31 + 69.696 = 184{,}006$$

Landing

Self-weight of landing = (1,4 *width of landing thickness of landing *unit of concrete) *0,5

(1,4*4*2,06*25) *0,5=144.2

Imposed load = (1,6*4*2,06*3) *0,5=19,776

Total design load =163,976

Total load on span length=163,97+184,006

$$W = 347.976$$

Mmax = wl/10 = (347.976*176):10 = 249.49KN

M=0 = 0*RA+163.97*2.06+184.006*(4126+1525)-RB*(4126+3050) =0

= 522.27611*(5.651)-RB*(7.176)

2951.38-7.176RB = 0

7.176RB=2951.38

$$RB = (2951.38/7.176) = KN$$

$$RA + RB = 347.976$$

$$RA + 112.21 = 347.976$$

$$RA = 347.976 - 112.21$$

$$RA = 235.76$$

$$Shear force at B = 112.21$$

$$SF at D = RB - FD = ½ - 184.006 = -71.79$$

$$SF at C = RB - FC = 112.21 - 163.97 = -51.76$$

$$SF at A = RB - FA = 112.21 - 184.006 - 163.97 = -235{,}766$$

$$Shear force at RB = 112.21$$

$$Area\ of\ steel\ is\ found\ by\ using\ chart$$

$$100\, As/bd = \ value\ from\ chart.$$

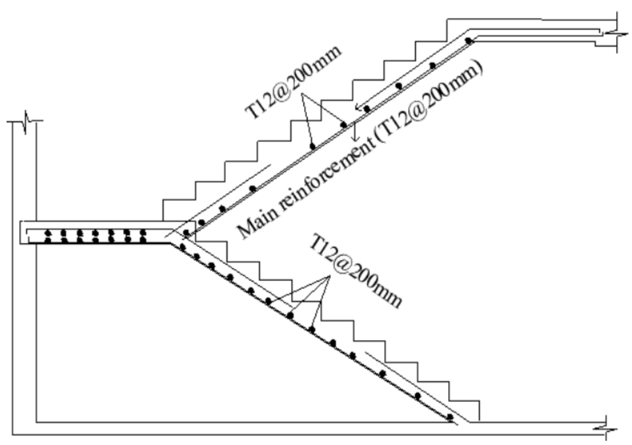


Figure 4.11: Detailing of stair

4.6. Design of ramp

Given Data:

- Ramp Length (L) = 3764 cm = 37.64 m

- Ramp Width (W)= 1200 cm = 12.00 m

- Height to be covered (Δh) = 4 m

Calculate the Slope of the Ramp

We need to calculate the slope or gradient of the ramp. The slope (S) can be calculated using the formula:

$$\mathbf{s = \frac{\Delta h}{l} = \frac{4}{37,64} = 0,1063}$$

convert the slope to percentage

$$S\% = 0,1063 * 100 = 10,63\%$$

The slope of the ramp is 10.63%, which is acceptable for vehicle ramps (typically between 8% and 12%).

Dead load calculation

- Material: Assume reinforced concrete with a unit weight of 24 kN/m³.
- Ramp Thickness (t): Let’s assume a slab thickness of 0.2 m (20 cm)

The dead load (self-weight of the ramp) per square meter is calculated as:

Dead load=thickness*unit weight=0,2*24=4,8 KN/m^2

Live load =For vehicle ramps, a live load of 5 kN/m² (typical for parking structures) will be assumed.

Total load

The total load (w) on the ramp will be the sum of the dead load and live load:

$$W = dead\ load + live\ load = 4{,}8KN/m2 + 5kN/m2$$

$$9KN/m2$$

Moment Calculation:

To calculate the bending moment, we need to know the span or support conditions. For simplicity, we’ll assume a simply supported ramp** with a span equal to its width (W = 12 m).

