TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS
DEPARTMENT OF CIVIL ENGINEERING

FINAL YEAR PROJECT REPORT on “STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING”

By:

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Supervisor:

Asst. Prof. Thaman Bahadur Khadka

MAY 2023

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR DEGREE IN CIVIL ENGINEERING
(Course Code: CE755)

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CERTIFICATE

This is to certify that this project work entitled **"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"** has been examined and declared successful for the fulfilment of academic requirement towards the completion of Bachelor Degree in Civil Engineering.

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ABSTRACT

Project I and II was put on the curriculum for the fulfilment of Degree of Bachelors in Civil Engineering, where we were given an opportunity to analyze and design a building by applying the theoretical knowledge that we obtained over the period of 4 years.

In this project entitled "Structural Analysis and Design of Commercial Building", we idealized, analyzed and designed a commercial building abiding by IS codes. The main aim of this project work was to be familiar with the analysis and design of buildings abiding by the codes given by Indian Standard and Nepal Building Codes. Despite the resource and time limitation, the project has been completed successfully on time. With the hope that the design and drawings will be enough as per ductile design consideration and codal provision, we have completed the report on building project.

Due to the extravagancy of testing and analyzing the building with physical model, only the computational modal was prepared. The computer aided design was done not only for visualization and drawing, but also for analysis and design using FEA based modelling tool, ETABS. Potential alternatives for design and analysis were evaluated in order to obtain the most promising output.

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NOTATIONS

Symbols	Description
α_x, α_y	BM coefficients for Rectangular Slab Panels
ϕ	Diameter of Bar, Angle of internal friction of soil
δ_m	Percentage reduction in moment
τc	Shear Stress in Concrete
$\tau c_{,max}$	Max. shear stress in concrete with shear reinforcement
τ_{bd}	Design Bond Stress
σ_{ac}	Permissible Stress in Axial Compression (Steel)
σ_{cbc}	Permissible Bending Compressive Strength of Concrete
σ_{sc}, σ_{st}	Permissible Stress in Steel in Compression and Tension respectively
γ_m	Partial Safety Factor for Material
γ_f	Partial Safety Factor for Load
γ	Unit Weight of Material
A_b	Area of Each Bar
A_g	Gross Area of Concrete
A_h	Horizontal Seismic Coefficient
A_{sc}	Area of Steel in Compression
A_{st}	Area of Steel in Tension
A_{sv}	Area of Stirrups
B or b	Width or shorter dimension in plan
b_f	Effective width of flange
d	Effective Depth
d'	Effective Cover
D	Overall Depth
D_f	Thickness of Flange
e_x	Eccentricity along x-direction
e_y	Eccentricity along y-direction
E_c	Modulus of Elasticity of Concrete
E_s	Modulus of Elasticity of Steel
EL_x, EL_y	Earthquake Load along X and Y direction respectively
f_{br}	Bearing stress in concrete
f_{ck}	Characteristics Strength of Concrete
f_y	Characteristic Strength of Steel
I	Importance Factor (For Base Shear Calculation)
I_{KK}, I_{FF}	Moment of Inertia (along x and y direction)
k	Coefficient of Constant or factor
k_a , k_p	Active and Passive Earth Pressure
K	Stiffness

L	Length of Member
l_{eff}	Effective Length of member
L_d	Development Length
M	Modular Ratio
M or BM	Bending Moment
N_u or P_u	Ultimate Axial Load on a compression member
Pc	Percentage of Compression Reinforcement
P_t	Percentage of Tension Reinforcement
q, q_u	Permissible and Ultimate bearing capacity of soil
Q_i	Design Lateral Force in i^{th} Level
Q	Stability Index
SR, r_{min}	Slenderness Ratio, (minimum) for structural steel section
R	Response Reduction Factor
Sa/g	Average Response Acceleration Coefficient
Sv	Spacing of Each Bar
T_i	Torsional Moment due to Lateral Force in i-direction
Ta	Fundamental Natural Period of Vibrations
V_B	Design Seismic Base Shear
V	Shear Force
W_i	Seismic Weight of i^{th} Floor
WL	Wind Load
x_u	Actual Depth of Neutral Axis
x_{ul}	Ultimate Depth of Neutral Axis
Z	Seismic Zone Factor
CM	Center of Mass
CR	Center of Rigidity
D.L	Dead Load
HSDB	High Strength Deformed Bars
IS	Indian Standard
L.L	Live Load
RCC	Reinforced Cement Concrete
SPT, N	Standard Penetration Test
M25	Grade of Concrete
Fe500	Grade of Steel
MOI	Moment of Inertia

1. INTRODUCTION

1.1. Background

The rapid growth of urbanization in recent decades has spurred the development of multistory structures around the world, particularly in emerging economies. The shortage of land in highly populated areas of the world is a major economic motivation for the rise of tall (especially residential) buildings. The race to create the highest buildings in a city, country, region, or world has fueled the growth of tall buildings all around the world.

In recent decades, the competition to build the tallest buildings has been expanded to include the competition to build the most iconic and aesthetically outstanding structures, which are generally characterized by complex geometrics and leaning/twisting forms. Earthquakes, as one of the most devastating natural disasters, have prompted further consideration in the design of these structures.

The design of the structure has been given special consideration as a result of the earthquake. With a magnitude of 7.8 Richter and a maximum Mercalli Intensity of VIII, it struck around 11:56 Nepal Standard Time on April 25, 2015. The entire damage was estimated to exceed $5 billion, with 8,959 people killed and 23,447 injured. Its epicenter was in Gorkha's Barpak. It is the deadliest natural disaster to strike Nepal since the earthquake that struck Nepal and Bihar in 1934. Hundreds of thousands of people were displaced, and entire communities were leveled in several parts of the country. At UNESCO World Heritage sites in the Kathmandu Valley, centuries-old structures were demolished. Nepal is located on the southern end of the diffuse collision boundary, which occurs when the Indian Plate pushes into the Eurasian Plate. In central Nepal, the plates are convergent at a rate of around 45 mm (1.8 in) every year.

For the seismic design and analysis of multistory buildings, it is important to consider the earthquake effect (seismic effect), unique loading patterns, and subsurface bearing capacity. Given that our country is located in an active tectonic zone where the Indian plate is thrusting against the Eurasian plate, multistory structure design that ignores seismic forces is unavoidable. For the seismic design and analysis of multistory buildings, it is important to examine the seismic effect, loading pattern, soil bearing capability, and other factors. In response to this, we recommend completing a project on **"Structural Analysis and Design of Commercial Building"**

1.2. Title and Theme of project

The title of the project is "Structural Analysis and Design of Commercial Building"

The theme of the project is to structurally analyze and design an earthquake resistant multi-storied building. During the analysis and design of the project, we have acquired knowledge and skill to consider practical application besides the utilization of analytical methods and design approaches, exposure and application of various available codes of practices.

1.3. Objectives

The specific objectives are:

- Reviewing of the available architectural drawing.
- Modification of Architectural drawing on the basis of earthquake force reduction principle.
- Preliminary sizing / design of the structural elements.
- Detailed structural analysis of the building using ETABS.
- Design of various structural components.
- Ductile detailing of structural members.
- Preparation of detailed structural drawings.
- Better acquaintance with the code provisions related to RCC design.
- Acquire knowledge on earthquake engineering.

1.4. Scope

To achieve the above objectives the following scope of work is planned:

- Identification of the building and the requirement of the space.
- Determination of the structural system of building to undertake the vertical and horizontal loads.
- Estimation of loads including those due to earthquakes.
- Preliminary design for geometry of structural elements.
- Determination of fundamental time period by free vibration analysis.
- Calculation of base shear and vertical distribution of equivalent earthquake load.
- Identification of load cases and load combination cases.
- Finite element modelling of the building and input analysis.
- The structural analysis of the building by ETABS for different cases of loads.
- Review of analysis outputs for design of individual components.

- Design of RC frame members (slabs, beams, and columns), walls, isolated and combined foundation, staircase, and other by limit state method of design
- Detailing of individual members and preparation of drawings as a part of a working construction document.

1.5. Salient Features

- Name of the Project: Structural Analysis and Design of Commercial Building
- Location:
    - Region: Bagmati Pradesh (Central Development Region)
    - Zone: Bagmati
    - District: Kathmandu
- Type of Building: Commercial Building
- Structural System: Special Moment Resisting Frame (SMRF)
- Soil Type: II
- Seismic zone: V
- No of Storey: 4 + 2 Basement
- Dimension of building:
    - Maximum length: 36.27m
    - Maximum breadth: 29.08m
- Type of Staircase: Open-well
- Type of foundation: Mat Foundation
- Floor Height: 3.9624m (13ft.)
- Infill wall: Brick Masonry
    - Main wall: 0.23m
    - Partition wall: 0.110m
- Design criteria: As per Indian Standard Relevant Codes
- Size of structural elements:
    - Main Beam: 650*400mm
    - Secondary Beam: 400*230mm
    - Column: 800mm*800mm
    - Slab thickness: 125mm
    - Depth of mat foundation: 1000 mm
- No of columns:
    - Typical floors: 35
    - Staircase roof cover: 8

2. LITERATURE REVIEW

Earthquakes is the natural phenomena caused by a sudden slip on a fault resulting in the release of seismic waves (p-wave and s-wave) form the earth’s surface. It can range from a faint tremor to a wild motion. It occurs in clusters. It dates as old as earth’s history itself, however our knowledge and ways to minimize them is recent. With the increase in the multistoried building construction the design of earthquake resistant structures is of utmost important to project the life and property of the people in case of major earthquakes.

The theoretical development of earthquake forces in structure reveals that the maximum elastic response acceleration during earthquake (range for which structure is designed) would be several times larger than the design acceleration i.e., the seismic coefficient specified in most of the codes. This situation is quite different to approach made in codes for loads such as design loads are usually higher than the actual ones. It is based on the probability of the in-frequent occurrence of large earthquakes and the energy absorption capacity of the structure.

It is assumed that the structure will respond in a nonlinear manner in severe earthquakes and thereby dissipate the energy of motion using material and structural ductility. It is clear that, to achieve ductile behaviors, brittle modes of failure due to shear, anchorage and bond should be avoided. This concept is derived from a basic philosophy that damage of the building is permissible as long as the structure doesn’t collapse catastrophically during a severe earthquake. This fact guides concept that vertical load-bearing member providing basic support of structure should be strong and can be achieved by applying strong column-weak beam concept.

2.1. Design Philosophy

There are three philosophies for the design of reinforced concrete viz.

- Working Stress Method
- Limit State Method
- Ultimate Load Method

Among above, Limit state method has been adopted for the design of the structural elements, due to its probabilistic approach and wide acceptability.

2.2. Limit State Method

Limit state design has been originated from ultimate or plastic design. The object of design based on the limit state concept is to achieve an acceptable probability that a structure will not become unserviceable in its lifetime for the use of which it is intended, i.e., it will not reach the limit state. A structure with appropriate degrees of reliability should be able to withstand safely all the loads that are liable to act on it through-out its life and it should satisfy the serviceability requirements. The three different design formats used in the limit states are; Multiple Safety Factor Format, Load and Resistance Factor Design Format and the Partial Safety Factor Format. All the relevant limit states must be considered in design to ensure an adequate degree of safety and serviceability.

2.3. Limit state of strength/collapse

This state corresponds to the maximum load carrying capacity. Violation of collapse limit state implies failure in sense that a clearly defined limit state of structural usefulness has been exceeded. However, it does not mean a complete collapse. This limit state may correspond to:

A. Flexure
B. Compression
C. Shear
D. Torsion

2.3.1. Assumptions for the limit state of collapse in flexure:

- The plane section normal to the axis of member remains plane after bending.
- The maximum strain in concrete at the outermost compression fiber is 0.0035.
- The relationship between the compressive stress distribution in concrete and the strain in the concrete may be assumed to be rectangle, trapezoid, parabola or any other shape. For design purpose, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor ϒm= 1.5 shall be applied.
- The tensile strength of concrete is ignored.

- The stresses in the reinforcement are derived from the representative stress-strain curve for the type of steel used. For design purpose the partial safety factor ϒm= 1.15 shall be applied.
- The maximum strain in the tension reinforcement in the section at failure shall not be less than:

  $f_y/1.15Es + 0.02$

  where, f_y = characteristics strength of steel.

  Es= modulus of elasticity of steel.

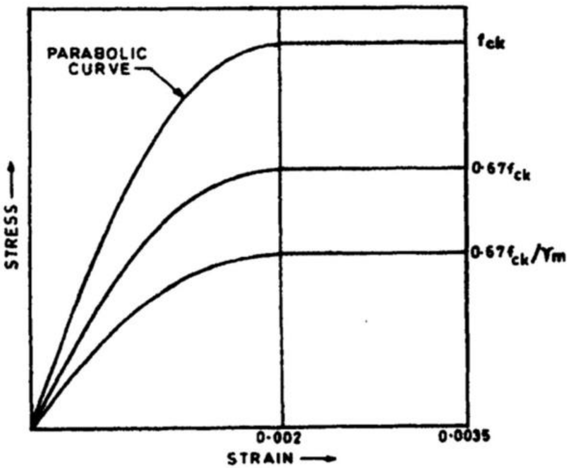


Fig 2.1: Stress-Strain curve of concrete (IS 456:2000)

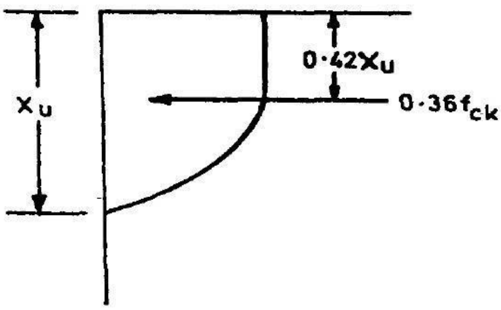


Fig 2.2: Stress Block Parameter (IS 456:2000)

2.3.2. Assumptions for the limit state of collapse in compression:

In addition to the assumptions for the limit state of collapse in flexure from above, the following shall be assumed:

- The maximum compressive strain in concrete in axial compression is taken as 0.002.

