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ULK POLYTECHNIC INSTITUTE (UPI)

DEPARTMENT OF CIVIL ENGINEERING

OPTION: CONSTRUCTION TECHNOLOGY

Submitted in partial fulfillment of the requirements for the grades of advanced diploma in civil engineering, construction technology in ULK POLYTECHNIC INSTITUTE.

Presented by: MUSONI Prosper

Supervisor: Eng. SINIGENGA Alphonse

Kigali September 2024

DECLARATION

This is to certify the project report entitled "structural design of a four storied apartment in Nyamagabe district, Gasaka sector." Is my own work for the best of my knowledge, the work reported does not form part of any project on basis of which a degree of award was conferred on earlier on this or any other candidate and were completed under supervision of

ENG. Sinigenga Alphonse

MUSONI Prosper 201850368

Signature………………...

CERTIFICATE

This is to certify that the project work entitled "structural design of a four storied apartment at Nyamagabe district in Gasaka sector……. "Is the original work done by Musoni Prosper submitted in partial fulfilment of the required for the Advanced Diploma A1in Civil Engineering option of construction technology in the academic year 2023-2024.

Supervisor HOD/Civil Engineering

Eng. SINIGENGA Alphonse Eng. NKIRANUYE Bonaventure

Sign……………………Date……/10/2024 Sign ………………Date……/10/2024

DEDICATION

We dedicate this project

To almighty God, for his support and guidance in undertaking this undergraduate degree program.

To our parents and families for their encouragement and support

To Ulk Polytechnique institute (UPI)

To our lovely colleagues and friends who being in our sides

To our supervisor who helped us in this project.

ACKNOWLEDGEMENT

This project has been achieved in cooperation of many persons to whom we greatly address our acknowledgements. Our first acknowledgement goes to almighty God who usually assists us even during this project until the end of it. Let just address our acknowledgements to all Civil engineering department lecturers and assistant lecturers of ULK polytechnic institute (UPI), who helped me from level one till the end of this program for getting the knowledge required for advanced diploma in civil engineering. I would like particularly to thank our supervisor Eng. Sinigenga Alphonse for his great advices and

encouragements to achieve the objectives of this project; we also thank our parents, brothers, sisters and our colleagues for their cooperation with us.
I give the great gratitude to my promotion for all they have been shared and provided with me, useful suggestions and tireless help towards me making the completion of this project.
The special acknowledgement is toward parents, families and others who had played a great attribution in the completion of this project from the beginning to the end.

ABSTRACT

The main purpose of this research was to conduct a technical detail study on the implementation of structural design of a four storied apartment at Nyamagabe district in Gasaka sector to enhance the problem of accommodating and delivering dueling units for all those who work and visit Nyamagabe district. During this research, the analysis of structural elements was made by combining manual analysis, Arch CAD 21 software for providing architectural plans Auto CAD for providing drawing details, Prokon software for analyzing and designing structures and Microsoft word and excel for writing the project report.
The study revealed that the building dimensions are 23.05 m by 22.40 m with area of (516.32m2), the minimum requirements for steel bars for slab we provide T10@200mm for Aspro=393mm2, for beams we provide 2T25 with As provided=982 mm2 at (top of the

beam in support) and 2T25 with As provided=982 mm2 at (bottom of the beam in middle span) and Provide H8@150mm, For interior columns we Provide4T12 (As=452mm2), 6T16(As=1210 mm2), 6T20 (As=1890 mm2), 6T25 (As=2950 mm2) and Provide H8@125mm (402 mm2) for exterior column we provide 4T20 with reinforcement area of As=1260mm2 and T8@200mm (As=252mm2) for footing we provide H20 at 250 mm C/C (ASP = 1260 mm2) and for stair we provide H12@125mm with As prov=905 mm2/m for main steel and we provide H12@200mm with As prov=566mm2/m for transversal distribution steel. This project gives data about how the design is done and how to know that a structural element is safe against the failure which can caused by loading the structural elements such as: column, beam, slab, stair and foundation.

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LIST OF SYMBOLS AND ABBREVIATION

@: Spacing (between two steel bars

Ac: Area of the transversal cross section of the column

As: Area of the tensile reinforcement

Asc: Area of the compression reinforcement

Asmin: The minimum required area of the reinforcement

Asv: Area of the nominal links or stirrups

b: The width of the member

BS: British Standard

bw: The width of the web (for the T beam)

C: The concrete cover

d: The effective depth of the member

dw: The depth of the web

Eng: Engineer

fcu: The compressive strength of the concrete

FEM: Fixed End Moment

FS: Service stress

fy: The characteristic strength of the stirrups

fy: The tensile strength of the reinforcement

Gk: The dead load

h: The overall depth of the member

hf: The overall depth of the flange

Lx, ly: the shortest and the longest side of the slab Respectively

M.F: Modification factor

M: Moment

N: The concentrated load

n: The uniformly distributed ultimate load

Nd: The total ultimate load

Qk: The live loadRCC: Reinforced Cement concrete

Sv: Nominal links spacing

T: High yield steel

V: Shear stress

Z: The lever arm

βsx, βsx: Moment coefficients

βvx, βvy: shear force coefficients

Φ: The diameter of the reinforcement

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CHAPTER 1: GENERAL INTRODUCTION

1.0.INTRODUCTION

This Chapter provide a comprehensive background of the study, the problem statement, the main objectives, the specific objectives, the significance of the study, scope and limitations and the organization structure for all chapters.

1.1. BACKGROUND OF THE STUDY

Any designed structure is made up of structural elements (load carrying members) such as foundation, column, beam, slab, wall and roof. All those structural elements are put together to constitute the "structural system". (ARYA, 2009)

To design a building structure is to provide adequate member size, reinforcement details, slab, stair, beam, column, pad footing, concrete strength and the achievement of an acceptable probability that the structures being designed, will perform satisfactorily during their intended purpose. With appropriate degree of safety, they should sustain all load deformations of normal construction. (Bachman, 2004)

The design of building structure must satisfy four basic requirements: stability to prevent over turning, sliding or buckling of structure, strength to resist safely the stresses induced by the loads in the various structure members, serviceability to insure satisfactory performance under service load conditions which implies providing adequate stiffness and reinforcements to contain deflections; crack width and vibrations within acceptable limits and also providing impermeability and durability and economical. (Megson, 2005)

The design of a construction structure is a multifaceted endeavor that demands a meticulous and innovative approach. In this pursuit, careful consideration is given to architectural aesthetics, structural integrity, environmental sustainability, and safety, all of which harmonize to create a functional and aesthetically pleasing built environment. (Francis D.K.Ching, 2013)

An apartment is self-contained living unit within a larger building, typically a residential complex, designed for individuals or families to reside in. It usually consists of one or more rooms, including a kitchen, bathroom, and living space, and may be rented or owned by the occupant.

Normally four storied apartment is self-contained housing or suit of rooms designed, occupied by more than one household. The building structure will be composed of one block four storied which will be occupied by four families on each level of the building.

Nyamagabe district is one of developing cities in Rwanda. has different infrastructure like roads, hospitals, schools, church, health facilities, water supply, market and trading center, government office etc. has good tourist attractions including Nyungwe national park and tea plantations. Where this city has no enough apartment for accommodation that's why we choose Nyamagabe district in Gasaka sector our case study.

The site has geographic coordinate of 2°28'19.91"South, 29°34'48.03"East and its elevation is 173.87m and area of 1,693.06m2 in Nyamagabe district, Gasaka sector, Nyamugari cell and Kabacuzi village. (Google earth 2015)

Figure 1. 1.Aerial image of plot (Google earth 2015)

1.2. PROBLEM STATEMENT

Nyamagabe district has the primary issues include an inadequate storied apartment which creates a significance interest for housing in the region. It faces several challenges that have implication for workers, visitors, traders in local housing market. This led to struggle for finding suitable and affordable accommodation due to the limited availability of apartments where by some families work in this area but do not live in due to the inadequate accommodation.

For the above highlighted problem, we have to overcome them by designing a four storied apartment to provide and facilitate accommodation which will receive four families on each story of the building and 20 families on the whole building by controlling the concentration and accommodation of people who come to work in this area and visitors.

Therefore, this project of structural design of G+4 apartment will similarly solve the develop of this city as attractive cities in south province that has well designed apartment if will be constructed.

1.3. Project Objectives

1.3.1. Main Objective

The main objective of this project is to make a structural design of a four storied apartment building in Nyamagabe district, Gasaka sector.

1.3.2. Specific Objectives

The specific objectives of this project were the following:

- To make architectural drawings
- To make [1] analysis and design of all structural members of the building
- To provide drawings of reinforcement details of each member.

1.4. Scope Of The Project

This project was focused on structural design of apartment with its drawings including the drawing details of building members, sections, views and plans.

The following was not covered: design of septic tank was not covered because there is no data collected about waste that will be used in the building. Soil bearing capacity was not covered because instrument to be used was expensive.

1.6. ORGANIZATION OF PROJECT

This project is organized as follow:

Chapter i: General introduction includes the following sub titles: background, problem statement, project objectives, justification, scope of the project and methodology and technics of the project.

Chapter ii: Literature review which consists: introduction, code to be used in design, main reason of design, limit stat design, architectural drawings, structural drawings, safe bearing capacity, design loads acting on structure, reinforced concrete design and structural elements.

Chapter iii: Methodology includes: introduction, documentation from library and internet, data interpolation, use of the British standard and site observation.

Chapter iv: Design of structural elements which involve the following content: introduction, the reinforced concrete design assumes the following condition, pre design details, design of beam, design of column, foundation design and stair design.

Chapter v: Conclusion and Recommendations include conclusion and recommendations.

1.7. SIGNIFICANCE OF PROJECT

- Technical significance

This project will expect to serve more skills on the Structural design of a multistoried apartment and basing on correctness of the results, they should be used either by the authorities or individuals having the project of constructing apartment or either take them as reference 1 for the design of similar building.

- Academic significance

This project would act as a reference for other students who would like to conduct more research in the same field as a source of secondary information. Actually, this project may be considered a reference document for students of civil engineering who may wish to read about the concept design of an office building.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

Apartment is a set of rooms for living in, usually on one floor of a large building, is a private residence in a building or house that's divided several separate dwellings. The other meaning of apartment is the structure that is made by the structural that is designed for accommodation providing for 4 or more families living independently, comfortably with family security.

2.2. ARCHITECTURAL DESIGN

Architectural design dealing with principles and standards design of construction and finally of ornamentation providing the aesthetical buildings.it also take into count the environment aspect of place and satisfy the expectation of clients. The architect must do studies and research and follow the restrictions and client advice. (Bachman, 2004)

Any architectural design of building should provide at least all of the following forms of the architectural drawings:

2.2.1. PLAN VIEW

Floor views are a form of orthographic projection that can be used to show the layout of rooms within building, as seen from above; they may be prepared as part of the design process, or to provide instructions for construction, often associated with other drawings, schedules, and specifications (Ernest and Peter.N., 1960).

2.2.2. SECTION VIEW

A section drawing shows a view of a structure as though it had been sliced in half or cut along another imaginary plane. This can be useful as it gives a view through the spaces and surrounding structures (typically across a vertical plane) that can reveal the relationships between the different parts of the building that might not be apparent on plan drawings.

2.2.3. ELEVATION VIEW

The term ‘elevation” refers to an orthographic projection of the exterior (or sometimes interior) faces of a building that is a two-dimensional drawing of the building of the building’s facades. As building are rarely simple rectangular shapes in plan, an elevation drawing is a first angle projection that shows all parts of the building as seen from a particular direction with the perspective flattened. Generally, elevations are produced for four directional views, for example, north, south, east and west (Ernest and Peter Neufert, 1987).

2.2.4. PERSPECTIVE VIEW

Perspective drawing is a technique for depicting 3-dimensional volumes and spatial relationships based on the eye level and vanishing point (or point) of the viewer. It can give a realistic impression of what a volume or space will look like in reality. (Ernest and P.N, 1960)

2.2.5. SITE PLAN

Here the whole project arrangement in the plot is implanted and presented clearly referring to the local regulations. (Watt, 2009)

MAIN REASON OF DESIGN

The main reason of this project of structural design of four storied apartment is to ensure 1 that the structure will perform satisfactorily during its design life. Specifically, the designer must check that the structure is capable of carrying the loads safely and economically. For the structure to be safe, it must be able to resist the worst loading conditions. Under normal working conditions, the deformation and cracking must not be excessive for the structure to remain serviceable, durable and aesthetically during the expected design life. the structure should be economical with regard to both construction and maintenance cost.