The bending moment at the center of the span can be calculated using the formula for a simply supported beam: M=$\frac{w*l^2}{8}$M=$\frac{9,8*12}{8}\frac{9,8*144}{8} = 176{,}4$KNm

As=$\frac{M}{fy.d}$

Where:

- M = bending moment = 176.4 kNm

- f_y= yield strength of steel (assume 500 MPa or 500 N/mm²)

- d= effective depth (assume an effective depth of 160 mm = 0.16 m for a 0.2 m slab)

First, convert the moment to Nmm:

M = 176.4 *10^6 Nmm

Now, calculate the area of steel:

$$As = \frac{176{,}4 * 10^6}{500 * 160} = \frac{176{,}4 * 10^6}{80000} = 2205$$
$$Asprov = 2513; 8T20$$

Shear force

V=$\frac{w*l}{2} = \frac{9{,}8KN/m*12m}{2} = 58{,}8KN$

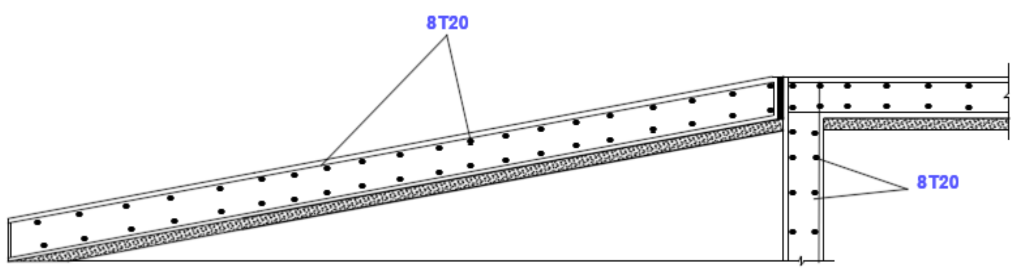


Figure 4.12: Detailing of ramp

Check the concrete section& 39; s capacity to resist this shear force, and if necessary, design shear reinforcement (stirrups) accordingly.

Deflection Check:

For serviceability, you need to check deflection. Maximum deflection for the ramp should be within the permissible limits (L/240 for live loads), where \(L\) is the span.

CHAPTER 5.CONCLUSION AND RECOMENDATIONS

5.1. Conclusion

The redevelopment project of Nyabugogo Station in Kigali, focusing on the design and construction of a modern G+3 commercial building using reinforced concrete, represents a significant step in improving urban transport infrastructure in Rwanda. The study demonstrated that the use of reinforced concrete provides a durable and efficient solution, especially in challenging areas like Nyabugogo, which is characterized by swampy conditions.

The integration of a multifunctional building with commercial spaces, offices, and restaurants not only enhances the functionality of the station but also stimulates the local economy. The project significantly improves the experience for travelers and the services provided, while addressing the growing mobility needs of an expanding city like Kigali. Additionally, the use of modern construction techniques ensured the building's safety and longevity, meeting current construction standards.

The main challenges encountered, particularly those related to the foundation in a swampy area, were overcome through in-depth geotechnical studies and appropriate reinforcement techniques. This highlights the importance of site analysis in similar projects. In summary, this project represents a major advancement for the development of Kigali's urban infrastructure, combining innovation, sustainability, and efficiency.

5.2. Recommendations

It is recommended to consider the future expansion of parking facilities to accommodate the ongoing increase in the number of travelers. The integration of green technologies, such as solar panels or rainwater harvesting systems, could also enhance the building’s sustainability and reduce its environmental impact. Furthermore, flexibility in design will allow for adaptation to the city’s future needs.

Adopting more modern construction techniques, such as prefabrication of concrete elements, would be beneficial to speed up project timelines and minimize disruptions at the station site. Given the swampy conditions around Nyabugogo, it is essential to implement regular monitoring of the foundation to ensure the building maintains its stability and durability in the long term.

REFERENCES

British Standards Institution. (1996). *BS 6399-1: Loading for Buildings – Part 1: Code of Practice for Dead and Imposed Loads*. BSI.

American Concrete Institute. (2019). *ACI 318-19: Building Code Requirements for Structural Concrete and Commentary*. ACI.

Eurocode. (2004). *EN 1997-1: Eurocode 7 – Geotechnical Design – Part 1: General Rules*. European Committee for Standardization.

Mosley, W.H., Bungey, J.H., & Hulse, R. (2012). *Reinforced Concrete Design: To Eurocode 2*. Palgrave Macmillan.

National Building Code. (2021). *International Building Code (IBC)*. International Code Council.

Neville, A.M. (2011). *Properties of Concrete*. Pearson Education.