- The maximum compressive strain at the highly compressed extreme fiber in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at least compressed extreme fiber.

The most important of these limit states which must be examined in design are as follows:

2.4. Limit state of serviceability

This state corresponds to development of the excessive deformation and is used for checking members in which magnitude of deformation may limit the use of the structure or its components. This state may correspond to:

A. Deflection
B. Cracking
C. Vibration.

2.4.1. Control of deflection

The deflection of a structure shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. Two methods are given in code for checking the deflections. These are:

- Limiting the span/effective depth ratio given in clause 23.2, IS: 456-2000 which should be used in all normal cases, and
- Calculation of deflection given in Appendix C of code to be followed in special cases.

2.4.2. Control of cracking

Cracking is a very complex phenomenon. Design considerations for crack control would require the following:

- Expression for crack width and spacing (Annex F of IS 456:2000).
- Allowable crack widths under different service conditions with due considerations to corrosion and durability of concrete (Clause 35.3.2 of IS 456:2000).
- Unless the calculation of crack widths shows that a greater spacing is acceptable for the flexural members in normal internal or external conditions of exposure, the maximum distance between bars in tension shall not exceed the value as given in IS 456:2000, Clause 26.3.3.

- Cracks due to bending in compression member subjected to design axial load >0.2fck×Ac, need not be checked. For flexural members (A member which is subjected to design load <0.2fck×Ac) if greater spacing of reinforcements as given in Clause 26.3.2, IS 456:2000 is required, the expected crack width should be checked by formula given in Annex F of IS 456:2000.c.

2.4.3. Control of Vibration

A dynamic load is any load of which the magnitude, direction or position varies with the time and almost any RCC structural system may be subjected to one form or another loading during its life-time. Similarly structural response i.e. resulting stresses or deflections is also time-varying or dynamic and is expressed in terms of displacements.

The limit state concept of design of reinforced concrete structures takes into account the probabilistically and structural variation in the material properties, loads and safety factors.

2.5. Loads

Basic objective of constructing building or any structure is to support loads. There are different types of loads, which come across and have to be dealt during analysis and design of any structure.

2.5.1. Design loads

The buildings and structures are subjected to a number of loads, forces and effects during their service life. The following loads usually determine the size of structural element:

A. Dead load (DL)
B. Imposed load (IL)
C. Wind load (WL)
D. Earthquake load (EL)

The following are the cause which generally causes internally-equilibrated stresses forming cracks in structure, but not collapse.

A. Foundation movement
B. Axial elastic shortening
C. Shrinkage
D. Temperature changes, etc.

Beside above-mentioned loads, the effect of other forms of load such as fatigue, construction loads, accidental loads, impact and collision, explosions, fire, etc. should also be considered in design of structure.

2.5.2. Load assessment

The proposed building is a RCC framed structure, located in Kathmandu. Thus wind loads, snow loads, and other special types of loads, as described by IS 875part 5):1987 can be taken as negligible as compared to the dead, live and seismic loads.

Dead Loads: According to the IS 875(Part 1):1987, the dead load in a building shall comprise the weight of all walls, partitions, beam, column, floors and roofs and shall include the weights of all other permanent features in the building.

Live Loads: It means the load assumed or known resulting from the occupancy or use of a building and includes the load on balustrades and loads from movable goods, machinery and plant that are not an integral part of the building. These are to be chosen from IS 875(Part 2):1987 for various occupancies where required. The code permits certain modifications in the load intensities where large contributory areas are involved, or when the building consists of many stories.

Eccentricity of vertical loads: When transferring the loads from parapets, partition walls, cladding walls and facade walls, etc. to the supporting beams or columns, the eccentricity with these loads should be properly considered in the case of rigid frames of reinforce concrete. Such eccentricities will produce externally-applied joint moments similar to these arising from projecting cantilevers and these should be included in frame design.

Seismic Loads: These are the loads resulting from the vibration of the ground underneath the super-structure during an earthquake. Earthquake is an unpredictable natural phenomenon. Nobody knows the exact timing and magnitude of such loads. Seismic loads are to be determined essentially to produce an earthquake resistant design.

Since the probable maximum earthquake occurrence is not frequent, designing building for such earthquake isn't practical as well as economically prudent. Instead, reliance is placed on kinetic dissipation in the structure through plastic deformation of elements and joints and the design forces are reduced accordingly. Thus, the philosophy of seismic design is to obtain a no-collapse structure rather than no-damage structure

2.6. Codes followed

- Indian Standard, Code of Practice for Plain and Reinforced Concrete IS 456:2000.
- Design Aids for Reinforced Concrete to IS 456:2000, SP-16.
- Criteria for Earthquake Resistant Design of Structures IS 1893:2016.
- Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic forces Code of Practice IS 13920:2016.
- Code of practice for Design loads IS 875 part-I (Dead load).
- Code of practice for Design loads IS 875 part- II (Imposed load).

3. METHODOLOGY

3.1. Planning Phase

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

3.1.1. Functional Planning

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

3.1.2. Structural Planning

The structural arrangement of building is chosen so as to make it efficient in resisting vertical and horizontal load. The material of the structure for construction should be chosen in such a way that the total weight of structure will be reduced so that the structure will have less inertial force (caused during earthquake). The regular geometrical shape building will yield economical structures and is analyzed and designed as per the guidelines of IS1893 (part1):2016. Horizontal and vertical irregularities in geometry and load must be avoided as far as possible.

3.2. Load Assessment

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

3.2.1. Gravity load

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

i. IS 875 (part I):1987 Dead Loads
ii. IS 875 (part II):1987 Imposed Loads

3.2.2. Lateral load

Lateral load includes wind load and earthquake load. Wind load acts on the elevation and roof level while an earthquake act over the entire structure. Wind load calculation is based on IS 875 (part III):1987 and earthquake on IS 1893 (part I):2016. The dominant load is taken into consideration for design.

3.3. Preliminary Design

Before proceeding for load calculation, preliminary size of slabs, beams and columns and the type of material used are decided. Preliminary design of structural member is based on the IS Code provisions for slab, beam, column, wall, staircase and footing of serviceability criteria for deflection control and failure criteria in critical stresses arising in the sections at ultimate limit state i.e. Axial loads in the columns, Flexural loads in slab and beams, etc. Appropriate sizing is done with consideration to the fact that the preliminary design based on gravity loads is required to resist the lateral loads acting on the structure. Normally preliminary size will be decided considering following points:

- Slab: The thickness of the slab is decided on the basis of span/d ratio assuming appropriate modification factor.
- Beam: Generally, width is taken as that of wall i.e. 230 or 300 mm. The depth is generally taken as 1/12-1/15 of the span.
- Column: Size of column depends upon the moments from the both direction and the axial load. Preliminary Column size may be finalized by approximate calculation of axial load on tributary area factored to consider the effect of moment and considering a reasonable percentage of reinforcement steel bars.

3.4. Idealization of structure

3.4.1. Idealization of support

It deals with the fixity of the structure at the foundation level. In more detail terms, this idealization is adopted to assess the stiffness of soil bearing strata supporting the foundation. Although the stiffness of soil is finite in reality and elastic foundation design principles address this property to some extent, our adoption of rigid foundation overlooks it. Elastic property of soil is addressed by parameters like Modulus of Elasticity, Modulus of Subgrade reaction, etc.

3.4.2. Idealization of load

The load acting on the clear span of a beam should include floor or any types of load acting over the beam on the tributary areas bounded by 45^0 lines from the corner of the panel i.e. Yield line theory is followed. Thus, a triangular or trapezoidal type of load along with uniformly distributed loads act on the beam.

3.4.3. Idealization of structural system

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

3.5. Modeling and Analysis of structure

3.5.1. Salient Features of ETABS 2019

ETABS 2019 represents one of the most sophisticated and user-friendly release of ETABS SERIES of computer programs. Creation and modification of the model, execution of the analysis, and checking and optimization of the design are all done through this single interface. Graphical displays of the results, including real-time display of time-history displacements are easily produced.

The finite element library consists of different elements out of which the three-dimensional frame element was used in this analysis. The Frame element uses a general, three-dimensional, beam-column formulation which includes the effects of biaxial bending, torsion, axial deformation, and biaxial shear deformations.

Structures that can be modeled with this element include:

- Three-dimensional frames
- Three-dimensional trusses
- Planar frames
- Planar grillages
- Planar trusses

A frame element is modeled as a straight line connecting two joints. Each element has its own local coordinate system for defining section properties and loads, and for interpreting output. Each frame element may be loaded by self-weight, multiple concentrated loads, and multiple distributed loads. End offsets are available to account for the finite size of beam and column intersections. End releases are also available to model different fixity conditions at the ends of the element. Element internal forces are produced at the ends of each element and at a user specified number of equally-spaced output stations along the length of the element. Loading options allow for gravity, thermal and pre-stress conditions in addition to the usual nodal loading with specified forces and or displacements.

The building is modeled as a 3D bare frame with slabs. Results from analysis are used in design of beams and columns only (i.e., linear elements). Joints are defined with constraints to serve as rigid floor diaphragm and hence slabs are designed manually as effect of seismic load is not seen on slab. The linear elements are also designed primarily by hand calculation to familiarize with hand computation and exude confidence where we are unable to trust fully on design results of ETABS. This has been done as we are quite unfamiliar with fundamentals of FEM analysis techniques based on which the software package performs analysis and gives results. As we are working with a computer-based system, the importance of data input is as important as the result of output derived from analysis. Hence with possibility of garbage- in-garbage-out, we need to check our input parameters in explicit detail.

Material properties are defined for elements in terms of their characteristic strength i.e. M25 for slabs, beams and M25 for columns. Also, section properties are defined as obtained from preliminary design. Loading values are input as obtained from IS 875. Loading combination based on IS 875 (part V):1987 and IS 1893 (part 1):2016 for ultimate limit state and IS

456:2000 for serviceability limit state is prepared. An envelope load case of all load combinations is prepared to provide us with the envelope of stresses for design of beams.

3.6. Design and Detailing

3.6.1. Limit State Method of Design for Reinforced Concrete Structures

Design of Reinforced Concrete Members is done based on the limit state method of design following IS 456:2000 as the code of practice. The basic philosophy of design is that the structure is designed for strength at the ultimate limit state of collapse and for performance at limit state of serviceability. A check for these two limit states is done based on code of practice to achieve safe, economic and efficient design.

3.6.2. Detailing Principle for Reinforced Concrete Structures

Ductile Detailing of Reinforced Concrete Structure

Ductile detailing of reinforced concrete structure is done based on IS 13920:2016 for the provision of compliance with earthquake resistant design philosophy. Special consideration is taken in detailing of linear frame elements (BEAMS & COLUMNS) to achieve ductility in the concrete to localize the formation of plastic hinge in beams and not columns to assurethe capacity theory of STRONG COLUMN | WEAK BEAMS.

Detailing provisions of IS 13920:2016 and IS 456:2000 are used extensively for these members to comply with the relevant codes of practice.

Ordinary Detailing of Reinforced Concrete Structure

Detailing of Substructures (MAT FOUNDATION) is done based on the design requirement of IS 456:2000. Reinforcement Detail drawings for typical representative elements are shown in detail on structural drawings. Thus, the detailing rules from different handbooks are followed along with enlisted codes of practice and then rebar arrangement is finalized. In this way, detailing of reinforcement is achieved to required specifications by code.

3.6.3. Codal References

The project report has been prepared in complete conformity with various stipulations in Indian Standards, Code of Practice for Plain and Reinforced Concrete IS 456:2000, Design Aids for Reinforced Concrete to IS 456:2000(SP-16), Criteria Earthquake Resistant Design Structures

IS 1893 (Part 1):2016, Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces- Code of Practice IS 13920:2016. Use of these codes have emphasized on providing sufficient safety, economy, strength and ductility besides satisfactory serviceability requirements of cracking and deflection in concrete structures. These codes are based on principles of Limit State of Design.

3.7. Drawings

As specified in the requirement of the project assignment, the report also includes the following drawings:

- Architectural Plan of Typical floors and Elevation of the building.
- Detailed Structural drawing of full size beam, full size column, slab, staircase and mat foundation. Longitudinal and Cross section drawings are made to represent specifically the proper detailing of rebar in individual elements, at beam column joints, at the end support of slabs, in staircase and in the foundation.

3.8. Organization and Preparation of Project Work Report

The project work report is prepared in the standard format availed by the Department of Civil Engineering.

This project report has been broadly categorized into eight chapters; summary of each chapter is mentioned below:

Chapter 1: Introduction

This chapter gives an overview of the project as a whole.