CODE TO BE USED IN DESIGN

Here is the list of British standards is being used to design the Structural elements and the loading:

- BS 6399 part one (1): loading of the buildings contain code of practice for dead and imposed loads. BS 6399 Part 1. (1996).
- BS 648:1964: Weights of building materials contain.
- BS 8110 part one (1): Structural use of concrete contain code of practice for design
- BS 8110 part two (2): Structural use of concrete contain Code of practice for special circumstances.
- BS 8110 part three (3): Structural use of concrete contain Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns.

2.3. EMPIRICAL REVIEW

2.3.1. ARCHITECTURAL DESIGN PROCEDURES

The architectural design must start by preliminary study, and then start the sketch scheme by drawing the individual rooms of the required areas as simple as rectangles drawn to scale and then after analyses the circulation and the relationship of rooms between each other.

2.3.2. LIMITS STATE DESIGN AND STRUCTURE ANALYSIS

Limit state design (LSD), also known as load and resistance factor design (LRFD), refers to a design method used in structural engineering. Those methods are listed below:

8 The load factor method in which the working loads are multiplied by a factor of safety

The permissible stress method in which ultimate strengths of the material are divided by a factor safety to provide design stresses which are usually within the elastic range.

The limit state method which multiplies the working loads by partial factor of safety and also divides the materials ultimate strengths by farther partial factor of safety.

The two types of limit state are the following:

Ultimate limit state: This requires that the structure must be able to with stand, with an adequate factor of safety against collapse, the loads for which it is designed. serviceability limit states: The structure should not become unfit for use due to excessive deflection, cracking or vibration. (Menon U. P., 2003)

2.3.3. SAFE BEARING CAPACITY

Bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity 8 divided by a factor of safety. These factors depend on types of soil.

Table 2. 1.Typical allowable bearing values

Rock or soil	Typical bearing value (KN/m2)
Massive igneous bedrock	10000
Sandstone	2000 to 4000
Shales and mudstone	600 to 2000
Gravel, sand and gravel, compact	600
Medium dense sand	100 to 300
Loose fine sand	less than 100
Hard clay	300 to 600

Medium clay

100 to 300

Soft clay

less than 75

2.4. DESIGN LOAD ACTING ON THE STRUCTURE

The types of loads acting on structures for buildings and other structures can be [1] broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load and impact load. The horizontal loads comprise of wind load and earthquake load. The longitudinal loads i.e., tractive and braking forces are considered in special case of design of bridges, gantry girders etc. but also in our project we will consider the Service loads because are actual loads that the structure is designed to carry. The characteristic loads used in the design are the flowing: Dead load, imposed load and wind load which are provided by (BS 8110 part, 1997).

2.4.1. TYPES OF LOADS

1. Dead load

The first vertical load that is considered is dead load. [1] Dead loads are permanent or stationary loads which are transferred to structure throughout the life span. Dead load is primarily due to self- weight of structural members, permanent partition walls, fixed permanent equipment and weight of different materials. It majorly consists of the weight of roofs, beams, walls and column etc.

which are otherwise the permanent parts of the building. The calculation of dead loads of each structure are calculated by the volume of each section and multiplied with the unit weight. [1] The unit weights of some of the common materials are provided by: (BS 6399 Part 1, 1996)

2. Imposed load or live load (IL, LL)

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

3. Wind loads

Wind load is primarily horizontal load caused by the movement of air relative to earth. Wind load is required to be considered in structural design especially when the heath of the building exceeds two times the dimension transverse to the exposed wind surface. For low rise building say up to four to five stories, the wind load is not critical because the moment of resistance provided by the continuity of floor system to column connection and walls provided between columns are sufficient to accommodate the effect of these forces. The calculation of wind loads depends on the two factors, namely velocity of wind and size of the building. Complete details of calculating wind load on structures are provided by (BS 6399 Part 1, 1996)

4. Environment load or other loads

those are load that act 1 as a result of weather, topography and other natural phenomenal such us wind, earthquake, temperature; wind load is estimated depend on the location, shape and dimension of the building. (Taranath, 2004)

Figure 2. 1.loads acting up on the structure

Combinations for the Ultimate State

Various combinations of the characteristic values of dead load Gk> imposed load Qk, wind load Wk. and their 39 partial factors of safety must be considered for the loading of the structure.

The partial factors of safety specified by BS 8110. Also are in table 2.2 of Partial factors of safety for loadings from (Smith, (2016)

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

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

Table 2. 2.load combination and values of for the ultimate limit state.

LOAD

COMBINATION

LOAD TYPE

DEAD LOAD (GK)

IMPOSED

(QK)

LOAD

WIND

(WK)

LOAD

Adverse

Beneficial

Adverse

Beneficial

Dead and imposed load

1.4

1.0

1.6

0

-

Dead and wind load

1.4

1.0

-

-

1.4

Dead, wind and live load

1.2

1.2

1.2

1.2

1.2

2.4.2. STRUCTURAL ELEMENTS

The complete building structure can be broken down into the following elements:

Beams: structures are an important type of structural element that construction professionals and some types of engineers must be familiar with. 25 These structures play a prominent role in how weight is transferred and ensures that a building's foundation is firmly planted in the ground. [9] The most common types of beam structures include over-hanging, fixed, trussed, and continuous and simply supported beams. In this article, we'll explore what a beam structure is, why it's important to understand these structures and the most common types of beams used by construction workers and engineers.

Slabs: [12] Horizontal slabs of steel, typically between 4 and 20 inches (100 and 500 millimeters) thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving. Sometimes [21] these thinner slabs, ranging from 2 inches (51 mm) to 6 inches (150 mm) thick, are called mud slabs, particularly when used under the main floor slabs or in crawl spaces

Columns: vertical members carrying primarily axial load but subjected to axial load and moment.

[1] Walls: vertical plate elements resisting vertical, lateral or in-plane loads.

Bases and foundations [6] pads or strips: supported directly on the ground that spread the loads from columns or walls so that they can be supported by the ground without any deformation. (Bhatt P. M., 2014)

2.4.3. REINFORCED CONCRETE SLAB

The complete building structure can be broken down into the following elements:

Beams: horizontal members carrying lateral loads.

Slabs: horizontal plate elements carrying lateral loads.

Columns: vertical members carrying primarily axial load but subjected to axial load and moment.

Walls: vertical plate elements resisting vertical, lateral or in-plane loads.

Bases and foundations pads or strips: supported directly on the ground that spread the loads from columns or walls so that they can be supported by the ground without any deformation. (Bhatt P. M., 2014)

The slab is called one way when [7] where Ly is length of longer side and lx is length of shorter side is delivered from (BS 8110 part 1, 1997) .

the [5] one-way slab can be designed in two ways such as:

1.single span one-way slabs is simply in designing.

2.continouos one-way spanning [15] slabs should in principle be designed to withstand the most unfavorable arrangements of loads, in the same manner as beams, bending moment coefficients are also given by table 3.12 in BS 8110-1:1997 clause:3.5.2.4 this table must use when the slab fulfil the following condition from BS 8110-1:1997 clause:3.5.2.3:

- Characteristic imposed load Qk may not exceed characteristic dead load Gk;
- Loads should be substantially uniformly distributed over three or more spans;
- Variations in span length should not exceed 15 % of longest.
- In a one-way slab, the area of each bay < 30 m2

Table 2. 3.Ultimate moments and shears in one-way spanning slabs.

End support

End span

penultimate support

interior span

interior support

Moment

0

0.086FL

-0.086FL

0.063FL

-0.063FL

Shear

0.4F

-

0.6F

-

0.5F

F=1.4Gk+1.6Qk and le: effective span

2.4.3.1. PROCEDURES OF DESIGNING A SLAB

- Determine a suitable 7 depth of the slab
- Determination of load.
- Determination of moments
- Calculate main reinforcement and secondary reinforcement areas.
- Check critical shear stresses.
- Check detailing requirements

Loadings

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

Moment (M) =(M) = where by M is the moment caused by applied load on the structure another hand is called applied moment.

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

Mu = 0.156fcu ⁎ b ⁎ d2 by having Mu and M we check if the member need Compression reinforcements

the following are how the check is done:

Compression reinforcements are required

Compression reinforcements are not required

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

Formulas used to find Steel reinforcement

2; if K>0.156 Compression reinforcements are required and K<0.156 Compression reinforcements are not required

where

and the transverse reinforcement are calculated from this formula known as main steel bars. In the case where Compression reinforcements are required the flowing formula are used: (for compression reinforcement) for tension reinforcements)

if < provide reinforcement corresponding to

Provided by BS8110-1:1997, close 3.12.5

Shear reinforcement formulas

(Provided by BS8110-1:1997, close 3.4.5.2)

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

Deflection formulas

= basic ratio × M.F

In checking deflection, the flowing tables in BS8110-1:1997 are conducted: table 3.9, 3.10 and 3.1

- Two-way slab:

The slab is called two ways when

Steps of designing two-way slab provided by BS 8110.

Design Moments

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

Shorter spanning side: Msx= Bsx×n×lx2 and longer spanning side: Msy= 2.

So, after getting moment on longer and shorter side to find reinforcement is the same as one-way slabs but in two ways provide reinforcement along shorter and longer direction.

The coefficient Bsx and Bsy are provided by BS 8110-1:1997 close:3.5.3.7 in table 3.14

Design for Shear

Shear is checked along both directions x and y

The coefficient Bvx and Bvy are provided by BS 8110-1:1997 close: 3.5.3.7 in table 3.15

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

And calculate (This ratio gives the value to be used while calculating of shear force in concrete (vc).

vc= *factor given by

Shear reinforcement are required when shear stress of the steel bars is greater than that of concrete vc Design of reinforcement bars

Assume diameter of main steel and secondary steel then provide effective depth (d) on both sides. Moment of resistance (Mu) = where ;

And ≥ bh.

If < provide reinforcement corresponding to

Provided by BS8110-1:1997, close 3.12.5

Design of steel for shear force

11 Deflection check

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

And = basic ratio × MF

If M.F > 2 take 2 to calculate permissible ratio = (1/d) * 2 or M.F and if the permissible ratio is greater than the real ratio, the section 12 of the slab is enough and adequate hence there is no deflection.

Crack check

The code of practice also states that the distance between the steel bars may be greater than 3d

in order to prevent cracks in the slab. In general reinforcement spacing rules is given by close 3.12.11 in BS8110-1:1997

2.4.4. REINFORCED CONCRETE BEAM

Reinforced concrete beam design consists primarily of producing member details which will adequately resist the ultimate bending moments, shear forces and torsional moments. 18 At the same time serviceability requirements must be considered to ensure that the member will behave satisfactorily under working loads. (Nour, 2007)

According to (Arya C. , 2022)Beams in reinforced concrete structures can be defined according to:

a. Cross-section.

b. Position of reinforcement.

c. Support conditions.

The following are three basic design stages but to be condensed

a. Preliminary analysis and member sizing.

b. Detailed analysis and design of reinforcement.

c. Serviceability calculations. (Patel, 2014)

2.4.4.1 Types of beam section

22 The three common types of reinforced concrete beam section are:

 Rectangular section with tension steels only (this generally occurs as a beam section in a slab)

 Rectangular section with tension and compression steel

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

49 Rectangular section with tension steel only

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

Area of tension reinforcement (As) (Mosley W. H., 1976)

The 30 preliminary analysis need only provide the maximum moments and shears in order to ascertain reasonable dimensions. Beam dimensions required are

i. Cover to the reinforcement(c).

ii. Breadth (b)

iii. Effective depth (d)

iv. Overall depth (h)

v. Diameter of steel (Ө)

vi. Link diameter (t)

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

Moment (M) =

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

by having Mu and M we check if the member need Compression reinforcements

the following are how the check is done:

Compression reinforcements are required

Compression reinforcements are not required

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

Formulas used to find Steel reinforcement

2; if K>0.156 Compression reinforcements are required and K<0.156 Compression reinforcements are not required

where ,

Rectangular section with tension and compression steel

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

(For compression reinforcement)

for tension reinforcements)

Flanged sections of either T or L shape

Figure 0-1:2: Section of T- beam

Figure 4 shows sections through a T-beam and an L-beam which may form part of a concrete beam and slab floor. When the beams are resisting sagging moments, part of the slab acts as a compression flange and the members may be designed as T· or L-beams. 19 With hogging moments, the slab will be in tension and assumed to be cracked, therefore the beam must then be designed as a rectangular section of width bw and overall depth (h). Before designing of these types of beams must be checking if 4 the neutral axis lies in the flange or does not lie within the flange. If it 20 lies within the flange, this beam (T or L) has to be designed as the rectangular beam with the width of the flange bf, where l is the length of the span (Mosley W. H., 1999)

By 4 neutral axis lies in the flange

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

2, then the moment arm ≤ 0.95d, the deep of the neutral axis and the deep of the compression block is a= 0.9x.