British Standards Institution. (1997). *BS 8110-1: Structural Use of Concrete – Part 1: Code of Practice for Design and Construction*. BSI.

British Standards Institution. (2005). *BS 4449: Specification for Carbon Steel Bars for the Reinforcement of Concrete*. BSI.

Terzaghi, K., Peck, R.B., & Mesri, G. (1996). *Soil Mechanics in Engineering Practice* (3rd ed.). Wiley.

Park, R., & Paulay, T. (1975). *Reinforced Concrete Structures*. Wiley.

Eurocode. (2004). *EN 1991-1-4: Eurocode 1: Actions on Structures – Part 1-4: General Actions – Wind Actions*. European Committee for Standardization.

Hibbeler, R.C. (2017). *Structural Analysis* (10th ed.). Pearson.

APPENDICES

Appendix 1) Basic span/effective depth ratio for rectangular or flanged beams

Table 3.9 — Basic span/effective depth ratio for rectangular or flanged beams

Support conditions	Rectangular section	Flanged beams with $\frac{b_w}{b} \leq 0.3$
Cantilever	7	5.6
Simply supported	20	16.0
Continuous	26	20.8

Appendix 2) Values of the coefficient β

BS 8110-1:1997

Table 3.22 — Values of the coefficient β

$\frac{N}{bhf_{cu}}$	0	0.1	0.2	0.3	0.4	0.5	≥ 0.6
β	1.00	0.88	0.77	0.65	0.53	0.42	0.30

Appendix 3) shear coefficient for uniformly loaded rectangular panel supported on four side

Table 3.15 — Shear force coefficient for uniformly loaded rectangular panels supported on four sides with provision for torsion at corners

Type of panel and location	β_{vx} for values of l_y/l_x								β_{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 short edge discontinuous									
Continuous edge	0.36	0.39	0.42	0.44	0.45	0.47	0.50	0.52	0.36
Discontinuous edge	—	—	—	—	—	—	—	—	0.24
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
Two short edges discontinuous									
Continuous edge	0.40	0.43	0.45	0.47	0.48	0.49	0.52	0.54	—
Discontinuous edge	—	—	—	—	—	—	—	—	0.26
Two long edges discontinuous									
Continuous edge	—	—	—	—	—	—	—	—	0.40
Discontinuous edge	0.26	0.30	0.33	0.36	0.38	0.40	0.44	0.47	—
Three edges discontinuous (one long edge discontinuous)									
Continuous edge	0.45	0.48	0.51	0.53	0.55	0.57	0.60	0.63	—
Discontinuous edge	0.30	0.32	0.34	0.35	0.36	0.37	0.39	0.41	0.29
Three edges discontinuous (one short edge discontinuous)									
Continuous edge	—	—	—	—	—	—	—	—	0.45
Discontinuous edge	0.29	0.33	0.36	0.38	0.40	0.42	0.45	0.48	0.30
Four edges discontinuous									
Discontinuous edge	0.33	0.36	0.39	0.41	0.43	0.45	0.48	0.50	0.33

3.5.4 Resistance moment of solid slabs

The design ultimate resistance moment of a cross-section of a solid slab may be determined by the methods given in **3.4.4** for beams.

Appendix 4) Bending moment coefficient for uniformly loaded rectangular panel supported on four side

BS 8110-1:1997

Table 3.14 — Bending moment coefficients for rectangular panels supported on four sides with provision for torsion at corners

Type of panel and moments considered	Short span coefficients, β_{sx}								Long span coefficients, β_{sy} for all values of l_y/l_x
	Values of l_y/l_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 short edge discontinuous									
Negative moment at continuous edge	0.039	0.044	0.048	0.052	0.055	0.058	0.063	0.067	0.037
Positive moment at mid-span	0.029	0.033	0.036	0.039	0.041	0.043	0.047	0.050	0.028
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
Two short edges discontinuous									
Negative moment at continuous edge	0.046	0.050	0.054	0.057	0.060	0.062	0.067	0.070	—
Positive moment at mid-span	0.034	0.038	0.040	0.043	0.045	0.047	0.050	0.053	0.034
Two long edges discontinuous									
Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
Positive moment at mid-span	0.034	0.046	0.056	0.065	0.072	0.078	0.091	0.100	0.034
Three edges discontinuous (one long edge continuous)									
Negative moment at continuous edge	0.057	0.065	0.071	0.076	0.081	0.084	0.092	0.098	—
Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.063	0.069	0.074	0.044
Three edges discontinuous (one short edge continuous)									
Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.058
Positive moment at mid-span	0.042	0.054	0.063	0.071	0.078	0.084	0.096	0.105	0.044
Four edges discontinuous									
Positive moment at mid-span	0.055	0.065	0.074	0.081	0.087	0.092	0.103	0.111	0.056