Chapter 2: Literature review

The chapter explains the basic design philosophy presented with chapter 1 along with the codes referred. Different loads, their estimation and combination are described in this part.

Chapter 3: Methodology

This chapter presents the method used in execution of project from initiation till completion with brief details of processes.

Chapter 4: Functional and Structural Planning of the Building

The first part of this chapter presents the functional planning of building with reference to architectural provisions of space, light, ventilation, etc. for specific areas of the building.

The second part deals with the structural planning for seismic resistant design andjustification of number of beams and columns, frames, their orientation/ arrangement.

Chapter 5: Load Assessment and Preliminary Design

In this chapter, justification of material selection, material characteristics are shown. It also includes calculation of preliminary design of slabs, beams, column, truss and other structural components. It also includes idealization of loads and load assessments with load combinations.

Chapter 6: Idealization and Analysis of Structure

This chapter includes the details of idealization of structure and idealization of load for modeling in computer. It comprises the analysis result obtained from ETABS analysis and the tabular presentation of storey drift calculation. Critical responses are also tabulated.

Chapter 7: Design and Detailing

It deals with the earthquake resistance design of beams, columns, slabs and footings considering limit state of collapse and serviceability. Design is further influenced by the useof codes pertinent to earthquake resistant design of building structures. Manual design of structural elements is done from the analysis results of ETABS using IS 456:2000 and compared with the design given by ETABS. However, consideration for earthquakeresistant design is incorporated in manual design with reference to IS 1893 (part 1):2016 with ductile detailing rules governed by IS 13920:2016.

Detailing of structures with ordinary detailing rules for area elements and ductile detailing for linear elements is done conforming to IS 456:2000 and IS 13920:2016 respectively.

Chapter 8: Drawings

Drawing includes architectural drawing of the building and the structural drawings with correct detailing as stated in the assignment.

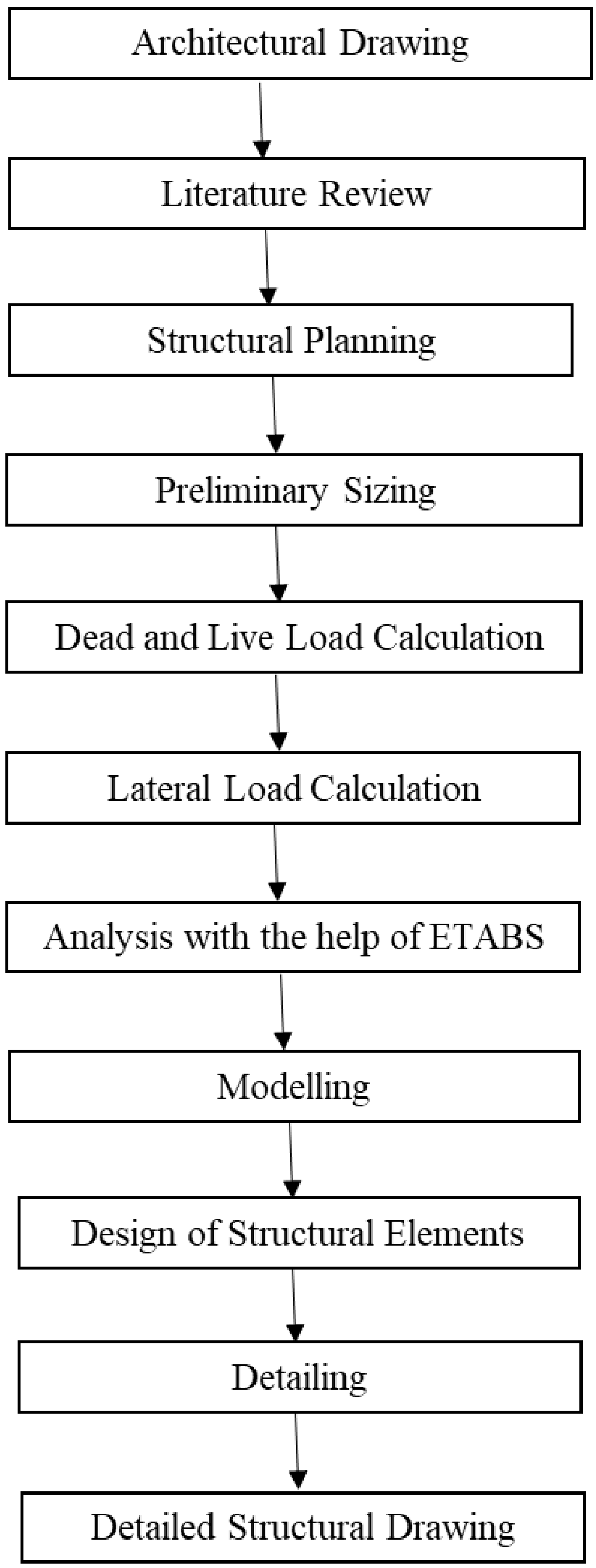


Fig 3.1: Flow Chart of Methodology

4. FUNCTIONAL AND STRUCTURAL PLANNING OF BUILDING

4.1. Functional Planning

Functional planning of the building is governed by the client requirement, site conditions, provincial by-laws, etc. It is carried out in two steps in detail as below.

4.1.1. Planning of Space and Facilities

The layout of the building plan is prepared and finalized as per client requirements.

For vertical mobility, open-well staircase is provided.

Washroom for ladies and gents are provided in each floor of the building.

All other functional amenities are only used for load assessment and ignoring their aesthetic and functional planning which is beyond the scope of this project.

4.1.2. Architectural planning of 3D framework of Building

The building to be designed is a multistory RCC apartment building. For reinforced concrete frames, a grid layout of beams is made considering the above functional variables. In most of grid intersection points, columns are placed.

This framework for each floor is then utilized with positioning of masonry wall between the columns. Separation of individual spaces is done with masonry wall.

A total of 35 numbers of columns are provided. The overall dimension of the building is 36.27m by 29.08m without any provision of expansion joint, the justification for which is presented in detail in following subheadings.

Arrangement of beams is done along the grid interconnecting the columns at grid intersections. With this framework of beam and column having RCC slab in the floor and roof, architectural planning of the building is complete and 3D framework is thus complete.

4.1.3. Compliance to Municipal By-Laws

All the functional planning of building is done conforming to Municipal By-Laws of Kathmandu Metropolitan City for Urbanized and urbanizing localities. Specific points in the by-laws that need special focus of designer are:

- Type of Building
- Land Area Available

- Floor Area Ratio (FAR)
- Maximum Ground Coverage (GCR)
- Maximum height of the building, etc.

These variables are also dictated by specific location of site in different wards.

Building height is a restricted by the position of widest road along the site and the light plane of 63.5^0 between the top of the building and the centerline of the road. A more comprehensive knowledge about such provisions can be referred in detail at the referenced publication.

This completes the overall functional planning of the building with coverage of maximum number of variables in preliminary stage planning.

4.2. Structural Planning

4.2.1. Structural System

The building system is functionally and legally planned appropriately as mentioned in detail in previous section. Our focus in the current section is the structural orientation of the building in horizontal and vertical plane avoiding irregularities mentioned in IS 1893 (part 1):2016.

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

Structural planning of the building is done over the proposed architectural plan for providing and preserving the structural integrity of the entire building. This is dealt in detail for each structural element with necessary justification.

Finalized structural plan is then employed for load assessment and preliminary design of structural members for modeling in ETABS.

4.2.2. Planning of Beam-Column Frame

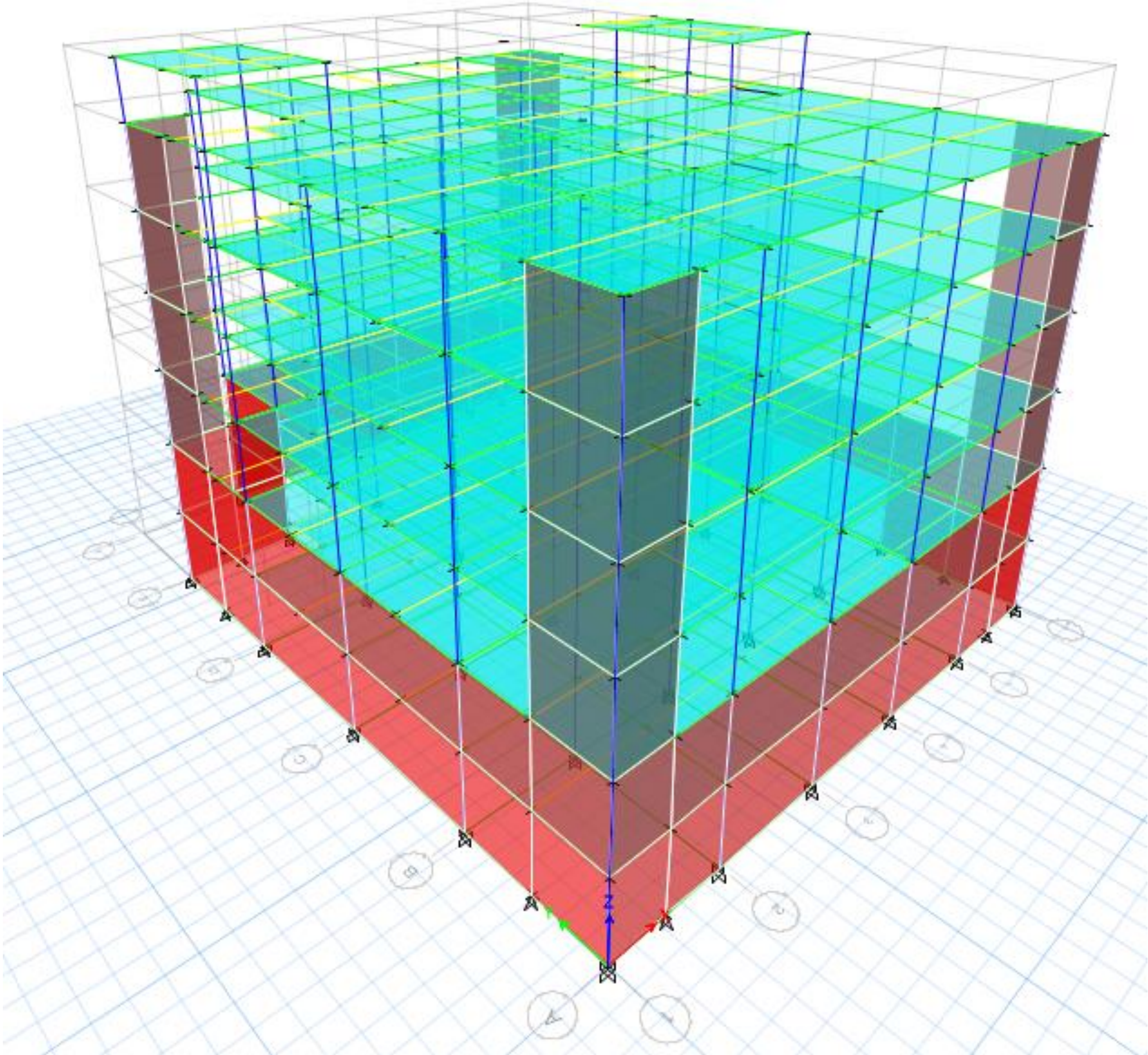
The numbers of beams and columns in the plan of building are obtained after careful planning of spaces to meet client requirements. Beams are provided varying in span.

Columns are 35 in number in each storey. Columns are of sizes 800*800 mm square. The floor to floor height of the building is 3.9624m (13ft.).