If a ≤ hf, the procedures of calculations are the same as rectangular beam design. Taking the width 1 of the beam as bf.

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

If when and , then where

=0.45) ( ) +0.15

Otherwise, the calculation has two parts. The first part is for balancing the compressive force from the flange, Cf, and the second part is for balancing the compressive force from the web, Cw. the ultimate resistance moment 20 of the flange is given by: The moment taken by the web is computed as: and the normalized moment resisted by the web is given by: If the beam is designed as a singly reinforced concrete beam. The reinforcement is calculated as the sum of two parts, one to balance compression in the flange and one to balance compression in the web.

Where ≤ 0.95d

If Kw > K', compression reinforcement is required. The ultimate 4 moment of resistance of the web only is:

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

Where, d' is the depth of the compression reinforcement from the concrete compression face and if

If

1) Shear reinforcement formulas

(Provided by BS8110-1:1997, close 3.4.5.2)

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

Table 2. 4.Basic span effective depth ratio for beams

Support conditions	Rectangular beam	Flanged beams, $bw/b \leq 0.3$
Cantilever	7	5.6
Simply supported	20	26
Continuous	26.0	20.8

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

And = basic ratio × MF

If M.F > 2 take 2 to calculate permissible ratio = (1/d) * 2 or M.F and if the permissible ratio is greater than the real ratio, the section [12] of the slab is enough and adequate hence there is no deflection.

Note about beam reinforcement

In accordance with BS8110: Part 1, clause 3.12.4.1, bars may be placed singly or in pairs or in bundles of three or four bars in contact. The minimum areas of reinforcement in a beam section to control cracking as well as resist tension or compression due to bending in different types of beam section are given in BS8110: Part 1, clause 3.12.5.3 and Table 3.2.7. The minimum spacing of bars is given in BS8110-1:1997, clause 3.12.11.1, (Bhatt P. M., 2005)

2.4.5. REINFORCED CONCRETE COLUMN

Columns are structural members in buildings carrying roof and floor loads to the foundations. Columns primarily carry axial loads, but most columns are subjected to moment as well as axial load. The internal column is designed for axial load while edge columns and corner column are designed for axial load and moment. (Khan, 2022)

Classification of column

A column may be considered as a short when both the ratios and are less than 15 (braced)

And less than 10(un braced). It should otherwise be considered as slender. Where Lex = effective height of the column in respect of the major axis (i.e., x-x axis). Ley = effective height of the column in respect of the major axis (i.e., y-y axis). b: width of the column cross-section.

h: depth of the column cross-section. (BS 8110-1:1997 clause: 3.8.1.3)

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

(BS 8110-1:1997 clause: 3.8.1.6

Practical design provisions

Columns with rectangular cross-sections should be reinforced with a minimum of four longitudinal bars, columns with circular cross-sections should be reinforced with a minimum of six longitudinal bars. Each of the bars [11] should not be less than 12 mm in diameter. Where **Asc** the area of steel in compression and Acc is the area of concrete in compression.

(BS 8110-1:1997 clause: 3.12.5.4)

Area of reinforcement

The code recommends that for columns with a gross cross-sectional area Acol, [1] the area of longitudinal reinforcement (**Asc**) should lie within the following limits: 0.4%Acol ≤ Asc ≤ 6%Acol in a vertically cast column and 0.4%Acol ≤ Asc ≤ 8%Acol in a horizontally cast column.

At laps the maximum [23] area of longitudinal reinforcement may be increased to 10 per cent of the gross cross-sectional area of the column for both types of columns.

(BS 8110-1:1997 clause: 3.12.5)

Design for links

The diameter of links should not be less than 6 mm or one-quarter of the diameter of the largest longitudinal bar; or 0.25 times the largest bar diameter, the maximum spacing is to be 12 times the diameter of the smallest longitudinal bar in column. (BS 8110-1:1997 clause: 3.12.7) 2.10.3.3

2.4.6. DESIGN OF THE COLUMN ACCORDING TO LOADING CONDITION

Short [34] columns are divided into three categories according to the degree of eccentricity of the loading as described in the flowing sections: 1. Columns resisting axial loads only; 2. [17] Columns supporting an approximately symmetrical arrangement of beams 3. Columns resisting axial loads and uniaxial or biaxial bending. (Bashir, 2014).

[26] Short Braced Axially Loaded Columns

This type of column can occur in precast concrete construction when there is no continuity between the members. When the load is perfectly axial the ultimate axial resistance is N=O.45fcuAc +O.87fyAsc. Perfect conditions never exist and to allow for a small eccentricity the ultimate load should be calculated from N=O.4fcuAc +O.75fyAsc (Kassim, 2018)) Short Braced Columns Supporting an Approximately Symmetrically Arrangement of Beams

The moments on these columns will be small and due primarily to unsymmetrical Arrangements of the live load. The ultimate load that can be supported should then be taken as N= 0.35fcuAc + 0.67fyAsc (BS 8110-1:1997 clause: 3.8.4.4) (Mosley W. H., 1999)

Short Columns Resisting Moments and Axial Forces

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

a) Using design charts or constructing M-N interaction diagrams

b) A solution of the basic design equations,

c) An approximate method. (Mosley W. H., 1999)

Biaxial Bending of Short Columns

For most columns, biaxial bending will not govern the design. [10] The loading patterns necessary to cause biaxial bending in a building's internal and edge columns will not usually cause large moments in both directions. Corner columns may have to resist Significant bending about both axes, but the axial loads are usually small and a design similar to the adjacent edge columns is generally adequate. In case [17] the column is subjected to the bending in two directions, it is said to be biaxial bending the following equations may be used.

1) for thus Mx ´= Mx + β x My

2) for thus My ´= My + β x Mx

Where: h: effective depth

B: Effective width

β: Coefficient obtained from table 3.22 in BS 8110-1:19

2.4.7. REINFORCED CONCRETE STAIR

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

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

1. [24] Those spanning horizontally in the transverse direction.
2. Those spanning longitudinally.

Table below shows the consideration point on maximum, minimum riser, tread and slope relation.

Table 2. 5.Minimum and maximum value of riser, tread and the slope relations

Types of building

Riser (R)

Tread

Slope relationship (2R+G)

Min

Max

Min

Max

Min

Max

Public

115

190

250

355

550

700

Private

115

190

240

355

550

700

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

 Waist, tread, riser, concrete cover and bar diameter.

 Vertical desistance from landing up to top slab (vertical distance).

 The part above the landing up to the slab (horizontal distance)

 Slop distance of the stair must be calculated

 The moment is calculated by

  where Imposed loading on the stair is given in (BS 6399 Part 1, 1996)

and

2.4.8. REINFORCED CONCRETE FONDATIONT DESIGN

Foundations are required primarily to carry the dead and imposed loads due to the structure's floors, beams, walls, columns, etc. and transmit and distribute the loads safely to the ground. 3 The purpose of distributing the load is to avoid the safe bearing capacity of the soil being exceeded otherwise excessive settlement of the structure may occur. There are many types of foundations which are commonly used, namely strip, pad and raft (OBOKPARO, 2016) Pad footing design

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

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

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

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

Plan area

Plan Area =

Where N=1.0GK+1.0 QK (serviceability load).

Design for reinforcement

Earth pressure Ps = where M = Ps* and N=1.4GK++1.6QK

Ultimate design moment Mu = 0.156fcubd² ≥ M = Ps*

K =

Z = d [0.5 + (√ (0.25 − K/0.9)] ≤ 0.95d then **AS** = =

The 5 reinforcements are provided in footing according to (clause 3.11.3.2, BS 8110-1:1997)

- Design for shear
- Punching Shear

Figure 2. 2Punching shear

Critical perimeter, pcrit, is= 3 column perimeter + 8 × 1.5d

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

Ultimate punching force, V, is V = load on shaded area Design punching shear stress, v=

and design concrete shear stress=

vc is shear resistance where vc = ∛ (fcu/25) × value of design concrete shear stress. The footing is satisfactory if vc ≥ v, If shear reinforcement is required refer to BS8110-1:1997 clause 3.7.7.5.

- Face shear

Figure 2. 3.face shear

Maximum shear stress (umax) occurs at face of column. Hence Vmax = the footing is satisfactory if Vmax< permissible (0.8×√fcu).

 Transverse shear

Figure 2. 4. Transverse shear

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

v = ≤ vc

(BS8110-1:1997). (Chong, 1980)

Cracking check

The rules for slabs in BS8110-1:1997 clause 3.12.11.2.7. The bar spacing is not to exceed 3d or 750 mm. The minimum grade of concrete to be used in foundations is grade 35. (BS81101:1997, Clause 3.3.1.4) states that the minimum cover should be 75 mm if the concrete is cast directly against the earth or 40 mm if cast against adequate blinding. Table 3.2 of the code class's nonaggressive soil as a moderate exposure condition. (Chong, 1980)

2.5. STRUCTURAL CONSTRUCTION MATERIAL

2.5.1. MASS CONCRETE

Concrete 28 is produced by the collective mechanical and chemical interaction of a large number of constituent materials or a mixture of cement, fine and coarse aggregate, water and admixtures.

The good concrete has different characteristics which are: compactness, strength, water/cement ratio, texture, parameters affecting concrete quality (quality of cement, adequate mixing), those materials are chosen in proper ingredients and proportion in order to obtain an efficient and desirable concrete satisfying the designer's strength and serviceability requirements. (Alexander, 2005)

2.5.2. REINFORCED CONCRETE

Concrete is strong in compression but weak in tension. 42 Therefore, reinforcement is needed to resist tensile stresses resulting from the induced loads. Additional reinforcement is occasionally used to reinforce the compression zone of concrete beam section. Such steel is necessary for heavy loads in order to reduce long term-deflections. The additional of reinforcement to concrete makes it resist to high tensile as well as compressive forces. (Reynolds, C. E., Steedman, J. C., & Threlfall, A. J, 2007).

Figure 2. 5.reinforced concrete slab

Steel and concrete have properties that are considered as show in table below:

Table 2. 6.properties of steel and concrete

Properties

Concrete

Steel

Strength in Tension

Poor

Good

Strength in compression

Good

Good but, slender bar will buckle

Strength in shear

Fair

Good

Durability

Good

Flexes if unprotected

Fire resistance

Good

Poor-suffer rapid loss strength high temperature

2.5.3. MASONRY

Masonry is the building of the structures from individual units, which often laid in and bonded together by mortar. The common material of masonry construction are bricks, blocks, stones and concrete block (Tomazevic, 1999)

Burnt clay bricks is used in this project due to its good qualities like durable and strong.

2.5.4. STAIR

Stairs [1] provide means of movement from one floor to another in a building. Stairs consist of a number of steps, going, riser, and waist with landings at suitable intervals to provide comfort and safety for the users. (Qasim, 2016)

Figure 2. 6.Cross section of stair

[13] A stairway, staircase, stairwell, flight of stairs, or simply stairs is a construction designed to bridge a large vertical distance by dividing it into smaller vertical distances, called steps. Stairs may be straight, round, or consist of two or more straight pieces connected at angles.

2.5.5. ELEVATOR

Elevator, also called lift, car that moves in a vertical shaft to carry passengers or freight between the levels of a multistory building. [29] Most modern elevators are propelled by electric motors, with the aid of a counterweight, through a system of cables and sheaves (pulleys).

The [16] main design considerations for choosing either electric traction drive or hydraulic for a particular project are the number of floors, the height of the building, the number of people to be transported, desired passenger waiting times and frequency of use. For the design of elevator handling capacity which [40] is the total number of passengers that the system can transport within time and elevator capacity which is delivered from up-peak traffic analysis. For the choice of elevator considers initial cost of the elevator plus the building structure needed to house the lift, maintenance costs over [1] the life of the building and running costs (Kinsey et al, 2011).

2.5.6. ROOF

Roof is [43] the upper most part of building, provided as structure covering to protect the building from weather (rain, sun and wind). It consists of structural elements to support the roof and

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1. INTRODUCTION

This chapter recognizes methods that should be used, including a detailed description of how this study would be conducted, dealing with tools and means to collect data that should be conducted, and dealing with tools and means to collect data that should be analyzed before they are used to get data from this research.

During the achievement of this project, the different methods have been used to perform and achieve the final work, those methods are written below:

- Document review
- Use of software related to building modelling and design
- Site Observation

3.2. DOCUMENT REVIEW

These methods are used while making research in books and on internet for having more evidence about subject.

3.2.1. READING BOOKS

This method is very important in this project of making structural analysis of four storied apartment building because the following reasons:

It will show the standard of rooms involved in the design of the modern apartment in making architecture drawing and make occupancy to be comfort.