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Appendix 5) Areas of groups of bars

Table 4.1 Areas of groups of bars

Diamenter (mm)	*Number of bars in groups*							
	1	2	3	4	5	6	7	8
6	28	56	84	113	141	169	197	226
8	50	100	150	201	251	301	351	402
10	78	157	235	314	392	471	549	628
12	113	226	339	452	565	678	791	904
16	201	402	603	804	1005	1206	1407	1608
20	314	628	942	1256	1570	1884	2199	2513
25	490	981	1472	1963	2454	2945	3436	3927
32	804	1608	2412	3216	4021	4825	5629	6433

Appendix 6) Bar spacing data

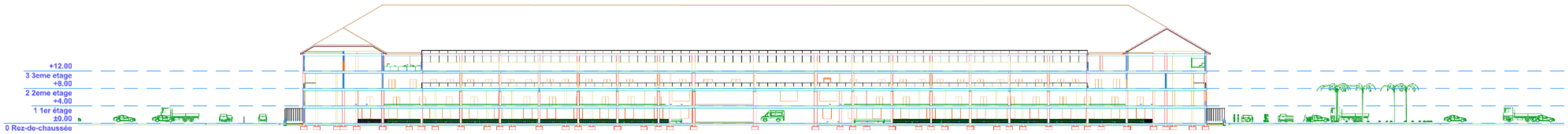
Table 8.2 Bar spacing data

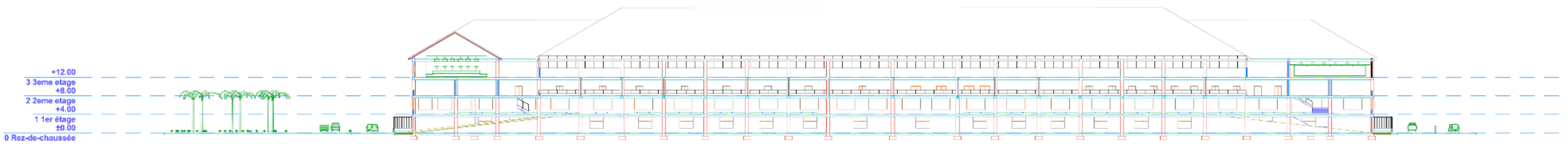
Diameter (mm)	*Area (mm^2) for spacing mm*												
	s=80	100	120	140	150	160	180	200	220	240	260	280	300
6	350	282	235	201	188	176	157	141	128	117	113	100	94
8	628	502	418	359	335	314	279	251	228	209	201	179	167
10	981	785	654	560	523	490	436	392	356	327	314	280	261
12	1413	1130	942	807	753	706	628	565	514	471	452	403	376
16	2513	2010	1675	1436	1340	1256	1117	1005	913	837	804	718	670

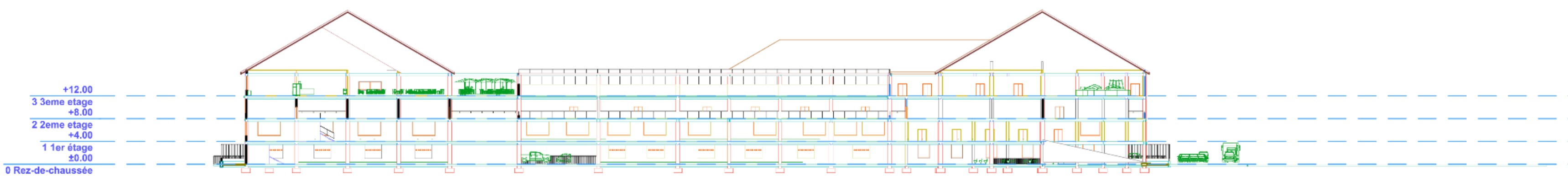
Spacing s in millimetres.