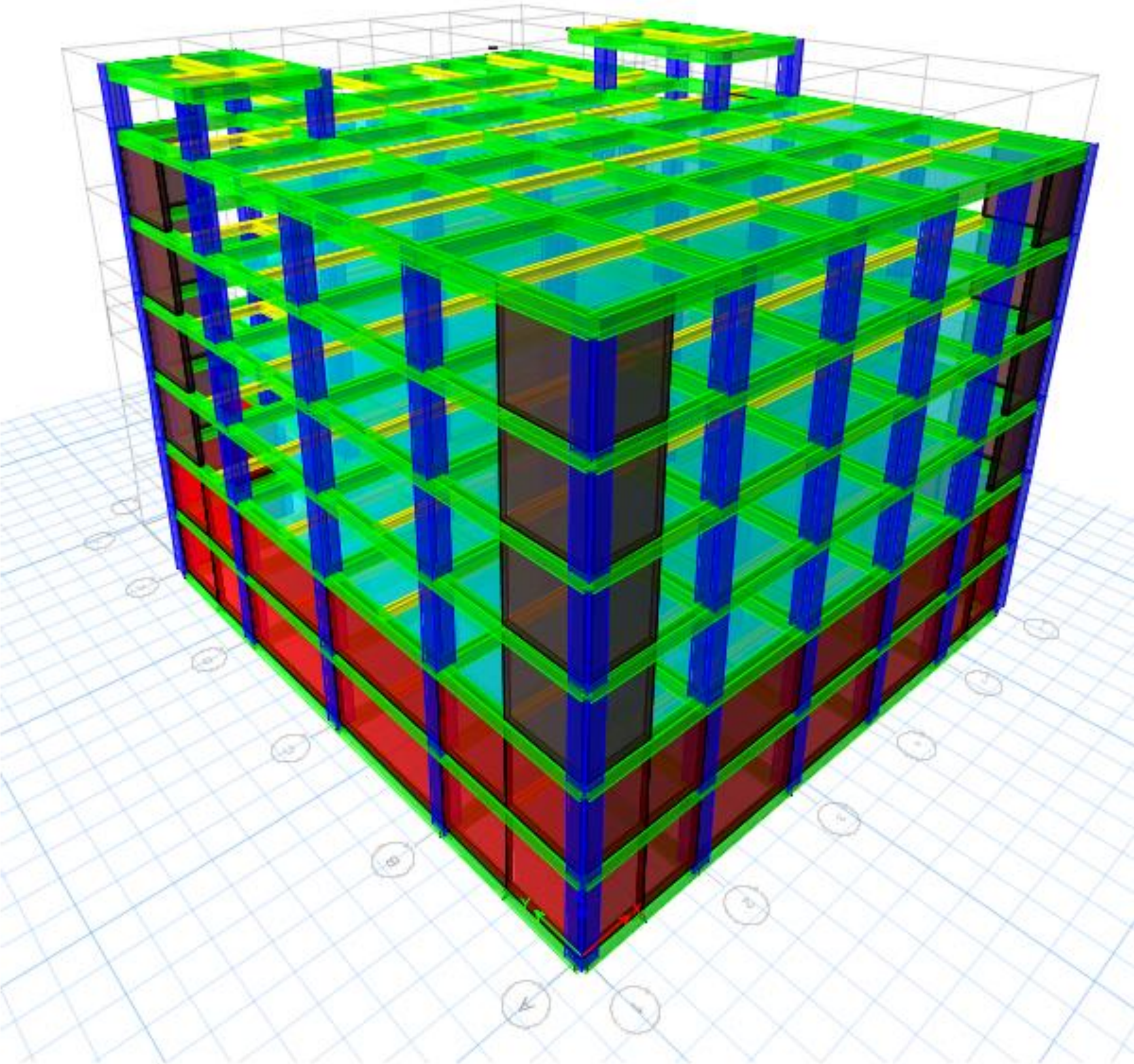
The orientation of beams and column grid in plan is in rectangular shape. This is done with a point of view of conforming to earthquake resistant design as prescribed by IS 1893 (Part 1): 2016. The same principle is followed in vertical planning of the building along both directions of layout.

Thus, the bare frame model of the building can now be created in ETABS with the structural plan and elevation. The area element occupying the floor space is also modeled in the program. The image generated from ETABS is shown below.

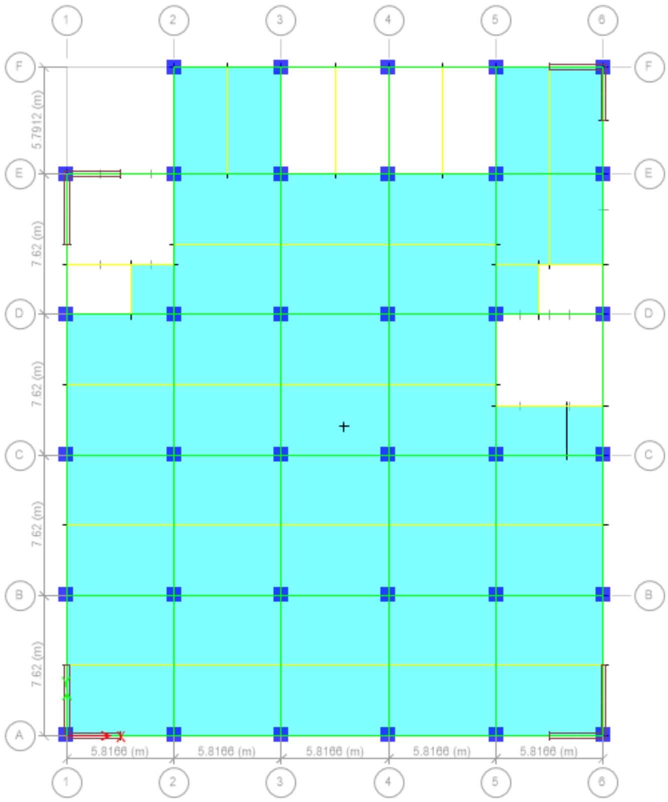
Completion of Structural Planning is achieved with numeration of frames for identification of building elements in the course of design. Sketch of these plans with appropriate nomenclature of frames is shown below.



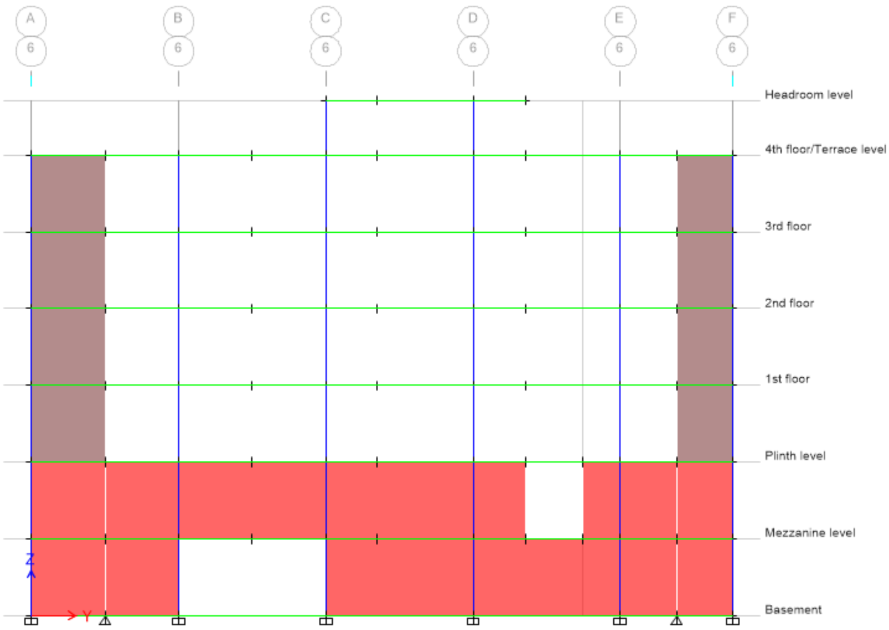
3D View



Extruded View



Plan



Elevation

5. LOAD ASSESSMENT AND PRELIMINARY DESIGN

5.1. Preliminary Design

The preliminary sizing of structural elements was carried out based on deflection controlcriteria and approximate loads obtained using the tributary area method.

The gravity loads on the structural elements are taken as per IS 875 Part I (dead loads) and IS 875 Part II (imposed loads) Table 1.

The unit weights of materials taken for the calculation of dead load of the structure are as follows.

S.N.	Material Used	Unit Weight	Type of Member
1.	Concrete	25kN/m^3	Beams, Columns, Slabs.
2.	Bricks	19.2kN/m^3	Infill & Partition Walls
3.	Floor finishing	1.5 kN/m^2	Load on Slab

The imposed load on the floors and roof have been taken as follows.

S.N.	Live Loads on Specified Spaces	Intensity of Load As per IS-875:1987; I, II	Member Loaded
1.	Retail Shops	4 kN/m^2	Live loads from buildingare acted on floor slabs, roof slabs and staircase slab.
2.	Toilets	2 kN/m^2	
3.	Corridors, passages, staircases including fire escapes and lobbies	4 kN/m^2	
4.	Corridors, passages, staircases subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5 kN/m^2	

5.2. Preliminary Design of Slab

Preliminary sizing of the slabs is worked out as per the limit state of serviceability (deflection) consideration by conforming to IS456:2000 Clause: 23.2.1.

The critical slab is one for which the ration of longer span to shorter span is maximum. Therefore, taking slab of size 7.62m x 5.8166m (25'00" x 19'01").

Longest span (ly) = 7.62m

Shortest span (lx) = 5.8166m

Then, Ratio of long to short span (ly/lx) = 1.31 < 2

So, two-way slab is designed.

According to Cl. 23.2 of IS 456:2000,

Deflection Control Criteria is:

(span/depth) < $\alpha\beta\gamma\lambda\delta$ where,

α = 26 for both end continuous

β =1 for span<10m

For modification factor,

Fs = 0.58×fs× (area of steel required/area of steel provided) Assuming area of steel required tends to or is equal to area of steel provided, so

Fs = 0.58×500×1 = 290 N/mm2

γ=1.4 for 0.2% of tensile reinforcement (from Fig.4 of IS456:2000)

δ = 1 for 0% of compression reinforcement (from Fig.5 of IS456:2000)

λ =1 for rectangular section

Bending occurs in shorter span. So,

(shorter span/depth) < $\alpha\beta\gamma\lambda\delta$

(5816.6/d) < 26×1×1.4×1×1 (=36.4)

d = 159.79 mm

Since the depth is greater than 150mm, it will lead to higher seismic mass so divide the slab by providing secondary beam.

For secondary beam,

Providing beam in the direction perpendicular to the longer span.

Longest span (ly) = 5.8166m

Shortest span (lx) = 3.81m

(lx/d) < 36.4

(3810/d)<36.4

d= 104.67mm

Adopt depth of slab (D) = 125mm.

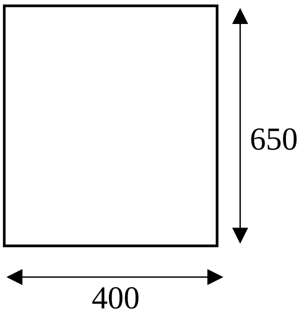
Provide clear cover of 20mm and bar dia. 12 mm.

Then, d = D – cc – bar dia. / 2

= 125-20-12/2 = 99mm

5.3. Preliminary Design of Beam

For Primary Beam,



Longest span of beam (l) = 7.62m = 7620mm

Overall depth (D) = l/10 to l/15, taking l/12

=7620/12 = 635mm

Adopt, D = 650mm

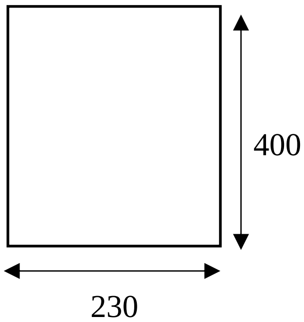
Effective depth (d) = D – cc - bar dia. / 2

= 650 – 25 – 20/2 = 615mm

Adopt, width (b) = 400mm

Width/Depth = 0.615 > 0.3, ok (IS13920-2016: Cl6.1.1)

For Secondary Beam,



Longest span of beam (l) = 5.8166m = 5816.6mm

Overall depth (D) = l/10 to l/15, taking l/15

=5816.6/15 = 387.77mm

Adopt, D = 400mm

Adopt, width (b) = 230mm

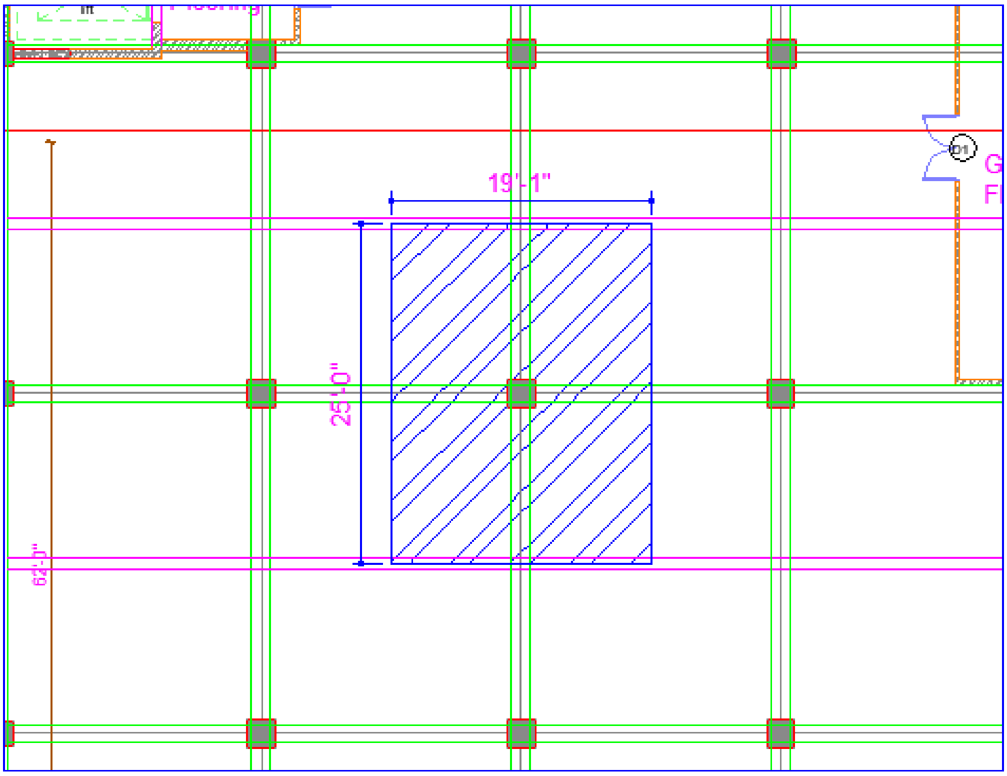
Width/Depth = 0.575 > 0.3, ok (IS13920-2016: Cl6.1.1)

This is preliminary design of the beam, so we have taken the above-mentioned dimension of beam. However, this depth may not be sufficient, during such case, we will change the depth at detailed design.