It has been also used to show the format project report and providing the important content of each chapter.

It will also use to know more formulas that is used during 1 the design of the project.

3.2.2. DOCUMENTATION FROM THE ONLINE RESOURCES.

This method has been used for finding out more information about the case study, different meaning of the structural members, standard, and to know the geographical condition of the area

3.2.3 STUDY AREA

The Plot is located at Nyamagabe district, Gasaka sector, Nyamugari cell and Kabacuzi village with Geographic information of latitude 2°28'19.91"South, 29°34'48.03"East and its elevation is 173.87m and area of 1,693.06m2

3.2.4. USE OF THE BRITISH STANDARD

The British standard that will be using in this design of the project will give the information related to the design standards. The followings are different standards used in design:

- BS 6399-part-1-1984-design-loading-for-buildings contain 11 code of practice for dead and imposed loads.
- BS 8110-1_ 1997_ 35 Structural use of concrete - Part 1_ Code of practice for design and constructions
- BS 8110 part three (3): Structural use of concrete contain Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns.
- BS 8110-2 1985_ 32 Structural use of concrete - Part 2_ Code of practice for special circumstances
- BS 8110-3 1985_ Structural use of concrete - Part 3_ Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns

3.2.5. DIFFERENT FORMULAE USED IN DESIGN

3.2.5.1. Slab

24 The thickness of the slab lies between (lx)/20 and lx/40 where lx is the shorter side of the panel, using the biggest panel among others.

The effective height (ho) = 11 thickness of the slab (hf) – the clear cover

1. Load on slab

a. Dead load

Dead loads are permanent loads that are acting on the structure. 1 The unit weights of the materials that helped in calculations were as follow:

Reinforced Concrete class: 25 N/mm2

However, this will be considered automatically in the software. As for super dead load to account for finishes cladding and any additional dead load, we consider it to be 1.5N/mm2 and will be the same for all floors throughout. Self –load=safety factor* meter*meter*thickness of slab* unite weight

Finishes = safety factor meter thickness of finishes

1 Total dead load = self – load + finishes

b. Live load

Live load is the load that accounts for the intended use or occupancy. As per BS the value of live 37 load shall be taken as 2kN/m2 and would be the same for all floors from top to bottom.

Live load= safety factor meter live load of material

c. Type of slab

λ=Ly/lx Where λ = ration of long side and short side ly=long side lx= short side

d. Bending moment

$Mx = \alpha sx \; P \; lx2$,

$My = \alpha sy \; P \; lx2$,

Where = Mx = moment at the long side My = moment at the shorter side

αsx, αsy = coefficient related 1 to the design of slabs P= total load on the slab,

lx = short side of slab

3.2.5.2. Required steel reinforcements

= ,

Where = coefficients related to the design of members subjected to bending moment Rb: design concrete compression strength b: the width of the compressive area ho: effective height M can positive or negative if M is positive = is the moment at the bottom M is negative the moment is at top.

As = ,

Where As: total [7] cross section of steel reinforcement, Rs: design steel tensile stress ho: effective height and η: (Muttoni & Ruiz, 2008).

3.2.5.3. Load on beam

Formula used

a. Computation of the depth of the beam

Where Lmax is the largest span between two consecutive beams.

b. Computation of web of flange of the beam (bw)

Where bw is the web of flange of the beam, [4] h is the height of beam

c. Computation of width flange of beam (bf)

bf≤ 12 hf

+bw,

bf≤1/ (3) of beam span

bf≤ D/2

Where bf is the width flange of the beam will [24] be equal to the lesser values from the above formulae, hf is the thickness of the slab, D is the distance between beams.

d. checks the slenderness of the beam

-For simply support and continuous beam L□ 60 bf

-For cantilever beam L□ 25 bf.

e. Dead load

Masonry load = safety factor × meter ×thickness of wall × height of the wall × unit weight

Plaster = safety factor × thickness of the finishes × height of wall that can be paint × meter

× in and out × unit weight

Non-factored own weight of the beam = $\gamma \times (bf \times hf)$

$+(bw \times h)$,

Factored [1] own weight of the beam = safety factor × non factored own weight of the beam

Deduction = $1.4 \times (bf-bw) \times hf \times \gamma$ where 1.4: safety factor; bw: web of the beam; bf: flange of the beam; hf: thickness of the slab; γ: [14] unit weight of concrete (Kollár, 2003).

3.2.5.4. Load on column

a. Dead load

Load from the slab = total [7] dead load of slab influence area from the slab

Self-load of the column = safety factor   area of column   height of column unite weight

Load from the beam = safety factor   width of the beam height of the beam (length +width of influence area) u nit weight

Masonry walls = safety factor thickness of slab height of slab (length +width of influence area unit weight

Plaster on the wall = safety thickness of finishes height of finishes (length +width of influence area   unit weight (Siddiqi, 2013).

Live load

Live load=live load of slab* influence area from the slab

1. Load applied on the column

a. Ground floor part of the column up to footing

Self-load of the underground column= safety factor area of column height of underground column unit weight

Loads= (load from the slab+ load from the beam+ masonry load+ plaster on the wall+ live load from the slab) * number of stories+ ((self-weight of the column   number floor) + self-load of the underground column) + (load from the slab+ load from the beam+ live load from the slab).

b. Floor party [1] of the column

Loads = (load from the slab+ load from the beam+ masonry load+ plaster on the wall+ live load from the slab) *number of stories+ (self-weight of the column number floor) + self-load of the underground column) + (load from the slab+ load from the beam+ live load from the slab).

2. Steel reinforcements on the column

Slenderness ratio (λ)=

0.7H/a,

Where λ= slenderness ratio

h=effective height of the column, a= width of

column

As = (N/φ)/Rsc-Rb*

Ab,

Where As: total [7] cross section of steel reinforcement, N: Total load on the floor, Rb: design concrete compression strength, Ab: the area of the column cross section, Rsc: area of steel compressive strength, φ: coefficient used to take into account the column slenderness and the construction inaccuracies.

3.2.5.5. Foundation

a. Load on foundation

Total design permanent load = design load-total live load

Total characteristic live load= (Total live load)/ (safety factor of live

load),

Total characteristic permanent load= (Total design permanent load)/ (safety factor of dead

load),

Total characteristic load = total characteristic live load + total characteristic permanent load

Estimation foundation weight soil on it = 10 % of total characteristic load

[7] Total load on the soil = total characteristic load + estimate foundation weight on it

(Seward, 2014).

b. [1] The required area of foundation

Af= (Total load on the soil)/ (Design bearing

capacity),

Where Af: area of foundation

c. Design pressure

P

=Nc/Af,

Where P: pressure design, NC: load on column

d. Checking of [11] shear force

The shear force Q ≤0.54Rbt ×

Ab,

Where Q: shear force; Rbt: concrete design tensile strength; Ab: average lateral area of punching pyramid

Ab=af ×

ho,

Where ho: effective height of footing; af: width of foundation

Q= P× bf (lc-

ho),

Where P: design pressure, bf: length of foundation, lc: distance from the effective height to the end of foundation

Checking for punching shear

Q=Nc– Δq Rbt ×

Ab,

Q: shear force; Rbt: concrete design tensile strength; Ab: average lateral area of punching pyramid having perimeter of

Um=2(ac+bc+2ho),

Ab=Um × ho

Δq =P (ac + 2ho) (bc+2ho) where **Δ**q: balanced shear force,

f. Moment calculation

5 Bending moment in the bf direction

Mbf= P. ,

Bending moment in the af direction were calculated

Maf= P. ,

Required steel in one direction ,

3.1.5.6. Stair

Where H: rise G: going

he = + where he: effective height dl: waist, h: going.

1. Load on stair

1 a. Dead load

Dead load = safety factor equivalent thickness meter unite weight

Finishes = safety factor thickness of finishes (Shigley, 2011).

b. Live load

Live load = safety factor live load of material

2. Required steel reinforcement in the stair

αm = M/(Rb 〖*ho〗 ^2*b) where αm = coefficients related to the design of members subjected to bending moment Rb: design concrete compression strength b: the width of the compressive area ho: effective height m can be positive or negative if m is positive= is the moment at the bottom if m is negative the moment is at top

As = M/ (η *Rs* ho) whereas: total 7 cross section of steel reinforcement, Rs: design steel tensile stress

ho: effective height η: coefficient related 1 to the design of members subjected to bending moment (Clayton et al., 2014).

3.2.5.7. Stirrups

,

Where total shear force carried by all legs of the stirrup at the distance

Q: [20] shear force acting on the cross section

Rsw = 0.8 Rs where Rsw: is the design strength of the stirrups and the inclined bars

Where n: number of legs of one stirrup, s: distance between stirrups,

Rbt: is the concrete design tensile strength

Rs: design steel tensile stress

S

Where Q: shear force acting on the cross section, Rbt: is the concrete design tensile strength, ho: effective height, : is the const.

3.3. USE OF SOFTWARE RELATED TO BUILDING MODELLING AND DESIGN

[47] The analysis of the data taken involve in this whole project have been analyzed by using different techniques and software.

The following are the techniques and software that have been [1] used in this project:

Engineering software such as

Arch Cad: to produce drawings such plans, views, sections, elevation, roof, and drainage system etc.

Auto cad drawings: to produce details of sections

Prokon software to draw [11] bending moment and shear force diagram.

Microsoft office such as Microsoft word, excel, PowerPoint to note down the project, computation of the loads and presentation respectively.

3.4. SITE OBSERVATION

In this method of the site observation, the following data have been taken in order [19] to be used in the project.

- Slope topography of the area
- The site area accesses the main roads

- The water supply is available around
- The electricity is available around the site
- Site is surrounded by the other buildings such us market, school, hospital and bank….

CHAPTER 4: RESULTS AND DISCUSSION

4.1. INTRODUCTION

The [4] Reinforced concrete design is crucial step in a building construction. The RC design is done to make safer the structure. The [27] major structural members in reinforced concrete structures comprise slabs, beams, columns, footings, and stairs case. They are reinforced against bending or shear forces. This project of structural design of G+4 floors apartment building is located in South Province, Nyamagabe District, Gasaka Sector, Nyamugari cell.

The study revealed that the building dimensions are 23.05 m by 22.40 m with area of (516.32m2) ,it will occupy 20 families, whereby each floor accommodate 4 families.

Figure 4. 1.FLOOR PLAN

The reinforced concrete design assumes the following conditions

Concrete is assumed to carry zero tensile stresses. -Plane sections of structural member before bending remain plane after bending.

At [6] the ultimate limit state, the strain in concrete is 0.0035((J.H. Boungey) -The strains in the concrete and in the reinforcing, steel is directly proportional to the distances from the neutral axis at which the strain is zero.

Partial safety factors for loads the load actually used in the design is called the design load; it's the product of the load and the relevant factor γf DL= γf *characteristic load γf for a characteristic dead load is 1.4 and for imposed load γf is 1.6 DL=1.4 Gk +1.6Qk -Partial safety factors for material strength, according to (BS8110) part1. γm is 1.15 for steel and 1.5 for concrete.

4.2. PRE- DESIGN DETAILS

Our design is concerned to building elements such as: slab, beams, columns, foundation and stair case. This design is done under BS code which provide the following information used in our design:

Table 4. 1.data used in calculation

BS8110-1997: 2 The structural use of Concrete

Relevant Building Regulations and Design Code

Residential building

Intended use of the building

Roof–Imposed 1.5kN/m2 Floor–Imposed and partitions

3kN/m2 Stairs–Imposed

3kN/m2 finishes to floors and stairs 2kN/m2 Cement screed 20KN/m3ou 0.4kN/m2 Granite

Tiling 2.75g/cm3, 26.9775KN/m3or 0.53955KN/m2

Iron galvanized sheets= 0.12KN/m2 Truss=0.3KN/m2

Purlins and system bracing=0.1KN/m2

Ceiling=0.1KN/m2

General loading conditions

BS6399-1:1996: Part1 Loading for building BS648:1964, Weights of building materials

2 Hours for all elements

Fire resistance requirements

Severe (external) and Mild (internal)

Exposure conditions

Variable according to the site conditions:

Allowable bearing capacity = 300kN/m2

Subsoil conditions

Reinforced Concrete Pad foundation.

Foundation type

Concrete: grade C 25 with 20mm max. Aggregates (BS8110 Table 3.3). for slab and C30 for column, beam and foundation Mix ratio 400 kg/ m^3 Cover (c) =25mm for slab Cover(c) =25mm for column, beams, stair

and 30mm for footing

Reinforcement:

-Characteristic strength for main bars: f_y = 460 N/mm2

-for stirrups f_y = 250 N/mm2

Material data

Self-weight of Reinforced concrete =25kN/ 31 m^3 Self weight of masonry = 18kN/ m^3 Self weight of plaster = 20kN/ m^3

Other relevant information

For dead loa1.4 and for live load: 1.6

Partial safety factor

Our structural analysis and reinforced concrete design have done by hand and the computer software called Prokon.