Appendix 7) Structural plans

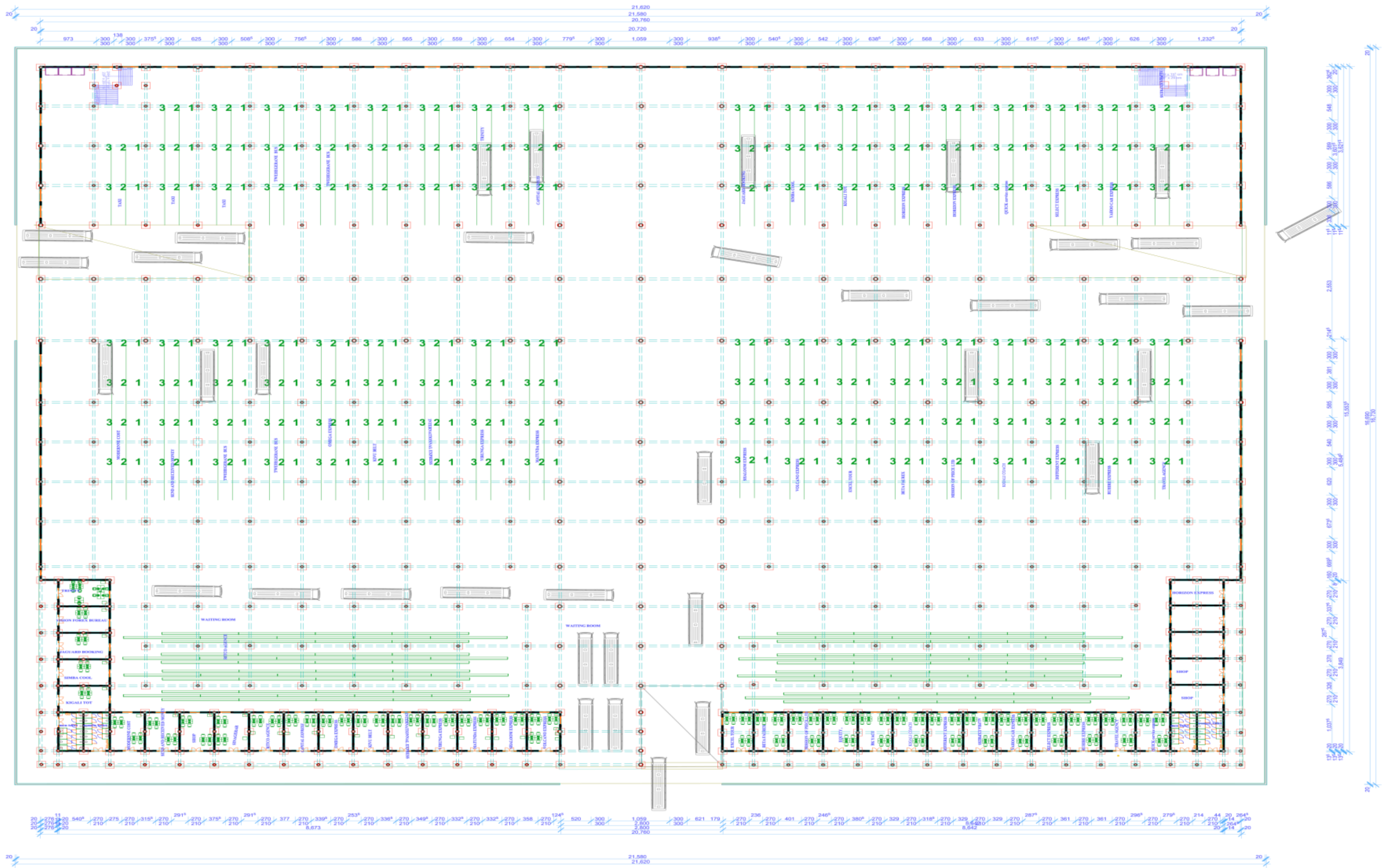
Appendix 8) Sections