5.4. Preliminary Design of Column

In the compression member i.e., columns, the cross section is worked out from the net vertical axial load on the column lying in the basement floor assuming suitable percentage of steel. The net vertical axial load on each column is worked out from the factored dead load and live load on the tributary area, which is taken as half of the slab areas adjacent to the column under consideration. The load is increased by 30% for the earthquake load to give the net vertical load.

Tributary area = 7.62m*5.8166m



Tributary Area for Column

Typical dead load on all floors:

Weight of slab = 25*(7.62*5.8166)*0.125 = 138.51 kN

Weight of 30mm screed = 24*0.030*(7.62*5.8166) = 31.912 kN

Weight of primary beam = 25*(0.650*0.400)*(7.62+5.8166) = 87.34 kN

Weight of secondary beam = 25*(0.400*0.230)*5.8166 = 13.378 kN

Typical storey dead load (SDL) = 138.51+31.912+87.34+13.378 = 271.14 kN

Load calculation for 3rd floor column:

Storey dead load (SDL) = 271.14 kN

Assuming column of size 800mm*800mm

Weight of column on 3rd floor = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from terrace, accessible) = 1.75*(7.62*5.8166) = 77.56 kN

Total load on 3rd floor column = 271.14+52.998+77.56 = 401.698 kN

Load calculation for 2nd floor column:

Load from 3rd floor = 401.698 kN

Storey dead load (SDL) = 271.14 kN

Weight of column on 2nd floor = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from 3rd floor) = 4*(7.62*5.8166) = 177.29 kN

Total load on 2nd floor column = 903.126 kN

Load calculation for 1st floor column:

Load from 2nd floor = 903.126 kN

Storey dead load (SDL) = 271.14 kN

Weight of column on 1st floor = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from 2nd floor) = 4*(7.62*5.8166) = 177.29 kN

Total load on 1st floor column = 1404.554 kN

Load calculation for plinth level column:

Load from 1st floor = 1404.554 kN

Storey dead load (SDL) = 271.14 kN

Weight of column on plinth level = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from 1st floor) = 4*(7.62*5.8166) = 177.29 kN

Total load on plinth level column = 1905.982 kN

Load calculation for mezzanine level column:

Load from plinth level = 1905.982 kN

Storey dead load (SDL) = 271.14 kN

Weight of column on mezzanine level = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from plinth level) = 4*(7.62*5.8166) = 177.29 kN

Total load on mezzanine level column = 2407.41 kN

Load calculation for basement level column:

Load from mezzanine level = 2407.41 kN

Storey dead load (SDL) = 271.14 kN

Weight of column on mezzanine level = 25*0.8*0.8*3.3124 = 52.998 kN

Live Load (from mezzanine level) = 5*(7.62*5.8166) = 221.61 kN

Total load on basement level column = 2953.158 kN

Factored load = 1.5*2953.158 = 4429.737 kN

Increasing by 30% for earthquake,

Design load (P_u) = 1.3*4429.737 = 5758.6581 kN

For axially loaded short column (From Code IS 456:2000 Cl 39.3)

$P_u = 0.4 * f_{ck} * A_c + 0.67 * f_y * A_s$

Taking M25 grade concrete, f_{ck} = 25 N/mm^2 and taking Fe500 grade rebar, f_y = 500 N/mm^2

Considering 2% reinforcement bar,

Area of rebar, A_s =2% of gross area, $A_g = 0.02A_g$ and A_c = 98% of $A_g = 0.98\ A_g$

Then,

$5758.6581 * 1000 = 0.4 * 25 * 0.98A_g + 0.67 * 500 * 0.02A_g$

Hence, gross area, A_g = 349009.5818 mm^2

Assuming square column, Column Size= 590.77 mm < 800mm, ok

Adopt column size of 800 mm X 800 mm

5.5. Load Assessment

Assessment of loads on the structural system thus planned is based on IS 875(part I-V):1987 and IS 1893 (part I):2016. The former code of practice is for design loads on building and structures other than earthquake loads while the latter explicitly describes design earthquake load on the building structure.

Load assessment is divided into two categories as aforementioned. However, a detailed acknowledgement to each referred code and the computation based on those codes are done in this section of the report.

Lumping is done with beams, slabs at one floor level added with column and wall loads distributed equally in both floors (upper and lower). These computations along with calculation of center of mass and center of stiffness from the preliminary design sizes are shown below.

Calculations of Gravity Load Acting on the Structural Elements are shown below.

5.5.1. Gravity Load Computation

Terrace Level

a. **Roof Slab**

Load from Slab = 4.625 kN/m^2

Imposed Load = 1.75 kN/m^2

b. **Beam**

Weight/m of Primary Beam = 6.5 kN/m

Weight/m of Secondary Beam = 2.3 kN/m

c. **Column**

Weight of Square Column = 45.517 kN

d. **Wall**

Weight/m of Wall = 9.692 kN/m

Reduced Weight/m of Wall = 6.785 kN/m

e. **Parapet wall**

Weight/m of parapet wall = 2.575 kN/m

Intermediate Level

a. **Roof Slab**

Load from Slab = 4.625 kN/m^2

Imposed Load = 4 kN/m^2

b. **Beam**

Weight/m of Primary Beam = 6.5 kN/m

Weight/m of Secondary Beam = 2.3 kN/m

c. **Column**

Weight of Square Column = 63.398 kN

d. **Wall**

Weight/m of Wall = 14.627 kN/m

Reduced Weight/m of Wall = 10.239 kN/m

e. **Parapet wall**

Weight/m of parapet wall = 2.575 kN/m

Calculation of weight of building elements for determination of seismic weight for design with size of the elements modified after ETABS analysis conforming to storey drift.

BEAM

The dimension of main beam from preliminary design is 400mm x 650mm. The total length of main beam spanning in an intermediate floor level is different from that in the roof level.

Main Beam

Size of beam = 400mm x 650mm

Unit weight of concrete = 25 kN/m^3

For 'L' span of beam, weight of beam = 0.650*0.400*L*25 kN

Secondary Beam

Size of beam = 400mm x 230mm

Unit weight of concrete = 25 kN/m^3

For 'L' span of beam, weight of beam = 0.230*0.400*L*25 kN

COLUMN

Column dimensions from preliminary design are 800mm x 800mm.

Height of a single column is taken from mid height of lower storey column to mid height of upper storey column. This height is 3.9624m for a storey.

Height of Column = 3.9624m

Size of Column = 800mm x 800mm

Unit Weight of Concrete = 25kN/m^3

Weight of one column = 63.398 kN

BRICK MASONRY WALL

Weight per m of wall = 14.627 kN/m

Reduced weight per m of wall = 10.239 kN/m

5.5.2. Lateral Load Assessment

Earthquake Load on the Super Structure

Seismic weight is the total dead load plus appropriate amount of specified imposed load. While computing the seismic load weight of each floor, the weight of columns and walls in any story shall be equally distributed to the floors above and below the storey. The seismic weight of the whole building is the sum of the seismic weights of all the floors. It has been calculated according to IS 1893(Part I): 2016. The code states that for the calculation of the design seismic forces of the structure, the imposed load on roof need not be considered.

With the results of mass center and stiffness center calculation, we follow IS 1893(part 1):2016 to compute the base shear and the corresponding lateral forces.

Theory of Base Shear Calculation

According to IS 1893 (Part I): 2016 Cl. No. 6.4.2, the design horizontal seismic coefficient Ah for a structure shall be determined by the following expression $\mathbf{A_h = (Z/2)*(I/R)*(S_a/g)}$

Where,

Z = Zone factor given by IS 1893 (Part I): 2016 Table 3, Here for Zone V, Z = 0.36

I = Importance Factor, I = 1.5 for commercial building, given by IS 1893(Part I):2016 Table 8

R = Response reduction factor given by IS 1893 (Part I): 2016 Table 9, R = 5.0 for SMRF

Sa/g = Average response acceleration coefficient which depends on approximate fundamental natural period of vibration (Ta) and type of soil, from IS1893 (Part I):2016 Cl 6.4.2

Soil Type II (Medium and Stiff Soil) from Table 1.

In x-direction

d = 29.083m, h = 15.8496m

For building with RC structural wall,

$$Ta = \frac{0.075h^{0.75}}{\sqrt{Aw}} \geq \frac{0.09h}{\sqrt{d}}$$

Ta = 0.09*15.8496/√29.083 = 0.2645sec

In y-direction

d = 36.2712m, h = 15.8496m

For building with RC structural wall,

$$Ta = \frac{0.075h^{0.75}}{\sqrt{Aw}} \geq \frac{0.09h}{\sqrt{d}}$$

Ta = 0.09*15.8496/√36.2712 = 0.2368sec

Therefore, Sa/g = 2.5sec for 0.1s<T<0.55s and soil type II from IS1893 (Part I):2016 Cl 6.4.2
The value of design horizontal seismic coefficient is

$$\boldsymbol{A_h = \frac{Z \times I \times S_a}{2 \times R \times g}}$$

$$= \frac{0.36 \times 1.5 \times 2.5}{2 \times 5}$$

=0.135

According to IS 1893 (Part I):2016 Cl. No. 7.2.1 the total design lateral force for design seismic base shear (V_B) along any principle direction is given by

$V_B = A_h * W$

Where, W = Seismic weight of the building = 63881.52 kN

V_B = 0.135 ∗ 63881.52 = 8624 kN

According to IS 1893 (Part I): 2016 Cl. No. 7.6.3 the design base shear (V_B) computed above shall be distributed along the height of the building as per the following expression:

$$\boldsymbol{Q_i = \frac{W_i {h_i}^2}{\sum W_i {h_i}^2} \times V_B}$$

Where,

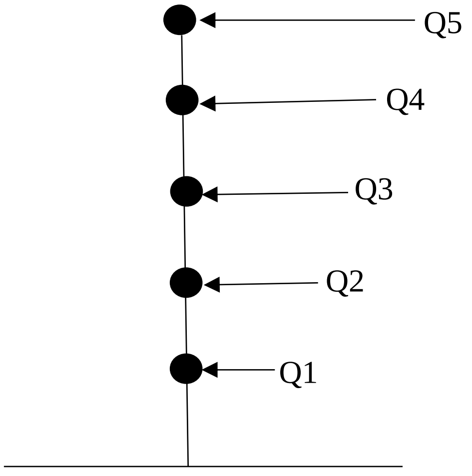
Qi = Design lateral force at floor i

Wi= Seismic Weight of floor i

hi = Height of floor i measured from base

n = No. of stories in the building

Distribution of base shear as lateral loads Qi:



Calculation for seismic weight and lateral forces:

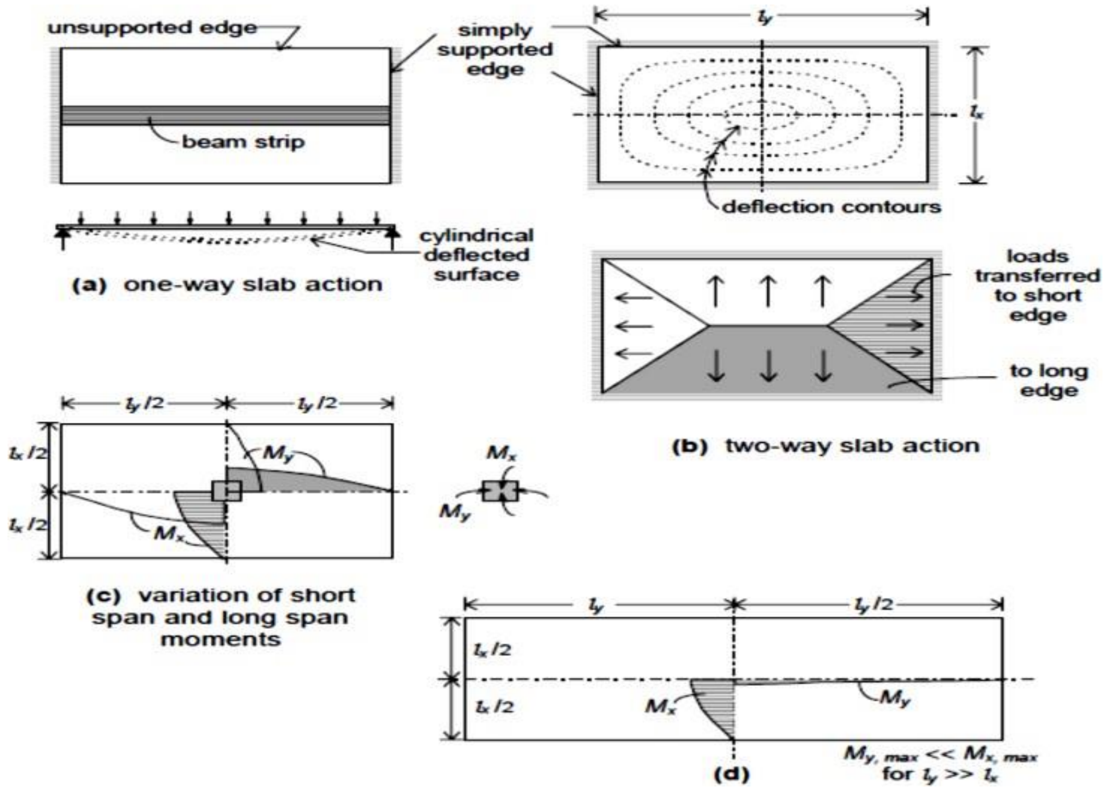
Storey	Slab, kN	Beam, kN	Brick Wall, kN	RCC Wall, kN	Column, kN	S.Beam, kN	Parapet, kN	Total DL ,kN
Headroom	536.51	384.52	0.00	0.00	0.00	75.30	0.00	996.33
4th	4649.82	2473.36	605.20	0.00	364.13	344.59	305.21	8742.32
3rd	4649.82	2473.36	1528.44	558.91	2218.94	344.59	0.00	11774.07
2nd	4649.82	2473.36	1528.44	558.91	2218.94	344.59	0.00	11774.07
1nd	4649.82	2473.36	1528.44	558.91	2218.94	344.59	0.00	11774.07
Plinth	4649.82	2473.36	1528.44	558.91	2218.94	344.59	0.00	11774.07

Storey	Total DL, kN	Total LL, kN	W_i, kN	h_i, m	$W_i h_i^2$	Q, kN_i
Headroom	996.33	0.00				
4th	8742.32	0.00	8742.32	15.85	2196156.53	3624.00
3rd	11774.07	2010.73	13784.80	11.89	1947868.33	3214.29
2nd	11774.07	2010.73	13784.80	7.92	865719.26	1428.57
1nd	11774.07	2010.73	13784.80	3.96	216429.81	357.14
Plinth	11774.07	2010.73	13784.80	0.00	0.00	0.00
		$\sum W_i$	**63881.52**	**$\sum W_i hi^2$**	**5226173.93**	

5.6. Idealization of load and load diagram

Idealization of loads acting on the structure is assessed with respect to the application of load and transfer of load in the elements separately. These idealizations are briefly explained in details for individual elements with necessary load diagrams.