SUMMARY SHEET TYPICAL FLOOR PLAN/SLAB AND BEAMS LAYOUT

Notes:

- Columns: 250x250mm
- Floor beams: 300x200mm
- Story height=3m
- Ring beams: 300x200mm (which is the same as floor beams)

4.3. SLAB DESIGN

Figure 4. 2.Grid Elements

TWO WAY SLAB PANELS

Figure 4. 3.slab panels

Loading

dmin> , assuming Mf=1.4

dmin> , lets take 120mm

h= dmin+C+

Let's assume the diameter of bars=10mm

Cover to the reinforcements=25mm

h= 120+25+

Floor finish = 2 KN/m2 (BS6399:pt1 clause 5.1.1. 37 Minimum imposed floor loads)

The overall depth (h) = 150 mm

Self-weight = 0.15m 25 KN/m2 m = 3.75 KN/m2

Dead load (GK) = 3.75KN/m2+2KN/m2 = 5.75KN/m2

Live load (QK) for Apartment building = 3 KN/m2

The ultimate design load due to the self-weight 2 of the slab and the finishes, N = (1.4Gk + 1.6Qk) (BS 8110 part 1, 1997) clause 3.2.1.2.2

N = (1.4 × 5.75) + (1.6 × 3) = 12.85KN/m2

Design load (N) = 13.75KN/m2*1m= 12.85 KN/m

4.3.1. DESIGN 11 OF TWO-WAY SPANNING SLAB

Two-way slabs are effective for medium span and heavy load or when high Resistance to lateral force is required for economy however two-way slabs are usually constructed as flat slab and plate without beam. The slab is called two ways when <2(Two-way panel)

Table 4. 2.Design [11] of two-way spanning slab

Slab panels

Ly

(m)

Lx

(m)

Lx2

N

(KN/m)

coefficients, βsx and βsy

at the support

coefficients, βsx and βsy At mid span

Bending moments At the support

Bending moments At mid span

βsxn

βsyn

βsxp

βsyp

Msxn

Msyn

Msxp

Msxp

1(P1)

3.85

2.1

4.41

1.83

12.85

0.088

0.045

0.066

0.034

4.98

2.55

3.74

1.92

2(P8)

2.9

2.15

4.62

1.34

12.85

0.066

0.037

0.048

0.028

3.91

2.19

2.84

1.66

3(P14)

2.15

1.7

2.89

1.26

12.85

0.050

0.037

0.037

0.028

1.85

1.37

1.37

1.03

4(P15)

3.4

1.7

2.89

2

12.85

0.063

0.032

0.048

0.024

2.33

1.18

1.78

0.89

5(P21)

2.7

2.15

4.62

1.25

12.85

0.059

0.037

0.044

0.028

3.50

2.19

2.61

1.66

6(P22)

3.4

2.7

7.29

1.25

12.85

0.044

0.032

0.033

0.024

4.12

2.99

3.09

2.24

7(P41)

3.4

2.9

8.41

1.17

12.85

0.040

0.032

0.030

0.024

4.32

3.45

3.24

2.59

8(P42)

3.85

2.9

8.41

1.32

12.85

0.046

0.032

0.036

0.024

4.99

3.45

3.89

2.59

Among all these moments in table exerting on the two-way slab's panels, the moments to be used are those exerting on the Panels 8(panel=10=11=41=42) because they are the greatest and more loaded means that their details will be apply to all remaining two-way slabs.

Formula to calculate moment at support and at middle

The moments at mid span and at the support of the two ways slabs, where the moments are found by using these formulas:

$\mathbf{MsXn} = \boldsymbol{\beta}\mathbf{sXn} \times \mathbf{n} \times \mathbf{l2x}$ negative moment 1 in the direction of Lx at the support

$\mathbf{Msyn} = \boldsymbol{\beta}\mathbf{syn} \times \mathbf{n} \times \mathbf{l2x}$ negative moment in the direction of Ly at the support

The following are the moments from table on loaded panels:

For the support $\mathbf{MsXn}$ = 4.99KNm; $\mathbf{Msyn}$ = 3.45KNm

For the mid span $\mathbf{MsXp}$ = 3.89KNm; $\mathbf{Msyp}$ = 2.59KNm

AT CONTINEOUS EDGE

Maximum Moment at the support is $\mathbf{MsXn}$ = 4.99KNm; $\mathbf{Msyn}$ = 3.45KNm (for panels of 10=11=41=42)

Main steel

Msxn=4.99KNm

Since k , means no compression reinforcement required

Hence find lever arm using the following formula =114mm

=118.2mm 114mm

Therefore, the critical Z is 114mm

7 The area of steel reinforcements,

Asmin=0.13%bh=0.13%*1000*150=195mm2

For As< Asmin, Asmin is critical to provide steel reinforcement

From steel reinforcement table, we provide T10@200mm for Aspro=393mm2

Secondary steel

Msyn=3.45KNm

d′= h-θ- =150-10- =110mm

Since k<0.156 means that no compression reinforcements required

Hence find lever arm 5 using the following formula: =104.5mm

=108.6mm>104.5mm

So the critical Z is 104.5mm

2

Asmin=0.13%bh=0.13%*1000*150=195mm2

For As< Asmin, Asmin is critical to provide steel reinforcement

From steel reinforcement table, we provide T10@200mm for Aspro=393mm2

AT MID-SPAN

Maximum Moment at mid-span

Msxp=3.89KNm

Msyp=2.59KNm

Main steel

Msxp: 3.89KNm

Since k<0.156 means that no compression reinforcements required

Hence find lever arm 5 using the following formula: =114mm

=118.6mm>114mm

So, the critical Z is 114mm

2

Asmin=0.13%bh=0.13%*1000*150=195mm2

For As< Asmin, Asmin is critical to provide steel reinforcement

From steel reinforcement table, we provide T10@200mm for Aspro=393mm2

Secondary steel

Msyp=2.59KNm and Z = 0.95*110=104.5mm

Asmin=0.13%bh=0.13%*1000*150=195mm2

For As< Asmin, Asmin is critical to provide steel reinforcement

From steel reinforcement table, we provide T10@200mm for Aspro=393mm2

4.3.1.1. Shear reinforcements

To design shear reinforcements, we design for a panel with maximum shear force, so the maximum shear force is at (panel=10=11=42=43)

Shear force coefficients are: $\beta vx=0.41$ and $\beta vy=0.33$

$Vsx = \beta vx \times n \times lx= 0.41\times12.85\times2.9= 15.27KN$ (The most critical one)

$Vsy= \beta vy \times n \times lx = 0.33\times12.85\times2.9= 12.29KN$

BS 8110, pt 1 clause 3.5.3.7. table 3.15 33 shear force coefficients for uniformly loaded rectangular panels supported on four sides with provision for torsion at corners

Ok

By interpolation, the value of /mm2) is 0.54 /mm2

0.54 /mm2

Since no shear reinforcements required

BS 8110 PT1, clause 3.5.4, table 3.16 4 form and area of shear reinforcements in solid slab

4.3.1.2. Deflection check

24.16

Mf= where

,

Mf= 2.73>2, hence take Mf=2(BS 8110 pt1, clause 3.4.7.table 3.10.modification factor for tension reinforcements)

=26*2=52; thus 52>24.16 therefore 7 the slab is safe against deflection

4.3.1.3. Check crack on slab

Maximum spacing between bars 48 should not exceed the lesser of 3d; equal (3*120 mm) or 360 mm. Actual spacing= 200 mm main steel and secondary steel (200<360). Ok (no crack on slab)

4.3.2. DESIGN 14 OF ONE-WAY SPANNING SLAB

Among the one-way spanning slabs, the panel P20 is the most critical with lx=1.7 and ly=6.2

Figure 4. 4.One way slab panels

4.3.2.1. Load calculation

Design moment= =

Ultimate moment Mu=0.156fcubd2=0.156*25*1000*1202=5.61KNm

As M4.64KNm, hence no compression reinforcement required

Main steel

,

No compression reinforcement required.

Hence find lever arm 5 using the following formula: =114mm

=118.24mm>114mm

Then the critical Z is 114mm

Asmin=0.13%bh=0.13%1000*150=195mm2

Since As Asmin, Asmin is critical to provide steel reinforcement

From steel reinforcement table, we provide T10@200mm for Aspro=393mm2

Secondary steel

Since there is no compression reinforcements required, the secondary in for that slab will be provided basing on the minimum steel area, which is 195mm2/m

Hence provide T10@200mm for Aspro=393mm2

4.3.2.2. Shear reinforcement

V=

V= =0.09N/mm2

, By interpolation value of /mm2) is

0. /mm2)

Since no shear reinforcements required

BS 8110 PT1, clause 3.5.4, table 3.16 [4] form and area of shear reinforcements in solid slab

4.3.2.3. Check for deflection

Where

=2.58 then take Mf as 2 (BS 8110 pt1, clause 3.4.7.table 3.10.modification factor for tension reinforcements)

Therefore, [7] the slab is safe against deflection

4.3.2.2. Check crack on slab

Maximum spacing between bars should not exceed the lesser of 3d (3*120 mm) or 360 mm. Actual spacing= 200 mm main steel and secondary steel (200<360). Ok (no crack on slab)

Slab Reinforcement detail

So according to our calculation shows that the reinforcements applied in [7] one way and two way are the same it means all slabs are unique to reinforcement which are T10@200mm for ASP =393 mm2

Figure 4. 5. Slab element details

Figure 4. 6.section 01

4.4. DESIGN OF BEAM

Figure 4. 7.Design of beam

4.4.3. CALCULATION OF LOADINGS

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

□ span 1 = 2.1m with A=4.042m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x4.042m2/2.1m = 12KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 4.042m2/2.1m=5.77KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m + 12KN/m +10.80KN/m

Total dead load = 24.3KN/m

Live load =5.77KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 24.3KN/m + 1.6x5.77KN/m

Design load = 43.02KN/m

□ span 2 = 1.7m with A=6.16m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x6.16 m2/1.7m =22.755KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 6.16m2 /1.7m= 10.87KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

Total dead load = 1.5KN/m+ 22.755KN/m + 10.80KN/m

Total dead load = 35.055KN/m

Live load = 10.87KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 35.055KN/m+ 1.6x10.87KN/m

Design load = 66.077KN/m

□ span 3 = 2.9m with A=10.49m2

Self-weight of slab with finishes = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+

0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x10.49m2/2.9m =22.71KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 10.49m2/2.9m= 10.85KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

Total dead load =1.5KN/m+ 22.71KN/m + 10.80KN/m

Total dead load = 35.01KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 35.01KN/m + 1.6x10.85KN/m

Design load = 66.374KN/m

□ span 4 = 1.7m with A=6.16m2

Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2=

6.28KN/m2

Load due to slab on beam = 6.28KN/m2x 6.16m2/1.7m = 22.755KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x6.16m2/ 1.7m= 10.87KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m + 22.755KN/m+ 10.80KN/m

Total dead load = 35.055KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x35.055KN/m+1.6x10.87KN/m

Design load = 66.077KN/m

- span 5 = 2.7m with A=9.78m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2x 9.78m2/2.7m =22.74KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x9.78m2/ 2.7m= 10.86KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m +22.74KN/m + 10.80KN/m

Total dead load = 35.04KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x35.04KN/m+1.6x10.86KN/m

Design load = 66.441KN/m

- span 6 = 2.7m with A=9.78m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2x 9.78m2/2.7m =22.74KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x9.78m2/ 2.7m= 10.86KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m +22.74KN/m + 10.80KN/m

Total dead load = 35.04KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x35.04KN/m+1.6x10.86KN/m

Design load = 66.441KN/m

□ span 7 = 1.7m with A=6.16m2

Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x6.16 m2/1.7m =22.755KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 6.16m2 /1.7m= 10.87KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

Total dead load = 1.5KN/m+ 22.755KN/m + 10.80KN/m

Total dead load = 35.055KN/m

Live load = 10.87KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 35.055KN/m+ 1.6x10.87KN/m

Design load = 66.077KN/m

□ span 8 = 2.9m with A=10.49m2

Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x10.49m2/2.9m =22.71KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 10.49m2/2.9m= 10.85KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

Total dead load =1.5KN/m+ 22.71KN/m + 10.80KN/m

Total dead load = 35.01KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 35.01KN/m + 1.6x10.85KN/m

Design load = 66.374KN/m

□ span 9 = 1.7m with A=6.16m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x6.16 m2/1.7m =22.755KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 6.16m2 /1.7m= 10.87KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m+ 22.755KN/m + 10.80KN/m

Total dead load = 35.055KN/m

Live load = 10.87KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 35.055KN/m+ 1.6x10.87KN/m

Design load = 66.077KN/m

□ span 10 = 2.1m with A=4.042m2

14 Self-weight of slab = 0.15m x 25KN/m3 = 3.75KN/m2 + 2KN/m2+ 0.53955KN/m2= 6.28KN/m2

Load due to slab on beam = 6.28KN/m2 x4.042m2/2.1m = 12KN/m

Self-weight of beam = 0.2m x 0.3m x 25KN/m3 = 1.5KN/m

Live load = 3 KN/m2 x 4.042m2/2.1m=5.77KN/m

Wall = 3 x 0.2 x 18KN/m3=10.80KN/m

1 Total dead load = 1.5KN/m + 12KN/m +10.80KN/m

Total dead load = 24.3KN/m

Live load =5.77KN/m

Design = 1.4Gk + 1.6Qk

Design load = 1.4 x 24.3KN/m + 1.6x5.77KN/m

Design load = 43.02KN/m

Note that the ultimate load exerting on the span: AB-3’, BC-3, CD-3, DF-3, FG-3 and GH-3

2 All spans loaded with the maximum design ultimate load (1.4Gk + 1.6Qk); by using Prokon software we found the following diagrams: bending moment diagram and Shear

force diagram.