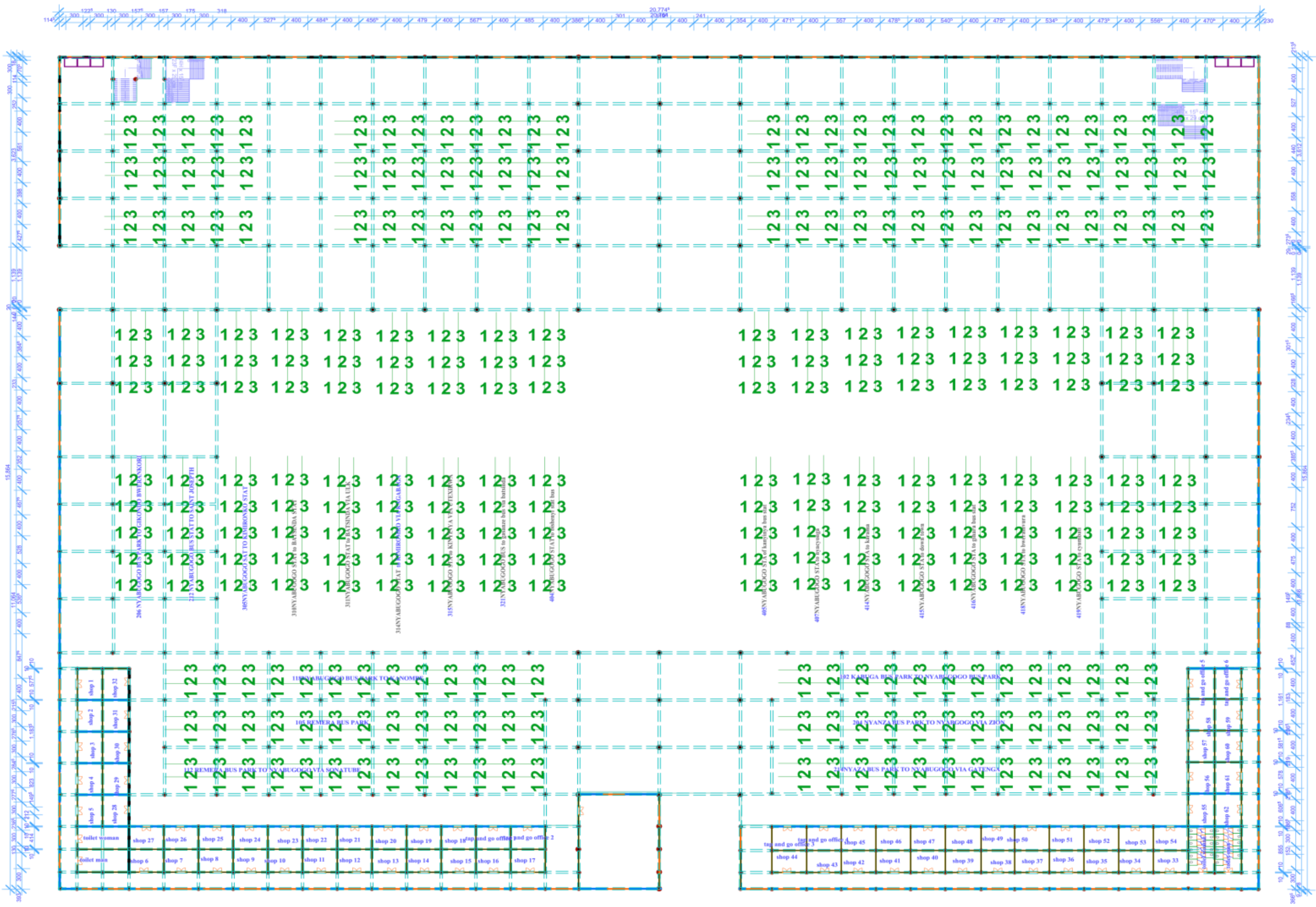




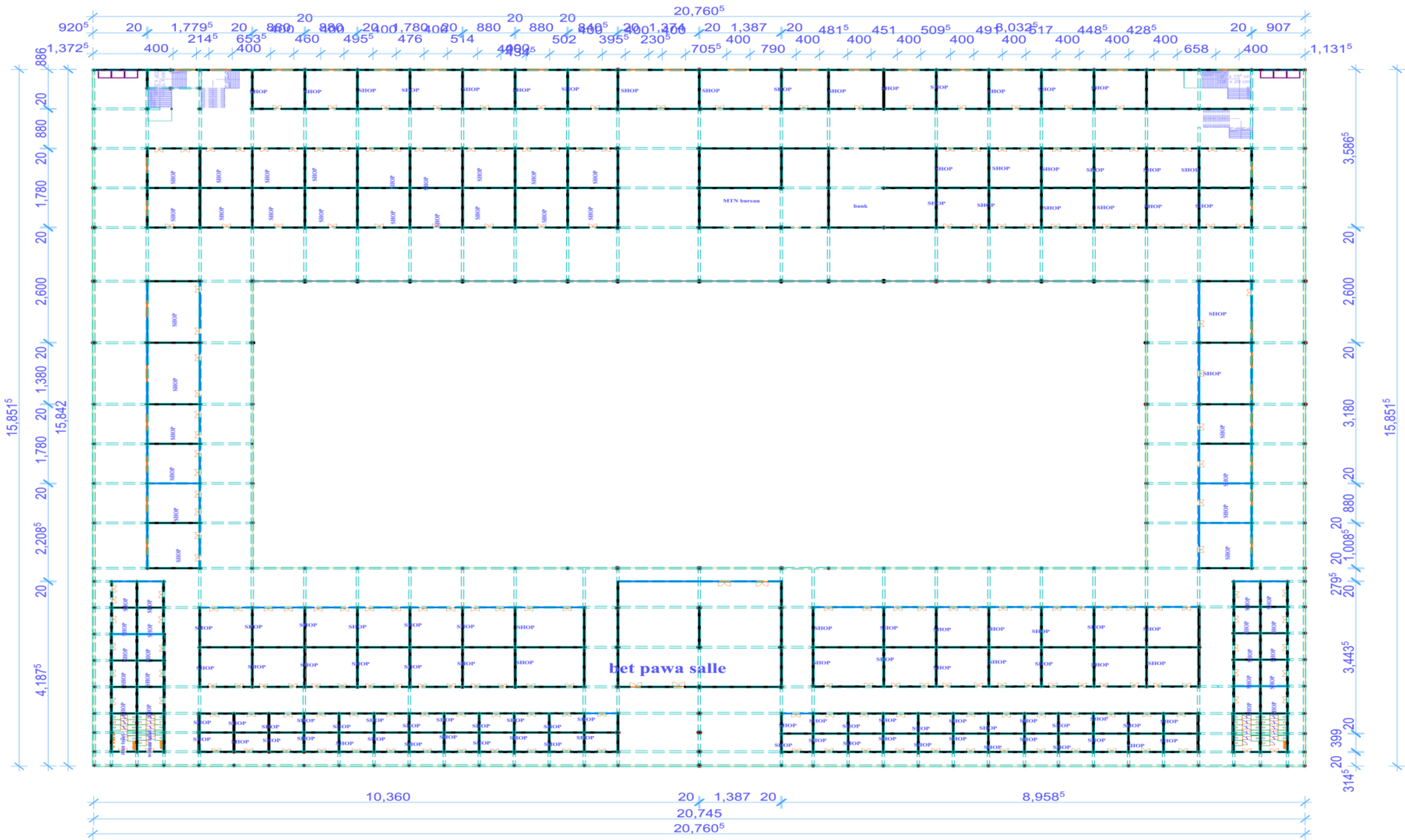
Appendix 9) Ground floor