5.6.1. SLABS



Loads acting on the slabs are idealized to act uniformly all over the entire area of the slab. This load is then idealized to be transferred uniformly to the frame by tributary method as explained in IS 456:2000. For rectangular slabs, Coefficient Method can be followed for analysis and design. Strip loads/ concentrated loads acting on the slabs are analyzed by Piguead's Method for evaluation of responses.

5.6.2. BEAMS

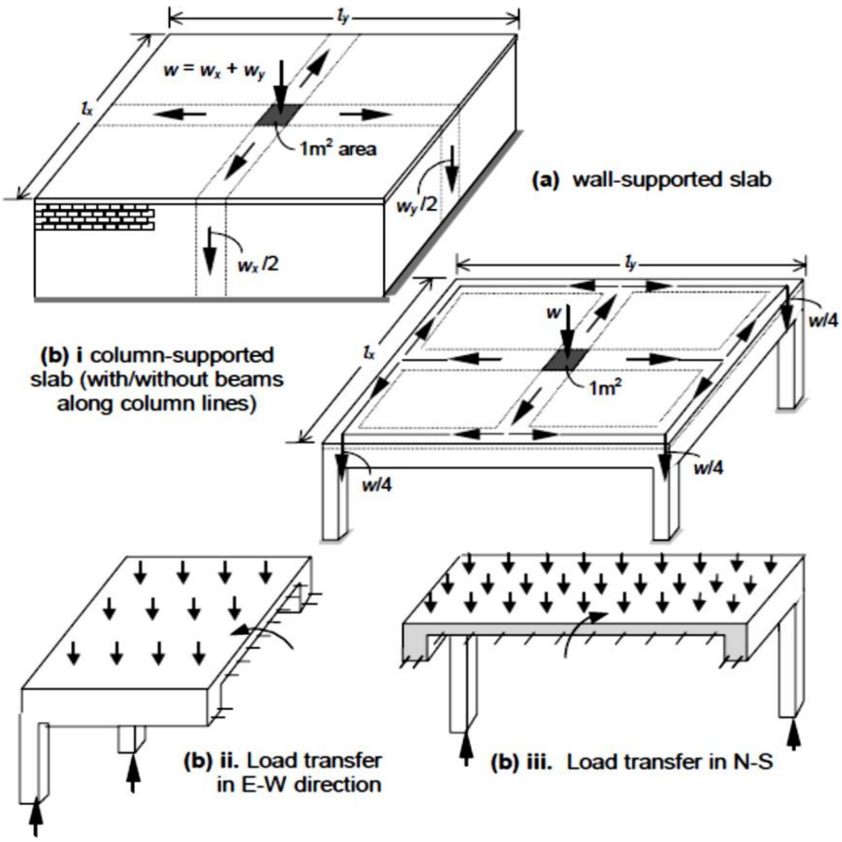
Idealization of self-weight of the RCC beam is done as uniformly distributed load acting along the centerline of the beam in the direction of gravity. Loads distributed from the slabs are however acting as distributed loads that may be uniform or varying as shown in the abovefigure in beams supporting the slab along the short and long edge.

5.6.3. COLUMNS

Thus, depicted in the above figures are the idealizations of loads transferred from slabs to beams to columns. This load in our structural plan transfers through a vertical load path to the mat foundation.

This completes the idealization of loads with load diagrams.

Load idealizations for wall and column supported slabs is shown in the figure below



6. IDEALIZATION AND ANALYSIS OF STRUCTURE

6.1. Idealization of Structure

Idealization of structure can be defined as the introduction of necessary constraints/restraints in the real structure as postulates to conform the design of this structure within the domain of available theories assuring required degree of performance to some probabilistic measure.

This type of idealization helps us constrain infinite number of design variables to those that we can address properly with the available design philosophies. In design of RCC structures, chiefly two idealizations are employed namely:

- Idealization of Load
- Idealization of Structure

Idealization of load has been dealt in detail in the previous chapter with necessary load diagrams.

The idealization of utmost importance however, is the idealization of structure. This idealization imposes restraints/constraints to those variables which we are unable to address properly otherwise. Imploring the details of these idealizations, we need to start at the elemental level. Thus, we process with idealization of supports, slab elements, staircase element, beam and column element and the entire structural system.

6.1.1. Idealization of Supports

In general, idealization of support deals with the assessment of fixity of structure at the foundation level.

In more details terms, this idealization is adopted to assess the stiffness of soil bearing strata supporting the foundation. Although the stiffness of soil is finite in reality and elastic foundation design principles address this property to some extent, out adoption of rigid foundation overlooks it. Elastic property of soil is addressed by parameters like Modulus of Elasticity, Modulus of Subgrade reaction, etc. addressing all these parameters are beyond the scope of this project. This is where idealization comes into play, equipping us with the simplified theory of rigid foundation in soil.

As we have designed mat foundation as substructure, idealizations for RCC framed structure supported over the mat are used. This idealization is used in defining the fixed support of our building frame for modeling and analysis. For buildings with basement walls or underground storey, the idealization depends upon the connection of basement wall with the superstructure.

6.1.2. Idealization of Slab

Idealization of slab element is done in earthquake resistant design to perform as a rigid floor diaphragm. This idealization is done for slab to behave as a thin shell element subjected to out-of-plane bending only under the action of gravity loads. Due to infinite in-plane stiffness of the shell element, lateral loads are not taken by the floor slab and hence resisted completely by the columns.

Idealization of slab element to thin plate member would have subjected the slab to behave as Kirchhoff's plate inducing out-of-plane bending which is beyond our scope at Bachelor's Level of Civil Engineering.

Hence such an idealized slab is then modeled in ETABS program for analysis.

6.1.3. Idealization of Staircase

Open-well staircase used in the building is idealized to behave as a simply supported slab in case of upper and lower flights and also in case of intermediate flight.

Detailing rules are then followed to address the negative bending moment that are induced on the joint of going and top flight in the staircase, the rigorous analysis of which is beyond our scope.

Staircase being an area element is also assumed not to be a part of the integral load bearing frame structure. The loads from staircase are transferred to the supports as vertical reactions and moments.

6.1.4. Idealization of Beam and Columns

Beam Column idealization is one of the most critical aspects of structural idealization to achieve the desired behavior of the overall integrated structure.

Beams and columns are idealized to behave as linear elements in 3D. Beam column joints in the structural planning are assumed to behave as perfectly rigid joints. In reality, perfect rigid joints do not exist. Effects of partial fixity can be addressed in modeling by rigorous analysis of sectional and material properties, which is beyond the limits of this project. Assumptions of rigid joints are also found to perform well in nature seen from years of practice.

Another idealization is addressing the section of main beam as rectangular in shape despite being integrally connected with the slabs. The flange portions of these beams when subjected to reversal of loading during earthquakes become ineffective in taking the tension induced in them and hence we ignore their contribution in design.

6.1.5. Idealization of the Structural System

After idealizing individual elements, we idealize the structural system in its entirety to behave as our theoretical approximation for first order linear analysis and corresponding design.

The building is idealized as unbraced space frame. This 3D space framework is modeled in the ETABS for analysis. Loads are modeled into the structure in several load cases and load combinations defined in the next section.

The building then, subjected to gravity and lateral loads are analyzed for necessary structural responses to design the members, the outputs of which are tabulated in later sections of this chapter.

Thus, idealization of individual structural elements and the entire structural system is complete to comply with our necessities of idealization for first order linear analysis.

6.2. Load Combination

Different load cases and load combination cases are considered to obtain most criticalelement stresses in the structure in the course of analysis. The wind load is not considered asa principal load case for the building as it is used only in design of Steel Roof Truss; insteadof wind load, earthquake load plays a significant role in the formation of load combinations. According to IS 875(Part V):1987, inclusive of amendments for partial live loadconsideration mentioned in IS 1893(Part 1):2016, the load combinations are divided into twoparts:

- Load Combinations for Limit State of Collapse
- Load Combinations for Limit State of Serviceability

6.2.1. Load Combinations for Limit State of Collapse

The basic load combinations for design considerations are:

i. 1.5(DL + LL)

ii. 1.2(DL + LL + ELx)

iii. 1.2(DL + LL - ELx)

iv. 1.2(DL + LL + ELy)
v. 1.2(DL + LL - ELy)
vi. 1.5(DL + ELx)
vii. 1.5(DL - ELx)
viii. 1.5(DL + ELy)
ix. 1.5(DL - ELy)
x. 0.9DL + 1.5 ELx
xi. 0.9DL – 1.5 ELx
xii. 0.9DL + 1.5 ELy
xiii. 0.9DL – 1.5ELy
xiv. 1.2(DL+%LL)

The above design combinations result in fourteen load combinations. The maximumstresses from these combinations are used in design of elements.

6.2.2. Load Combination for Limit State of Serviceability

The basic load combinations for serviceability consideration are:

i. DL + LL
ii. DL + ELx
iii. DL - ELx
iv. DL + Ely
v. DL - ELy
vi. DL + 0.8LL + 0.8ELx
vii. DL + 0.8LL - 0.8ELx
viii. DL + 0.8LL + 0.8ELy
ix. DL + 0.8LL - 0.8ELy

Load Combination for design of foundation is taken as combination of dead load and live load; modification for soil bearing capacity for earthquake load consideration is done according to IS 1893(Part 1):2016. Since the Codes of Practice for foundation design are based on Working Stress Method, the factored loads are converted to service loads and then the codal provisions are followed for design.

6.3. Analysis of Structure

The analysis of structure is carried out in a commercial computer software ETABS, the salient features of which are already explained in detail in methodology.

The results of analysis are used according to our necessities in designing representative beams and columns sections. A detailed manual design of these sample representative sections is presented with summary in the next chapter.

Immediate subsections show tabular data of Storey Drift Computation for one the 2D frames of the building in both the X and Y direction of its orientation in horizontal plane.

Sample output data from ETABS are also shown at the end of the chapter. These are only a representation of actual data extracted from ETABS and used for design purposes.

6.3.1. Storey Drift Computation from ETABS Analysis

Now that we have computed all the loads and developed all possible load combinations, we can model these loads in the building. Analysis is done and the value of inter-storey drift for serviceability condition is computed from absolute displacements for earthquake loads in both horizontal directions.

During the first run with our preliminary size of column, the inter-storey drift did not exceed the permissible value stated in Clause 7.11 of IS 1893(part 1):2016. Hence, resizing of columns was not done.

Thus, without changing the loading values final model was analyzed that was safe in storey drift.

The analyzed values of storey drift are tabulated below for the most vulnerable column line in X-direction (shorter direction) and verified.