Figure 4. 8.Beam loaded with 1 dead load and live load (source from prokon)

Figure 4. 9.Shear force diagram (source from prokon)

Figure 4. 10.Bending moment diagram (source from prokon)

4 The maximum positive moment on the mid span is 35 KNm @ 5.55m and it occur when the beam is minimized loaded, So the tensile reinforcement to resist this moment should be at the bottom, On the other hand the maximum moment on the supports is 40.61KNm as it is located when the beam is loaded at the maximum so 5 the reinforcement should be placed at the top. And the maximum shear force is obtained as 100.2KN.

4.4.4. DESIGN OF REINFORCEMENTS

 Reinforcements at the support

Web(bw) = 200mm

bf = bw + LZ/ 5

Lz = shortest span x 0.7

Bf=200+ =438mm

M=40.61KNm

dw=150mm

hf=150mm

d= (hf+ dw-cover-Φ/2- ′) =150 + 150 − 25 − − 8 = 257mm

Assuming the main reinforcing bars to be 20mm ( ) and links of 8mm ( )

Ultimate moment

Mu=0.156fcubd2=0.156*25*200*2572=51.5KNm

Since Mu>M, no compression reinforcements required

Moment of resistance

Mf=0.45fcu*bw*hf(d-)= 0.45*25*200*150(257-)=54.6KNm

M< Mf, i.e 40.61KNm<54.6KNm, so the stress block [20] lies within the flange so the design of this T beam will be proceeded as the rectangular beam with width=bf and effective depth as d

□ Tensile reinforcements at support

No compression reinforcement required.

Hence find lever arm [5] using the following formula:

>0.95d, so we use Z=0.95d

=244.15mm

Then the critical Z is 215.4mm

Checking if neutral axis lies within flange or web

=92.4mm

a= 0.9x=0.9x92.4=83.16mm, so, a ≤ hf, the procedures of calculations are the same as rectangular beam design. Taking the width [1] of the beam as bf. means 83.16mm<150mm so means [2] neutral axis lies within flange

As min=0.13%bh=0.13%*200*300=580mm2>

So, provide 2T25 with As provided=982 mm2 at the top

□ Tensile reinforcement at the middle

□ M=35$\boldsymbol{KNm}$

No compression reinforcement required

>0.95d, so we use Z=0.95d

=244.1mm

Then the critical Z is 128.8mm

As min=0.13%bh=0.13%*200*300=580mm2< mm

Provide 2T25 with As provided=982 mm2 at the bottom

 Design for shear

The maximum shear force (Vmax)= 100.2KN

B=200mm

d=257mm

fyv=250N/mm2

The shear stress (V) = = =1.82

, BS 8110 pt1, clause 3.4.5.6. table 3.8 value 2 of Vc design concrete shear stress, the value of /mm2 is 0.653 /mm2)

/mm2

Vc+0.4=0.70+0.4=1.1

Vc+0.4 4 form and area of shear reinforcements in beam)

= =0.662( )

From table 4.4. Values of Asv /sv (from Bs part I), Provide H8@150mm

 Deflection check

= = 11.2

Where

=74.9

2.7>2 (BS 8110 part 1, clause 3.4.7. table 3.10. modification factor for tension reinforcements)

, Thus 52> Therefore, there is no deflection.

 Checking for crack.

Within BS 8810 Part 1 clause 3.12.11.2.7

This clause states that the clean distance between bars should not exceed 3d=3×257= 771 mm. Where the spacing between bars =300 mm<771mm, ok (the beam is safe against cracks).

Figure 4. 11.Beam element details

4.4. DESIGN OF COLUMN

4.4.1. INTERNAL COLUMN

During the column design, the most loaded column will be taken where the maximum moment.

Figure 4. 12.Influence area on internal column

Table 4. 3.Loads acting upon the internal column

Story

No

Element

Unity weight (KN/m2)

(KN/m3)

volume from the influence zone

Axial load in KN

4

Iron galvanized sheet and insulation board

0.12KN/m2

3.625*2.7=9.77m2

1.17KN

Truss

0.3KN/m2

3.625*2.7=9.18m2

2.93KN

Purlins and system bracing

0.1KN/m2

3.625*2.7=9.18m2

0.97KN

Ceiling

0.1KN/m2

3.625*2.7=9.77m2

0.97KN

Finishes roof

0.01KN/m2

3.625*2.7=9.77m2

0.097KN

T-beam(x)

25KN/m3

3.625*0.2*0.3=0.215m3

5.43KN

t-beam (y)

25KN/m3

2.7*0.2*0.3=0.162m3

4.055KN

Column

25KN/m3

3.45*0.25*0.25=0.215m3

5.15KN

Imposed loads (Qk)

1.5KN/m2

3.625*2.7=9.78m2

14.68KN

TOTAL DEAD LOADS(KN)

20.77KN

Total load N4=1.4Gk+1.6Qk=1.4*20.77KN+1.6*14.68KN=52.6KN

3

Slab

25KN/m3

0.150*2.7*3.625=1.46m3

36.7KN

T-beam(x)

25KN/m3

3.625*0.2*0.3=O.217 m3

5.43KN

t-beam (y)

25KN/m3

2.7*0.2*0.3=0.16 m3

4.055KN

Column

25KN/m3

3.45*0.25*0.25=0.22 m3

5.4KN

Masonry brick wall

18KN/m3

[(3.625+2.7)] *0.24*3=4.55m3

81.97KN

Finishes

1.5KN/m2

3.625*2.7=9.78m2

14.68KN

Imposed loads (Qk)

3KN/m2

3.625*2.7=9.78m2

29.34KN

TOTAL DEAD LOADS(KN)

148.23KN

Total load N3=1.4Gk+1.6Qk=1.4*148.23KN+1.6*29.34KN=254.46KN

Total design load from S4 to S3=52.6KN +2454.46KN =307.06KN

2

Slab

25KN/m3

0.150*2.7*3.625=1.46m3

36.7KN

T-beam(x)

25KN/m3

3.625*0.2*0.3=O.217 m3

5.43KN

t-beam (y)

25KN/m3

2.7*0.2*0.3=0.16 m3

4.055KN

Column

25KN/m3

3.45*0.25*0.25=0.22 m3

5.4KN

Masonry brick wall

18KN/m3

[(3.625+2.7)] *0.24*3=4.55m3

81.97KN

Finishes

1.5KN/m2

3.625*2.7=9.78m2

14.68KN

Imposed loads (Qk)

3KN/m2

3.625*2.7=9.78m2

29.34KN

TOTAL DEAD LOADS(KN)

148.23KN

Total load N2=1.4Gk+1.6Qk=1.4*148.23KN+1.6*29.34KN=254.46KN

Total design load from S3 to S2= 254.46KN +307.06KN =561.52KN

1

Slab

25KN/m3

0.150*2.7*3.625=1.46m3

36.7KN

T-beam(x)

25KN/m3

3.625*0.2*0.3=O.217 m3

5.43KN

t-beam (y)

25KN/m3

2.7*0.2*0.3=0.16 m3

4.055KN

Column

25KN/m3

3.45*0.25*0.25=0.22 m3

5.4KN

Masonry brick wall

18KN/m3

[(3.625+2.7)] *0.24*3=4.55m3

81.97KN

Finishes

1.5KN/m2

3.625*2.7=9.78m2

14.68KN

Imposed loads (Qk)

3KN/m2

3.625*2.7=9.78m2

29.34KN

TOTAL DEAD LOADS(KN)

148.23KN

Total load N1=1.4Gk+1.6Qk=1.4*148.23KN+1.6*29.34KN=254.46KN

Total design load from S2to S1= 254.46KN +561.46KN =815.92KN

0

Slab

25KN/m3

0.150*2.7*3.625=1.46m3

36.7KN

T-beam(x)

25KN/m3

3.625*0.2*0.3=O.217 m3

5.43KN

t-beam (y)

25KN/m3

2.7*0.2*0.3=0.16 m3

4.055KN

Column

25KN/m3

3.45*0.25*0.25=0.22 m3

5.4KN

Masonry brick wall

18KN/m3

[(3.625+2.7)] *0.24*3=4.55m3

81.97KN

Finishes

1.5KN/m2

3.625*2.7=9.78m2

14.68KN

Imposed loads (Qk)

3KN/m2

3.625*2.7=9.78m2

29.34KN

TOTAL DEAD LOADS(KN)

148.23KN

Total load N1=1.4Gk+1.6Qk=1.4*148.23KN+1.6*29.34KN=254.46KN

Total design load from S1 to S0= 254.46KN +815.92KN =1070.38KN

Axial loads from column transmitted to the footing

Underground semi column

25KN/m3

1.5*0.3*0.3=0.135m3

3.375KN

Ground beam

25KN/m3

3.45*0.2*0.3=0.237m3

5.175KN

Stone Masonry

18KN/m3

[(3.625+2.7)] *0.4*1.5=3.79m3

68.31KN

Total loads

76.86KN

Factored dead loads=1.4*75.18=107.6KN

Total design loads from S0 to the footing=1023.8KN +105.252KN=1177.98KN

 Check the slenderness of 17 the column

The column is braced if the ratios are less than 15.

The column is said to be short (may fail due to the Compression failure of the concrete/steel reinforcement) if are greater than 15. They are slender (may fail due to Buckling).

The column is unbraced if the ratios are less than 10 the column is said to be short if it is not slender.

$lex = lox * \beta = 3 \times 0.75 = 2.25m$ and b=0.25m $ley = loy * \beta = 3.45 \times 0.75 = 2.59m$ and h=0.25m $lex = ley = lo * \beta = 3 \times 0.75 = 2.25m$ and both b and h=0.25m

And 10.36 both 2 are less than 15 so they are short braced column

Column=Kcolumn⁄∑K

Member stiffness; K =bh3/12l

Here l is the total span length; b and h are respectively the width and 36 overall depth of the cross section of the member.

Here l is the total span length; b and h are respectively the width and overall depth of the cross section of the member.