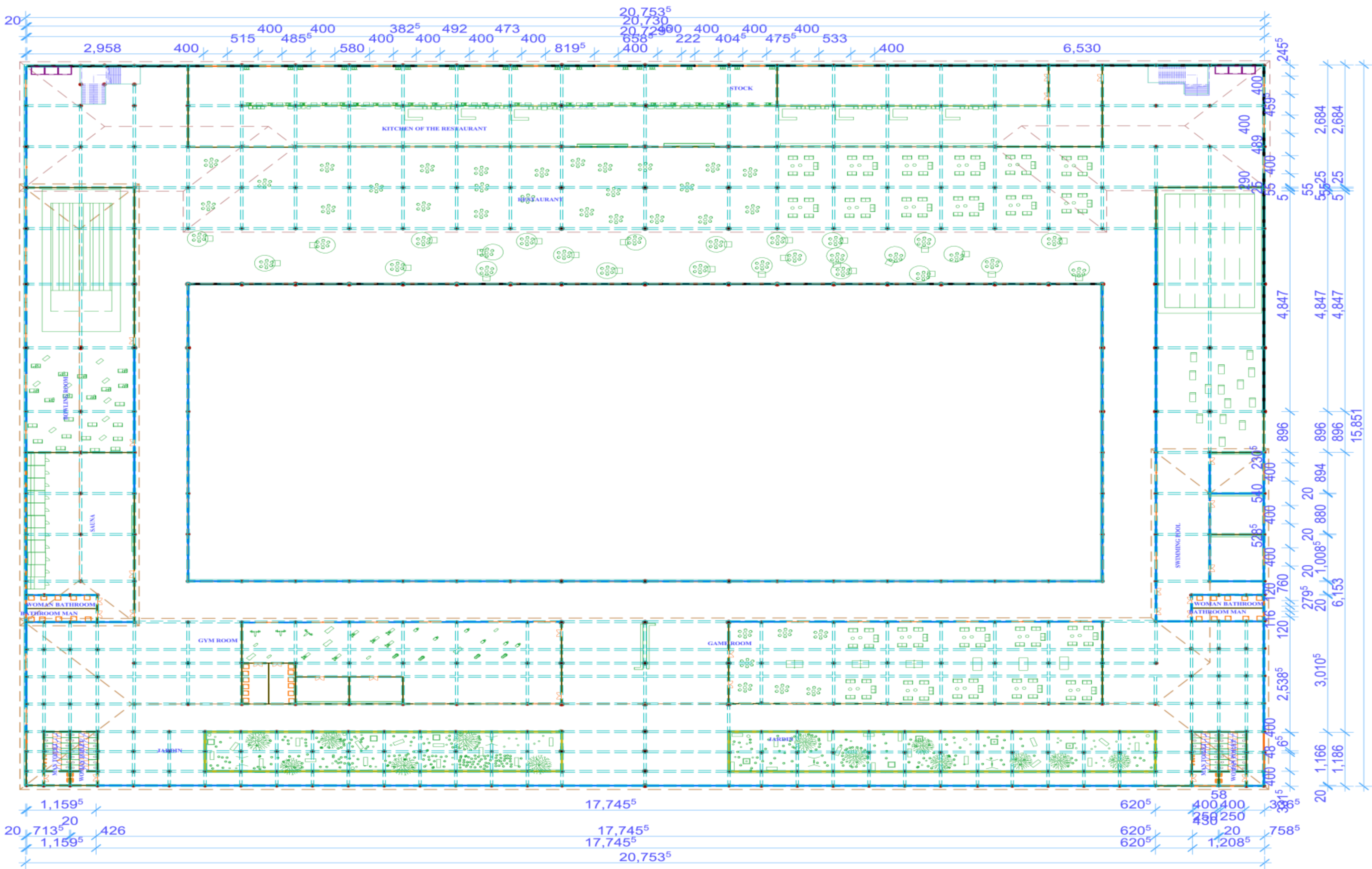
Appendix 10) First floor



Appendix 11) Second floor



Appendix 12) Third Floor

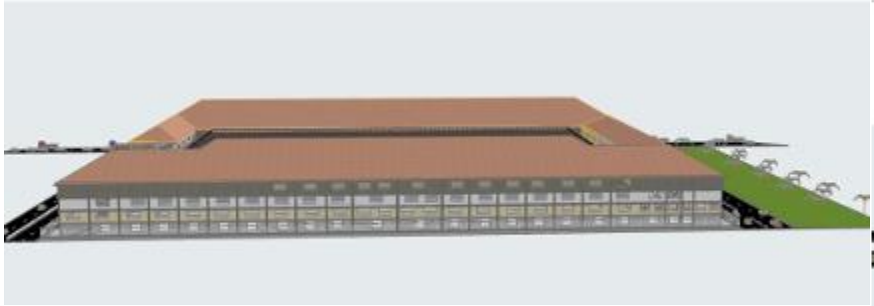


Appendix 13) Views

Front view

Right view

Back view



Lift view