Drift Check		
Storey	Drift ratio in X-Direction	Drift ratio in Y-Direction
Headroom level	0.00094	0.00092
4th floor/Terrace level	0.00149	0.00137
3rd floor	0.00161	0.00144
2nd floor	0.00150	0.00129
1st floor	0.00102	0.00085
Plinth level	0.00019	0.00017
Mezzanine level	0.00006	0.00005

Center of mass for plinth level, 1st, 2nd and 3rd floor

Grid No.		Descriptions	Load Calculations				Total Load (KN)	Centroid(m)		WY	WX
YY	XX		Unit Wt. (KN/m3)	Length (m)	Breadth (m)	Height (m)		Y	X		
Column											
1-A		Column	25	0.8	0.800	3.3124	52.998	0.000	0.000	0.000	0.000
1-B		Column	25	0.8	0.800	3.3124	52.998	7.620	0.000	403.848	0.000
1-C		Column	25	0.8	0.800	3.3124	52.998	15.240	0.000	807.696	0.000
1-D		Column	25	0.8	0.800	3.3124	52.998	22.860	0.000	1211.543	0.000
1-E		Column	25	0.8	0.800	3.3124	52.998	30.480	0.000	1615.391	0.000
2-A		Column	25	0.8	0.800	3.3124	52.998	0.000	5.817	0.000	308.270
2-B		Column	25	0.8	0.800	3.3124	52.998	7.620	5.817	403.848	308.270
2-C		Column	25	0.8	0.800	3.3124	52.998	15.240	5.817	807.696	308.270
2-D		Column	25	0.8	0.800	3.3124	52.998	22.860	5.817	1211.543	308.270
2-E		Column	25	0.8	0.800	3.3124	52.998	30.480	5.817	1615.391	308.270
2-F		Column	25	0.8	0.800	3.3124	52.998	36.271	5.817	1922.316	308.270
3-A		Column	25	0.8	0.800	3.3124	52.998	0.000	11.633	0.000	616.541
3-B		Column	25	0.8	0.800	3.3124	52.998	7.620	11.633	403.848	616.541
3-C		Column	25	0.8	0.800	3.3124	52.998	15.240	11.633	807.696	616.541
3-D		Column	25	0.8	0.800	3.3124	52.998	22.860	11.633	1211.543	616.541
3-E		Column	25	0.8	0.800	3.3124	52.998	30.480	11.633	1615.391	616.541

3-F	Column	25	0.8	0.800	3.3124	52.998	36.271	11.633	1922.316	616.541
4-A	Column	25	0.8	0.800	3.3124	52.998	0.000	17.450	0.000	924.811
4-B	Column	25	0.8	0.800	3.3124	52.998	7.620	17.450	403.848	924.811
4-C	Column	25	0.8	0.800	3.3124	52.998	15.240	17.450	807.696	924.811
4-D	Column	25	0.8	0.800	3.3124	52.998	22.860	17.450	1211.543	924.811
4-E	Column	25	0.8	0.800	3.3124	52.998	30.480	17.450	1615.391	924.811
4-F	Column	25	0.8	0.800	3.3124	52.998	36.271	17.450	1922.316	924.811
5-A	Column	25	0.8	0.800	3.3124	52.998	0.000	23.266	0.000	1233.082
5-B	Column	25	0.8	0.800	3.3124	52.998	7.620	23.266	403.848	1233.082
5-C	Column	25	0.8	0.800	3.3124	52.998	15.240	23.266	807.696	1233.082
5-D	Column	25	0.8	0.800	3.3124	52.998	22.860	23.266	1211.543	1233.082
5-E	Column	25	0.8	0.800	3.3124	52.998	30.480	23.266	1615.391	1233.082
5-F	Column	25	0.8	0.800	3.3124	52.998	36.271	23.266	1922.316	1233.082
6-A	Column	25	0.8	0.800	3.3124	52.998	0.000	29.083	0.000	1541.352
6-B	Column	25	0.8	0.800	3.3124	52.998	7.620	29.083	403.848	1541.352
6-C	Column	25	0.8	0.800	3.3124	52.998	15.240	29.083	807.696	1541.352
6-D	Column	25	0.8	0.800	3.3124	52.998	22.860	29.083	1211.543	1541.352
6-E	Column	25	0.8	0.800	3.3124	52.998	30.480	29.083	1615.391	1541.352
6-F	Column	25	0.8	0.800	3.3124	52.998	36.271	29.083	1922.316	1541.352
Beam										
1.00 A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	0.000	168.897	0.000
1.00 B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	0.000	506.692	0.000

1.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	0.000	844.487	0.000
1.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	0.000	1182.281	0.000
2.00	A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	5.817	168.897	257.850
2.00	B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	5.817	506.692	257.850
2.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	5.817	844.487	257.850
2.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	5.817	1182.281	257.850
2.00	E-F	Main Beam	25	4.9912	0.400	0.65	32.443	33.376	5.817	1082.798	188.707
3.00	A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	11.633	168.897	515.700
3.00	B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	11.633	506.692	515.700
3.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	11.633	844.487	515.700
3.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	11.633	1182.281	515.700
3.00	E-F	Main Beam	25	4.9912	0.400	0.65	32.443	33.376	11.633	1082.798	377.414
4.00	A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	17.450	168.897	773.550
4.00	B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	17.450	506.692	773.550
4.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	17.450	844.487	773.550
4.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	17.450	1182.281	773.550
4.00	E-F	Main Beam	25	4.9912	0.400	0.65	32.443	33.376	17.450	1082.798	566.120
5.00	A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	23.266	168.897	1031.400
5.00	B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	23.266	506.692	1031.400
5.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	23.266	844.487	1031.400
5.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	23.266	1182.281	1031.400
5.00	E-F	Main Beam	25	4.9912	0.400	0.65	32.443	33.376	23.266	1082.798	754.827

6.00	A-B	Main Beam	25	6.82	0.400	0.65	44.330	3.810	29.083	168.897	1289.249		
6.00	B-C	Main Beam	25	6.82	0.400	0.65	44.330	11.430	29.083	506.692	1289.249		
6.00	C-D	Main Beam	25	6.82	0.400	0.65	44.330	19.050	29.083	844.487	1289.249		
6.00	D-E	Main Beam	25	6.82	0.400	0.65	44.330	26.670	29.083	1182.281	1289.249		
6.00	E-F	Main Beam	25	4.9912	0.400	0.65	32.443	33.376	29.083	1082.798	943.534		
1,2	A	Main Beam	25	5.0166	0.400	0.65	32.608	0.000	2.908	0.000	94.834		
1,2	B	Main Beam	25	5.0166	0.400	0.65	32.608	7.620	2.908	248.472	94.834		
1,2	C	Main Beam	25	5.0166	0.400	0.65	32.608	15.240	2.908	496.944	94.834		
1,2	D	Main Beam	25	5.0166	0.400	0.65	32.608	22.860	2.908	745.417	94.834		
1,2	E	Main Beam	25	5.0166	0.400	0.65	32.608	30.480	2.908	993.889	94.834		
2,3	A	Main Beam	25	5.0166	0.400	0.65	32.608	0.000	8.725	0.000	284.501		
2,3	B	Main Beam	25	5.0166	0.400	0.65	32.608	7.620	8.725	248.472	284.501		
2,3	C	Main Beam	25	5.0166	0.400	0.65	32.608	15.240	8.725	496.944	284.501		
2,3	D	Main Beam	25	5.0166	0.400	0.65	32.608	22.860	8.725	745.417	284.501		
2,3	E	Main Beam	25	5.0166	0.400	0.65	32.608	30.480	8.725	993.889	284.501		
2,3	F	Main Beam	25	5.0166	0.400	0.65	32.608	36.271	8.725	1182.728	284.501		
3,4	A	Main Beam	25	5.0166	0.400	0.65	32.608	0.000	14.542	0.000	474.168		
3,4	B	Main Beam	25	5.0166	0.400	0.65	32.608	7.620	14.542	248.472	474.168		
3,4	C	Main Beam	25	5.0166	0.400	0.65	32.608	15.240	14.542	496.944	474.168		
3,4	D	Main Beam	25	5.0166	0.400	0.65	32.608	22.860	14.542	745.417	474.168		
3,4	E	Main Beam	25	5.0166	0.400	0.65	32.608	30.480	14.542	993.889	474.168		
3,4	F	Main Beam	25	5.0166	0.400	0.65	32.608	36.271	14.542	1182.728	474.168		

4,5	A	Main Beam	25	5.0166	0.400	0.65	32.608	0.000	20.358	0.000	663.835
4,5	B	Main Beam	25	5.0166	0.400	0.65	32.608	7.620	20.358	248.472	663.835
4,5	C	Main Beam	25	5.0166	0.400	0.65	32.608	15.240	20.358	496.944	663.835
4,5	D	Main Beam	25	5.0166	0.400	0.65	32.608	22.860	20.358	745.417	663.835
4,5	E	Main Beam	25	5.0166	0.400	0.65	32.608	30.480	20.358	993.889	663.835
4,5	F	Main Beam	25	5.0166	0.400	0.65	32.608	36.271	20.358	1182.728	663.835
5,6	A	Main Beam	25	5.0166	0.400	0.65	32.608	0.000	26.175	0.000	853.502
5,6	B	Main Beam	25	5.0166	0.400	0.65	32.608	7.620	26.175	248.472	853.502
5,6	C	Main Beam	25	5.0166	0.400	0.65	32.608	15.240	26.175	496.944	853.502
5,6	D	Main Beam	25	5.0166	0.400	0.65	32.608	22.860	26.175	745.417	853.502
5,6	E	Main Beam	25	5.0166	0.400	0.65	32.608	30.480	26.175	993.889	853.502
5,6	F	Main Beam	25	5.0166	0.400	0.65	32.608	36.271	26.175	1182.728	853.502
Secondary Beam											
1,2	A'	Secondary Beam	25	5.4166	0.230	0.4	12.458	3.810	2.908	47.466	36.232
1,2	B'	Secondary Beam	25	5.4166	0.230	0.4	12.458	11.430	2.908	142.397	36.232
1,2	C'	Secondary Beam	25	5.4166	0.230	0.4	12.458	19.050	2.908	237.328	36.232
1,2	D'	Secondary Beam	25	5.4166	0.230	0.4	12.458	25.565	2.908	318.495	36.232
										0.000	0.000
2,3	A'	Secondary Beam	25	5.4166	0.230	0.4	12.458	3.810	8.725	47.466	108.696
2,3	B'	Secondary Beam	25	5.4166	0.230	0.4	12.458	11.430	8.725	142.397	108.696
2,3	C'	Secondary Beam	25	5.4166	0.230	0.4	12.458	19.050	8.725	237.328	108.696
2,3	D'	Secondary Beam	25	5.4166	0.230	0.4	12.458	26.670	8.725	332.260	108.696

3,4	A'	Secondary Beam	25	5.4166	0.230	0.4	12.458	3.810	14.542	47.466	181.161
3,4	B'	Secondary Beam	25	5.4166	0.230	0.4	12.458	11.430	14.542	142.397	181.161
3,4	C'	Secondary Beam	25	5.4166	0.230	0.4	12.458	19.050	14.542	237.328	181.161
3,4	D'	Secondary Beam	25	5.4166	0.230	0.4	12.458	26.670	14.542	332.260	181.161
4,5	A'	Secondary Beam	25	5.4166	0.230	0.4	12.458	3.810	20.358	47.466	253.625
4,5	B'	Secondary Beam	25	5.4166	0.230	0.4	12.458	11.430	20.358	142.397	253.625
4,5	C'	Secondary Beam	25	5.4166	0.230	0.4	12.458	19.050	20.358	237.328	253.625
4,5	D'	Secondary Beam	25	5.4166	0.230	0.4	12.458	26.670	20.358	332.260	253.625
5,6	A'	Secondary Beam	25	5.4166	0.230	0.4	12.458	3.810	26.175		
5,6	B'	Secondary Beam	25	5.4166	0.230	0.4	12.458	11.430	26.175	142.397	326.089
5,6	C'	Secondary Beam	25	5.4166	0.230	0.4	12.458	17.844	26.175	222.298	326.089
5,6	D'	Secondary Beam	25	5.4166	0.230	0.4	12.458	25.565	26.175	318.495	326.089
1,2	D'	Secondary Beam	25	2.3901	0.230	0.4	5.497	24.213	3.505	133.102	19.269
2,3	E'	Secondary Beam	25	5.3912	0.230	0.4	12.400	33.376	8.725	413.849	108.187
3,4	E'	Secondary Beam	25	5.3912	0.230	0.4	12.400	33.376	14.542	413.849	180.311
4,5	E'	Secondary Beam	25	5.3912	0.230	0.4	12.400	33.376	20.358	413.849	252.436
5,6	D'	Secondary Beam	25	2.3901	0.230	0.4	5.497	24.213	25.578	133.102	140.607
5,6	D"	Secondary Beam	26	4.5999	0.230	0.4	11.003	28.023	26.175	308.331	287.999
5,6	E'	Secondary Beam	25	5.3912	0.230	0.4	12.400	33.376	26.175	413.849	324.560
Slab											
A-C	1,6	Slab	25	29.083	15.240	0.125	1385.078	7.620	14.542	10554.293	20141.110
C-D	1,5	Slab	25	23.266	7.620	0.125	554.031	19.050	11.633	10554.293	6445.155