Table 4. 4.Member stiffness

Member

Member stiffness

Column of 3m

$bh3/12l$ = (0.25 × 0.253) ⁄12 × 3= 1.09×10-4

Beam of 2.7m

$bh3/2 \times 12l$ = (0.25 × 0.253) ⁄2 × 12 × 2.7= 0.603×10-4

Beam of 2.7m

$bh3/2 \times 12l$ = (0.25 × 0.253) ⁄2 × 12 × 2.7= 0.603×10-4

Beam of 3.4m

$bh3/2 \times 12l$ = (0.25 × 0.253) ⁄2 × 12 × 3.4= 0.479×10-4

Beam of 3.85m

$bh3/2 \times 12l$ = (0.25 × 0.253) ⁄2 × 12 × 3.85=0.423×10-4

Total member stiffness=2.755×10−4

The distribution factor for the column =1.017x10-4/2.755x10-4=0.36

For the span which is in y Direction:

Influence area for the first span (A) is 3.4m2

For the span which is in y Direction:

Influence area for the first span (A) is 4.9m2

1 The length of the span L=2.7m

The self-weight of the beam=0.2×0.3×25=1.5KN/m

The self-weight of the slab= (0.15×25×4.9)/ 2.7= 6.8KN/m

5 The self-weight of the wall= 0.2×3×18=10.8KN/m

The total finishes=1. 5×4.9/2.7=2.72KN/m

The total dead 1 load per unit length Gk = 1.44+6.53+10.8+2.72= 21.49KN/m

The live load per unit length Qk is = Q × (A/L) =3x (4.9/2.7)=7.26N/m

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{N}$ = (1.4 × $\mathbf{21.49}$) + (1.6 × $\mathbf{7.26}$) = $\mathbf{41.71}\boldsymbol{KN}$

Influence area for the second span (A) is 4.9m2

The length of the span L=2.7m

5 The self-weight of the beam=0.2×0.3×24=1.44KN/m

The self-weight of the slab= (0.15×24×4.9)/ 2.7= 6.53KN/m

The self-weight of the wall= 0.2×3×18=10.8KN/m

The total finishes=1. 5 ×4.9/2.7=2.72KN/m

The total dead 1 load per unit length Gk = 1.44+6.53+10.8+2.72= 21.49KN/m

The live load per unit length Qk is = Q ×(A/L) =3x(4.9/2.7)=7.26N/m

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{N}$ = (1.4 × $\mathbf{21.49}$) + (1.6 × $\mathbf{7.26}$) = $\mathbf{41.71}\boldsymbol{KN}$

Influence area for the first span (A) is 4.59m2

The length of the span L=3.4m

5 The self-weight of the beam=0.2×0.3×24=1.44KN/m

The self-weight of the slab= (0.15×24×4.59)/3.4=4.86KN/m

The self-weight of the wall= 0.2×3×18=10.8KN/m

The total finishes=1. 5 ×4.59/3.4=2.03KN/m

The total dead 1 load per unit length gk = 1.44+4.86+10.8+2.03=19.13 KN/m

The live load per unit length Qk is= Q ×(A/L) =3x (4.59/2.7) =5.4N/m

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{n}$ = (1.4 × $\mathbf{19.13}$) + (1.6 × $\mathbf{5.4}$) = 35.422$\boldsymbol{KN/m}$

Influence area for the second span is 5.20m2

The length of the span L=3.85m

5 The self-weight of the beam=0.2×0.3×24=1.44 KN/m

The self-weight of the slab= (0.15×24×5.20)/ 3.85 =4.86KN/m

The self-weight of the wall= 0.2×3×18=10.8 KN/m

The total finishes=1. 5 ×5.20/3.85=2.03KN/m

The total dead load per unit length Gk = 1.44+4.86+10.88 +2.03=19.13KN/m

The live load per unit length Qk is= Q ×(A/L) =3x (4.59/2.7) =5.4N/m

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{N} = (1.4 \times \mathbf{19.13}) + (1.6 \times 5.40) = \mathbf{35.422}\boldsymbol{KN}/$

FIXED END MOMENT COMPUTATION

Fixed end moment for the span in Y direction

FEM2.7m =25.34KNm and

FEM2.7m =25.34KNmfinally MY=0.341*(25.34-25.34) =0KNm `

Fixed end moment for the span in X Direction

FEM3.4m =34.12KNm

FEM3.85m =43.75KNm and finally Mx=0.341 (43.75-34.12) =3.28KNm

Due to moment in Y-direction is zero it means that the design moment is turning in X direction

Let's assume the diameter of main bars equal to 20mm and the diameter of links equal to 8mm and cover to the reinforcements equal to 25mm

Then,

$\mathbf{Mx}'$>N*emin where $\boldsymbol{emin} = \mathbf{0.05}\boldsymbol{h}\ \boldsymbol{or}\ \mathbf{20}$ as the lesser value of eccentricity.

So, 3.28KNm< 1177.98KN *0.05*0.25→ 3.28KNm < 14.72KNm

as $\mathbf{Mx}$ < N*emin let design the column as it is axially loaded.

. (From Clause 3.8.4.4, BS8110)

From the above equation,

Table 4. 5.The story, Axial load in Newton(N), fy in N/mm2, fcu in N/mm2, Ac in mm2

The story

Axial load in Newton(N)

fy in

N/mm2

fcu in N/mm2

Ac in mm2

(250*250)

Asc in mm2

4

52.26X103

460

25

62500

-1604.9

3

307.06X103

460

25

62500

-778.1

2

561.52X103

460

25

62500

47.6

1

815.92X103

460

25

62500

872.9

0

1070.38X103

460

25

62500

1698.6

Underground column

1177.98x103

460

25

62500

2047.7

As the reinforcements on 4th and3rd story are negatives, the standard states that in that case, the reinforcements corresponding to **Asmin**=0.4%bh must be provided.

As=0.4%bh< Asc < 6%bh, where the longitudinal bars in vertical cast column should be provided from the minimum reinforcement.

so, also, we use this for 2nd stored because 47.6<250

So, let we provide reinforcement according to the calculated area:

- Provide4T12 (As=452mm2) for 4rd floor.
- Provide4T12 (As=452mm2) for 3rd floor.
- Provide 4T12 (As=452mm2) for 2nd floor columns.
- Provide 6T16(As=1210 mm2) for 1st floor columns.
- Provide 6T20 (As=1890 mm2) ground floor columns.
- Provide 6T25 (As=2950 mm2) for under ground floor columns

Links design

Minimum diameter of links = 0.25 times the largest compression bar and not less than 6mm. that's means 0.25×25=6.25mm; Therefore, we use stirrup of 8mm diameter

Maximum spacing of links is equal to 12 times the smallest diameter of bar 12×12=144 mm. Therefore, we take T8@125mm ($\mathbf{As}$=402mm2) for all floors.

 Check for cracking

BS 8110 -2: 1985 states that if the design load on the column (N) is greater than 0.2fcuAc, there is no cracking in the column. 0.2fcubd = 0.2 ⋆ 25 ⋆ 250 ⋆ 250 = 312.5KN

hence N > 0.2fcuAc ↔ 1177.98KN > 312.5KN. 5 So, there is no cracking in column.

Figure 4. 13.Internal column reinforcement details

4.4.2. EXTERNAL COLUMN

Figure 4. 14.Influence area on external column

Figure 4. 15Influence area on external column

Story

No

Element

Unity weight (KN/m2)

(KN/m3)

volume from the influence zone

Axial load in KN

4

Iron galvanized sheet and insulation board

0.12KN/m2

2.7*1.925=5.197m2

0.0.62KN

Truss

0.3KN/m2

2.7*1.925=5.197m2

1.55KN

Purlins and system bracing

0.1KN/m2

2.7*1.925=5.197m2

0.519KN

Ceiling

0.1KN/m2

2.7*1.925=5.197m2

0.519KN

Finishes roof

0.01KN/m2

2.7*1.925=5.197m2

0.0619KN

T-beam(x)

25KN/m3

2.7*0.2*0.3=0.162m3

4.05KN

t-beam (y)

25KN/m3

1.925*0.2*0.3=0.115m3

2.88KN

Column

25KN/m3

2.7*0.25*0.25=0.168m3

4.218KN

Imposed loads (Qk)

1.5KN/m2

2.7*1.925=5.197m2

7.795KN

TOTAL DEAD LOADS(KN)

13.85KN

Total load N3=1.4Gk+1.6Qk=1.4*13.85KN +1.6*7.795KN =32.11KN

3

Slab

25KN/m3

0.150*3.4*1.925=0.98m3

24.54KN

T-beam(x)

25KN/m3

2.7*0.2*0.3=0.162m3

4.05KN

t-beam (y)

25KN/m3

1.925*0.2*0.3=0.115m3

2.875KN

Column

25KN/m3

2.7*0.25*0.25=0.135m3

3.375KN

Masonry brick wall

18KN/m3

[(2.7+1.925)] *0.24*3=3.33m3

71.93KN

Finishes

1.5KN/m2

2.7*1.925=5.197m2

7.79KN

Imposed loads (Qk)

3KN/m2

2.7*1.925=5.197m2

15.591KN

TOTAL DEAD LOADS(KN)

114.5KN

Total load N3=1.4Gk+1.6Qk=1.4*114.5KN +1.6*15.591KN =185.24KN

Total design load from S4 to S3=32.11KN +185.24KN =217.355KN

2

Slab

25KN/m3

0.150*3.4*1.925=0.98m3

24.54KN

T-beam(x)

25KN/m3

2.7*0.2*0.3=0.162m3

4.05KN

t-beam (y)

25KN/m3

1.925*0.2*0.3=0.115m3

2.875KN

Column

25KN/m3

2.7*0.25*0.25=0.135m3

3.375KN

Masonry brick wall

18KN/m3

[(2.7+1.925)] *0.24*3=3.33m3

71.93KN

Finishes

1.5KN/m2

2.7*1.925=5.197m2

7.79KN

Imposed loads(Qk)

4KN/m2

2.7*1.925=5.197m2

15.591KN

TOTAL DEAD LOADS(KN)

114.5KN

Total load N3=1.4Gk+1.6Qk=1.4*114.5KN +1.6*15.591KN =185.24KN

Total design load from S3 to S2=217.355KN +185.24KN =402.595KN

1

Slab

25KN/m3

0.150*3.4*1.925=0.98m3

24.54KN

T-beam(x)

25KN/m3

2.7*0.2*0.3=0.162m3

4.05KN

t-beam (y)

25KN/m3

1.925*0.2*0.3=0.115m3

2.875KN

Column

25KN/m3

2.7*0.25*0.25=0.135m3

3.375KN

Masonry brick wall

18KN/m3

[(2.7+1.925)] *0.24*3=3.33m3

71.93KN

Finishes

1.5KN/m2

2.7*1.925=5.197m2

7.79KN

Imposed loads (Qk)

4KN/m2

2.7*1.925=5.197m2

15.591KN

TOTAL DEAD LOADS(KN)

114.5KN

Total load N3=1.4Gk+1.6Qk=1.4*114.5KN +1.6*15.591KN =185.24KN

Total design load from S2 to S1=402.595KN +185.24KN =587.835KN

0

Slab

25KN/m3

0.150*3.4*1.925=0.98m3

24.54KN

T-beam(x)

25KN/m3

2.7*0.2*0.3=0.162m3

4.05KN

t-beam (y)

25KN/m3

1.925*0.2*0.3=0.115m3

2.875KN

Column

25KN/m3

2.7*0.25*0.25=0.135m3

3.375KN

Masonry brick wall

18KN/m3

[(2.7+1.925)] *0.24*3=3.33m3

71.93KN

Finishes

1.5KN/m2

2.7*1.925=5.197m2

7.79KN

Imposed loads (Qk)

4KN/m2

2.7*1.925=5.197m2

15.591KN

TOTAL DEAD LOADS(KN)

114.5KN

Total load N3=1.4Gk+1.6Qk=1.4*114.5KN +1.6*15.591KN =185.24KN

Total design load from S1 to S0=587.835KN +185.24KN =773.075KN

Axial loads from column transmitted to the footing

Underground semi column

25KN/m3

1.5*0.3*0.3=0.135m3

3.375KN

Ground beam

25KN/m3

4.25*0.2*0.3=0255m3

6.375KN

Stone Masonry

18KN/m3

[(2.7+1.925)] *0.3*1.5=2.08m3

37.462KN

Total loads

47.212KN

Factored dead loads=1.4*47.212KN =66.096KN

Total design loads from S0 to the footing=773.075KN +66.096KN =839.171KN

LOAD CALCULATION DUE TO DIRECTION

For the span which is in y Direction:

Influence area for the first span (A) is 2.60m2

1 The length of the span L=2.7m

The self-weight of the beam=0.25 0.25 24=1.5KN/m

The self-weight of the slab= (0.15 24 2.60)/ 2.7=3.5KN/m

5 The self-weight of the wall= 0.2 3 18=10.8KN/m

The total finishes=1. 5 ×2.60/2.7=1.44KN/m

The total dead 1 load per unit length Gk = 1.5+3.5+10.8+1.44= 17.244KN/m

The live load per unit length 3x

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$N = (1.4 \times \mathbf{17.244}) + (1.6 \times \mathbf{3.86}) = 30.32\boldsymbol{KN}$

Influence area for the second span (A) is 2.60m2

The length of the span L=2.7m

5 The self-weight of the beam=0.25 0.25 24=1.5KN/m

The self-weight of the slab= (0.15 24 2.60)/ 2.7=3.5KN/m

The self-weight of the wall= 0.2 3 18=10.8KN/m

The total finishes=1. 5 ×2.60/2.7=1.44KN/m

The total dead 1 load per unit length Gk = 1.5+3.5+10.8+1.44= 17.244KN/m

The live load per unit length 3x

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{N}$ = (1.4 × $\mathbf{17.244}$) + (1.6 × $\mathbf{3.86}$) = 30.32$\boldsymbol{KN}$

For the span which is in x Direction:

Influence area for the first span is 5.20m2

The length of the span L=3.85m

5 The self-weight of the beam=0.25 0.25 24=1.5KN/m

The self-weight of the slab= (0.15 24 5.2)/3.85=4.87KN/m

The self-weight of the wall= 0.2 3 18=10.8KN/m

The total finishes=1. 5 ×5.2/3.85=2.03KN/m

The total dead 1 load per unit length gk = 1.5+4.87+10.8+2.03=19.20 KN/m

The live load per unit length Qk is = 3x

Thus, the ultimate load exerting on the first span is given by N=1.4Gk+1.6Qk

$\boldsymbol{n}$ = (1.4 × $\mathbf{19.10}$) + (1.6 × $\mathbf{5.40}$) = 35.38$\boldsymbol{KN/m}$

Influence area for the second span is 0m2 so no loading here.

FIXED END MOMENT COMPUTATION

Fixed end moment for the span in Y direction

FEM2.7m =18.42KNm and

FEM2.7m =18.41KNmfinally MY=0.341*(18.42-18.42) =0KNm

Fixed end moment for the span in X Direction

FEM3.85 =43.70KNm and finally Mx=0.341 (43.70-0) =14.90KNm

The check has proved 17 that the column is biaxial loaded, in X- Direction

Total design load on that column (N) =839.171KN

Mx′ 10.48 KNm asMx′>N*emin let design the column as it is biaxial loaded.h′ = b′ 3 = h − c − θ′ − θ/2

curve 1.3=

100Asc=1.3 bh

Asc=1.3 2

Let provide 4T20 with reinforcement area of As=1260mm2

Provision of links and spacing.

Minimum diameter of links = * the largest compression bar and not less than 6mm. that gives =5mm, for the case let provide θ=8mm

Maximum spacing between center to center of the links is equal to12* the smallest diameter of bar, that gives 12×20=240mm, so let take 200mm. Provide T8@200mm (As=252mm2)

External Column element details

Figure 4. 16.external column details

Notice: this column reinforcement details 2 is applied to all external columns

4.5. DESIGN OF FOOTING

Clause 3.3.1.4 in BS of the code states that the minimum cover should be 75 mm if the concrete is cast directly against the earth but if blinding concrete is provided cover should be 50 mm and the minimum grade of concrete to be used in foundations is grade 35.the soil bearing capacity used has been considered as medium clay because we didn't make taste to our plot; that is why we use this the soil bearing capacity as 150KN/m2 according to existing building. The considered 3 bearing capacity of the soil is sufficient, so, no need to consider the raft foundation. If the columns were near one another at great distance, the combined footing could be preferable to use but it is not the case so the Pad footing (Square) was chosen. (Bayer, 2014).

The following data have been used during the design:

- Concrete cover: 50mm
- The compressive strength (fcu) is 35N/mm2
- fy is 460 N/mm2
- Bearing pressure 3 of the soil is 150KN/m2

 Total dead load from the 4 floors up to the foundation = 573.06KN

 The total live load from the 4 floors up to the foundation =102.7KN

 The 4 ultimate axial load on the footing is 1177.98KN

Figure 4. 17.Loaded column

4.5.1. CALCULATION OF THE LOADINGS

Computation of 3 the plan area of the footing:

 Total load =573.06KN+102.7KN=675.76KN

 The self-weight of the footing range between 10-15% of the vertical load

 Let Self-weight of the footing 15% of total weight =675.76KN*15%=101.36KN

Let assume self-weight of footing =101KN

 Total dead load =573.06 KN+101KN =674.06KN

 The total serviceability load including 5 the self-weight of the footing (N) = 1*GK + 1*QK = (1.0 $*$ 674.06KN) + (1.0 $*$101KN) =775.06KN

Plan area of footing=

= m2, hence provide 3m square base (base area =9m2)

Self-weight of footing

101KN=9*h*25↔h=0.44m

Let's 3 the overall depth of footing (h) =400mm

4.5.2. DESIGN MOMENT

Total ultimate load (W) = 1.4Gk+1.6Qk=1.4*573.06KN +1.6*102.7KN =966.6KN

Earth pressure (Ps) = = 107.4KN/m2

Figure 4. 18.Loaded column with Earth pressure

Maximum design moment occurs at face of column (M) = =97.86KNm/m width of slab.

Effective depth

Le t's assume the 20 mm diameter bars will be needed as bending reinforcement in both directions

Hence, average effective depth of reinforcement, d is

d=h-c-ϕ=400-50-20=330 mm

Ultimate moment

Mu=0.156fcubd2=0.156*35*1000*3302=1533.7KNm

Since Mu = 594.5KNm M=90.75KNm/m 4 no compression reinforcement is required

Main steel

k= 0.156, hence no compression reinforcement is required.

313.5mm

Let's Take Z= = mm

,

3 Minimum steel area is = 0.13%bh = 0.13%*1000*400=

Since As min As OK

Hence from table3.22, Provide H20 at 250 mm C/C (ASP = 1260 mm2) distributed uniformly across the full width of the footing parallel to the x-x and y-y axis (see clause 3.11.3.2, BS 8110).

4.5.3. CRITICAL SHEAR STRESS

Figure 0-2:4: Punching shear

Critical perimeter Pcrit = (3*330+300)4=5160mm

Area within perimeter = (300+3d) 2= (300+3*330)2=1.66

Ultimate punching force, V=load on shaded area=107.4*(9-1.66) =788.31KN

Design punching shear stress V = N/ <5N/mm2

= , by interpolation = y1=y0 + (y2-y0)

By interpolation Vc =0.45

Vc = (*0.45=0.50

Since Vc >V, 3 punching failure is unlikely and 400mm depth of Footing is acceptable.

Figure 4. 19.Face shear

Maximum shear stress (Vmax) occurs at column

Vmax= = = 2.97Nmm2 permissible (0.8 35=5N/mm2) OK

Figure 4. 20.Transverse shear

Ultimate shear force (V) = load on shaded area = Ps*area =107.4(3*970) =312.5KN

Design shear stress V

V= = =0.31N/mm2 =0.50N OK

Hence, no shear reinforcement is required

Figure 4. 21.Pad footing reinforcement details

4.6. STAIR DESIGN

The following data are to be considered while designing a stair:

- Thickness of waist=150mm
- Assume Riser=170mm
- Width of stair=1200mm
- Cover=25mm
- Height from landing to the slab=1725mm
- Length of flight=4600mm
- Diameter of reinforcements (=10mm

4.6.1. CALCULATING RISER AND GOING

Number of risers is equal to risers and height of riser is 172.5mm

Number of going will be 10-1=9 treads and the length of treads 2 will be determined by the formula of 2R+G=630mm hence, G=650-2*172.5=305 mm

Summary: 1. Number of risers is 20 of 172.5mm

2. Number of treads is 18 of 305mm

3. Slope or pitch = tan-1(29.40

4.6.2. CALCULATION OF LOADS

Slope length of stair= =4.91m

Area of rise and going= = 0.305 x 0.1725/2=0.02630m2

Area of waist=thickness of waist *slop length

Self-weight of stair= (0.1725*4.91+ *9)*25=27.06KN/m width of stair

Live loads=3KN/m2*4.6m*1m=13.8KN/m width of stair

Ultimate design load

F=1.4*Gk+1.6Qk

F=1.4*27.06+1.6*13.8=59.96KN/m width of stair

4.6.3. DESIGN MOMENT

M= =34.47KNm

,

d= taking Mf=1.4

d= 84mm, take 110mm

0.11<0.156 no compression reinforcements required

=102.3 mm

= 841.95mm2

Provide H12@125mm with As prov=905 mm2/m

Transverse distribution of steel

As min=0.24%bh=0.24%*1000*172.5=414mm2/m

Provide H12@200mm with As prov=566mm2/m

4.6.4. CHECK DEFLECTION

= 2.8

Where

=267.47N/mm2

=1.01<2

MF× basic ratio = 1.01×26=27

= =10.9

For 27>10.9, There is no deflection in stair

4.6.5. CHECK CRACK ON STAIR

Maximum spacing between bars [48] should not exceed the lesser of 3d equal (3*110 mm) = 330 mm. Actual spacing= 125 mm main steel and 200mm secondary steel <330). Ok (no crack on slab).so the stair is safe against cracking.

Figure 4. 22.Stair details

CHAP V CONCLUSION AND RECOMMENDATIONS

1.1. CONCLUSION

[1] In the present study building of four story is designed and analysis of a four storied apartment in Nyamagabe district, Gasaka sector. with its (Slabs, Beams, Columns, Footings and staircase) using software like (Auto CAD, prokon and archcard21). After planning, drawing, analyzing and designing all Structural member by respecting BS code

like BS 6399. (1996) Part 1, BS 8110 part 1. (1997), BS 8110, part 2. (1985) and other references, we can conclude that it is safe, durable, comfortable, structurally stable and economical structure which can occupy 20 families, whereby each floor accommodate 4 families.

[1] In the present study building of four stories is designed and analysis with its (Slabs, Beams, Columns, Footings and staircase) using software like (Auto CAD, Excel, prokon and archcard21). Also, The Structural members designed are well executed respecting the BS standards and the reinforcement details are provided for each member. for slab we provide T10@200mm for Aspro=393mm2, for beams we provide 2T25 with As provided=982 mm2 at [9] (top of the beam in support) and 2T25 with As provided=982 mm2 at (bottom of the beam in middle span) and Provide H8@150mm, For interior columns we Provide4T12 (As=452mm2), 6T16(As=1210 mm2), 6T20 (As=1890 mm2), 6T25 (As=2950 mm2) and Provide H8@125mm (402 mm2) for exterior column we provide 4T20 with reinforcement area of As=1260mm2 and T8@200mm (As=252mm2) for footing we provide H20 at 250 mm C/C (ASP = 1260 mm2) and for stair we provide H12@125mm with As prov=905 mm2/m for main steel and we provide H12@200mm with As prov=566mm2/m for transversal distribution steel.

1.2. RECOMMENDATIONS

After the completion of this project, many challenges and problems were incountered.so we would like to give the following recommendations to the college authorities:

- To include Structural design software learning program in the academic program Such as: Autodesk robot structural design professional and MS Spreadsheet.
- To conduct soil test or provide soil test results.
- To keep this report in the library as a reference for the coming years graduates willing to do Structural design.
- By the fact that this project is well designed and fit the proposed location, if possible, it can be financed and implemented.

To provide a greater number of project reports in the library for use as references

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APPENDICES

Appendices contain the part of description which contain the tables of values used in calculations, drawings, the views of the building, and project schedules and budget of plans.

APPENDIX 1. TABLES USED (BS 8110 part 1, 1997) AND (BS 6399 Part 1, 1996)

APPENDIX A :Cross Section Areas of Group Bars

APPENDIX B: Section area perimeter width for various bar spacing

APPENDIX C: Section areas per meter width for various bars spacing (mm2)

APPENDIX D: AS/Sv for varying stirrup diameter and spacing

Type of panel and moments considered

Short span coefficients, sx

Long span

coefficients,

sy for all values of ly/lx

Values of ly/lx

1.0

1.1

1.2

1.3

1.4

1.5

1.75

2.0

Interior panels 4 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 2 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

APPENDIX E: Bending moment coefficients for rectangular panels supported on four sides with provision for torsion at corners

Type of panel and location

vx for values of ly/lx

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 4 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 2 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 4 discontinuous

Discontinuous edge

0.33

0.36

0.39

0.41

0.43

0.45

0.48

0.50

0.33

APPENDIX F: Values of beta for braced column (BS8110part1, 1997)

End condition at top

End condition at bottom

1

2

3

1

2

3

0.75

0.80

0.90

0.80

0.85

0.95

0.90

0.95

1.00

APPENDIX G: 2 Values of VC design concrete shear stress

APPENDIX H: load combination and values of $_{\gamma}f$ for the ultimate limit state

LOAD

COMBINATION

LOAD TYPE

DEAD LOAD (GK)

IMPOSED

(QK)

LOAD

WIND LOAD(WK)

Adverse

Beneficial

Adverse

Beneficial

Dead and imposed load

1.4

1.0

1.6

0

-

Dead and wind load

1.4

1.0

-

-

1.4

Dead, wind and live load

1.2

1.2

1.2

1.2

1.2

APPENDIX I : FLOOR PLAN

APPENDIX J : FRONT VIEW PERSPECTIVE

APPENDIX K : BACK WIEW PERSPECTIVE

APPENDIX L :LEFT SIDE VIEW PERSPECTIVE

APPENDIX M : RIGHT SIDE PERSPECTIVE

APPENDIX: TOP VIEW PERSPECTIVE

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