D-E	2,5	Slab	25	17.45	7.620	0.125	415.523	26.670	14.542	11082.008	6042.333
E-F	2,3	Slab	25	5.8166	5.791	0.125	105.266	33.376	8.725	3513.313	918.435
E-F	5,6	Slab	25	5.8166	5.791	0.125	105.266	33.376	26.175	3513.313	2755.304
D-D'	1'-2	Slab	25	2.3114	2.705	0.125	19.539	24.213	4.661	473.097	91.071
D-D'	5-5'	Slab	25	2.3114	2.705	0.125	19.539	24.213	24.422	473.097	477.190
D'-E	5-5'	Slab	25	2.9083	4.915	0.125	44.669	28.023	24.721	1251.735	1104.239
D'-E	5'-6	Slab	25	2.9083	4.915	0.125	44.669	28.023	27.629	1251.735	1234.149
C-C'	5,6	Slab	25	5.8166	2.654	0.125	48.247	16.567	26.175	799.316	1262.848
Wall											
1.00	A-B	Main wall	19.2	4.41	0.230	3.3124	45.155	6.015	0.000	271.609	0.000
1.00	B-C	Main wall	19.2	6.82	0.230	3.3124	69.832	11.430	0.000	798.179	0.000
1.00	C-D	Main wall	19.2	6.82	0.230	3.3124	69.832	19.050	0.000	1330.299	0.000
1.00	D-E	Main wall	19.2	4.41	0.230	3.3124	45.155	25.065	0.000	1131.817	0.000
1,2	E	Main wall	19.2	2.5083	0.230	3.3124	25.683	30.480	4.162	782.824	106.905
2.00	E-F	Main wall	19.2	4.9912	0.230	3.3124	51.106	33.376	5.817	1705.705	297.265
2,3	F	Main wall	19.2	5.0166	0.230	3.3124	51.366	36.271	8.725	1863.122	448.167
3.00	E-F	Main wall	19.2	4.9912	0.230	3.3124	51.106	33.376	11.633	1705.705	594.530
3,4	E	Main wall	19.2	5.0166	0.230	3.3124	51.366	30.480	14.542	1565.649	746.945
4,5	E	Main wall	19.2	5.0166	0.230	3.3124	51.366	30.480	20.358	1565.649	1045.723
5.00	E-F	Main wall	19.2	4.9912	0.230	3.3124	51.106	33.376	23.266	1705.705	1189.061

5,6	F	Main wall	19.2	2.5083	0.230	3.3124	25.683	36.271	24.921	931.561	640.040
6.00	E-F	Main wall	19.2	2.4956	0.230	3.3124	25.553	34.623	29.083	884.738	743.163
6.00	D-E	Main wall	19.2	6.82	0.230	3.3124	69.832	26.670	29.083	1862.418	2030.923
6.00	C-D	Main wall	19.2	6.82	0.230	3.3124	69.832	19.050	29.083	1330.299	2030.923
6.00	B-C	Main wall	19.2	6.82	0.230	3.3124	69.832	11.430	29.083	798.179	2030.923
6.00	A-B	Main wall	19.2	4.41	0.230	3.3124	45.155	6.015	29.083	271.609	1313.251
1,2	A	Main wall	19.2	2.5083	0.230	3.3124	25.683	0.000	4.162	0.000	106.905
2,3	A	Main wall	19.2	5.0166	0.230	3.3124	51.366	0.000	8.725	0.000	448.167
3,4	A	Main wall	19.2	5.0166	0.230	3.3124	51.366	0.000	14.542	0.000	746.945
4,5	A	Main wall	19.2	5.0166	0.230	3.3124	51.366	0.000	20.358	0.000	1045.723
5,6	A	Main wall	19.2	2.5083	0.230	3.3124	25.683	0.000	24.921	0.000	640.040
1,1'	D	Main wall	19.2	3.1052	0.230	3.3124	45.421	22.860	1.953	1038.335	88.690
1,1'	D'	Main wall	19.2	3.1052	0.230	3.3124	45.421	25.565	1.953	1161.205	88.690
1,2	D'	Partition wall	19.2	2.3901	0.110	3.3124	11.704	24.255	3.505	283.892	41.026
5',6	D	Main wall	19.2	3.1052	0.230	3.3124	45.421	22.860	27.130	1038.335	1232.303
5',6	D'	Main wall	19.2	3.1052	0.230	3.3124	45.421	25.565	27.130	1161.205	1232.303
5,6	D'	Partition wall	19.2	2.3901	0.110	3.3124	11.704	24.255	25.578	283.892	299.374
5,6	C-C'	Partition wall	19.2	2.3393	0.110	3.3124	11.456	16.610	27.083	190.275	310.254
1.00	A-B	RCC wall	25	3.41	0.260	3.3124	73.419	2.105	0.000	154.548	0.000

1,2	A	RCC wall	25	2.5083	0.260	3.3124	54.005	0.000	1.654	0.000	89.335
5,6	A	RCC wall	25	2.5083	0.260	3.3124	54.005	0.000	27.429	0.000	1481.301
6.00	A-B	RCC wall	25	3.41	0.260	3.3124	73.419	2.105	29.083	154.548	2135.255
1.00	D-E	RCC wall	25	3.41	0.260	3.3124	73.419	28.375	0.000	2083.274	0.000
1,2	E	RCC wall	25	2.5083	0.260	3.3124	54.005	30.480	1.654	1646.079	89.335
5,6	F	RCC wall	25	2.5083	0.260	3.3124	54.005	36.271	27.429	1958.834	1481.301
6.00	E-F	RCC wall	25	2.4956	0.260	3.3124	53.732	34.623	29.083	1860.376	1562.681
							Total			Total	Total
							8870.285			155548.321	131595.910

x=	14.836
y=	17.536

Center of stiffness for plinth level, 1st, 2nd and 3rd floor

Stiffness(k)=	$12EI/L^3$

where

$Ec=5000*(fck)^{1/2}$			
$I=bd^3/12$	b=d=	0.8	m

I=	0.034
Ec=	25000.000

Column	I	E	k	xi	yi	k*xi	k*yi
1-A	0.034	25000	281.755	0.000	0.000	0.000	0.000
1-B	0.034	25000	281.755	0.000	7.620	0.000	2146.973
1-C	0.034	25000	281.755	0.000	15.240	0.000	4293.946
1-D	0.034	25000	281.755	0.000	22.860	0.000	6440.919
1-E	0.034	25000	281.755	0.000	30.480	0.000	8587.892
2-A	0.034	25000	281.755	5.817	0.000	1638.856	0.000
2-B	0.034	25000	281.755	5.817	7.620	1638.856	2146.973
2-C	0.034	25000	281.755	5.817	15.240	1638.856	4293.946
2-D	0.034	25000	281.755	5.817	22.860	1638.856	6440.919
2-E	0.034	25000	281.755	5.817	30.480	1638.856	8587.892
2-F	0.034	25000	281.755	5.817	36.271	1638.856	10219.592
3-A	0.034	25000	281.755	11.633	0.000	3277.712	0.000
3-B	0.034	25000	281.755	11.633	7.620	3277.712	2146.973
3-C	0.034	25000	281.755	11.633	15.240	3277.712	4293.946
3-D	0.034	25000	281.755	11.633	22.860	3277.712	6440.919
3-E	0.034	25000	281.755	11.633	30.480	3277.712	8587.892
3-F	0.034	25000	281.755	11.633	36.271	3277.712	10219.592
4-A	0.034	25000	281.755	17.450	0.000	4916.568	0.000
4-B	0.034	25000	281.755	17.450	7.620	4916.568	2146.973
4-C	0.034	25000	281.755	17.450	15.240	4916.568	4293.946
4-D	0.034	25000	281.755	17.450	22.860	4916.568	6440.919
4-E	0.034	25000	281.755	17.450	30.480	4916.568	8587.892
4-F	0.034	25000	281.755	17.450	36.271	4916.568	10219.592
5-A	0.034	25000	281.755	23.266	0.000	6555.424	0.000
5-B	0.034	25000	281.755	23.266	7.620	6555.424	2146.973

5-C	0.034	25000	281.755	23.266	15.240	6555.424	4293.946
5-D	0.034	25000	281.755	23.266	22.860	6555.424	6440.919
5-E	0.034	25000	281.755	23.266	30.480	6555.424	8587.892
5-F	0.034	25000	281.755	23.266	36.271	6555.424	10219.592
6-A	0.034	25000	281.755	29.083	0.000	8194.281	0.000
6-B	0.034	25000	281.755	29.083	7.620	8194.281	2146.973
6-C	0.034	25000	281.755	29.083	15.240	8194.281	4293.946
6-D	0.034	25000	281.755	29.083	22.860	8194.281	6440.919
6-E	0.034	25000	281.755	29.083	30.480	8194.281	8587.892
6-F	0.034	25000	281.755	29.083	36.271	8194.281	10219.592
		Total	9861.425			147497.051	179916.345

xi=	14.957
yi=	18.244

e_x=	-0.121
e_y=	-0.709

Center of mass for mezzanine level

Grid No.		Descriptions	Load Calculations				Total Load (KN)	Centroid(m)		WY	WX
YY	XX		Unit Wt. (KN/m3)	Length (m)	Breadth (m)	Height (m)		Y	X		
Column											
1-A		Column	25	0.8	0.8	3.3124	52.998	0.000	0.000	0.000	0.000
1-B		Column	25	0.8	0.8	3.3124	52.998	7.620	0.000	403.848	0.000
1-C		Column	25	0.8	0.8	3.3124	52.998	15.240	0.000	807.696	0.000
1-D		Column	25	0.8	0.8	3.3124	52.998	22.860	0.000	1211.543	0.000
1-E		Column	25	0.8	0.8	3.3124	52.998	30.480	0.000	1615.391	0.000
2-A		Column	25	0.8	0.8	3.3124	52.998	0.000	5.817	0.000	308.270
2-B		Column	25	0.8	0.8	3.3124	52.998	7.620	5.817	403.848	308.270
2-C		Column	25	0.8	0.8	3.3124	52.998	15.240	5.817	807.696	308.270
2-D		Column	25	0.8	0.8	3.3124	52.998	22.860	5.817	1211.543	308.270
2-E		Column	25	0.8	0.8	3.3124	52.998	30.480	5.817	1615.391	308.270
2-F		Column	25	0.8	0.8	3.3124	52.998	36.271	5.817	1922.316	308.270
3-A		Column	25	0.8	0.8	3.3124	52.998	0.000	11.633	0.000	616.541
3-B		Column	25	0.8	0.8	3.3124	52.998	7.620	11.633	403.848	616.541
3-C		Column	25	0.8	0.8	3.3124	52.998	15.240	11.633	807.696	616.541
3-D		Column	25	0.8	0.8	3.3124	52.998	22.860	11.633	1211.543	616.541
3-E		Column	25	0.8	0.8	3.3124	52.998	30.480	11.633	1615.391	616.541

3-F		Column	25	0.8	0.8	3.3124	52.998	36.271	11.633	1922.316	616.541
4-A		Column	25	0.8	0.8	3.3124	52.998	0.000	17.450	0.000	924.811
4-B		Column	25	0.8	0.8	3.3124	52.998	7.620	17.450	403.848	924.811
4-C		Column	25	0.8	0.8	3.3124	52.998	15.240	17.450	807.696	924.811
4-D		Column	25	0.8	0.8	3.3124	52.998	22.860	17.450	1211.543	924.811
4-E		Column	25	0.8	0.8	3.3124	52.998	30.480	17.450	1615.391	924.811
4-F		Column	25	0.8	0.8	3.3124	52.998	36.271	17.450	1922.316	924.811
5-A		Column	25	0.8	0.8	3.3124	52.998	0.000	23.266	0.000	1233.082
5-B		Column	25	0.8	0.8	3.3124	52.998	7.620	23.266	403.848	1233.082
5-C		Column	25	0.8	0.8	3.3124	52.998	15.240	23.266	807.696	1233.082
5-D		Column	25	0.8	0.8	3.3124	52.998	22.860	23.266	1211.543	1233.082
5-E		Column	25	0.8	0.8	3.3124	52.998	30.480	23.266	1615.391	1233.082
5-F		Column	25	0.8	0.8	3.3124	52.998	36.271	23.266	1922.316	1233.082
6-A		Column	25	0.8	0.8	3.3124	52.998	0.000	29.083	0.000	1541.352
6-B		Column	25	0.8	0.8	3.3124	52.998	7.620	29.083	403.848	1541.352
6-C		Column	25	0.8	0.8	3.3124	52.998	15.240	29.083	807.696	1541.352
6-D		Column	25	0.8	0.8	3.3124	52.998	22.860	29.083	1211.543	1541.352
6-E		Column	25	0.8	0.8	3.3124	52.998	30.480	29.083	1615.391	1541.352
6-F		Column	25	0.8	0.8	3.3124	52.998	36.271	29.083	1922.316	1541.352
Beam											
1.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	0.000	168.897	0.000
1.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	0.000	506.692	0.000

1.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	0.000	844.487	0.000
1.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	0.000	1182.281	0.000
2.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	5.817	168.897	257.850
2.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	5.817	506.692	257.850
2.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	5.817	844.487	257.850
2.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	5.817	1182.281	257.850
2.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	5.817	1082.798	188.707
3.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	11.633	168.897	515.700
3.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	11.633	506.692	515.700
3.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	11.633	844.487	515.700
3.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	11.633	1182.281	515.700
3.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	11.633	1082.798	377.414
4.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	17.450	168.897	773.550
4.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	17.450	506.692	773.550
4.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	17.450	844.487	773.550
4.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	17.450	1182.281	773.550
4.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	17.450	1082.798	566.120
5.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	23.266	168.897	1031.400
5.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	23.266	506.692	1031.400
5.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	23.266	844.487	1031.400
5.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	23.266	1182.281	1031.400
5.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	23.266	1082.798	754.827

6.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	29.083	168.897	1289.249
6.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	29.083	506.692	1289.249
6.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	29.083	844.487	1289.249
6.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	29.083	1182.281	1289.249
6.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	29.083	1082.798	943.534
1,2	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	2.908	0.000	94.834
1,2	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	2.908	248.472	94.834
1,2	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	2.908	496.944	94.834
1,2	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	2.908	745.417	94.834
1,2	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	2.908	993.889	94.834
2,3	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	8.725	0.000	284.501
2,3	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	8.725	248.472	284.501
2,3	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	8.725	496.944	284.501
2,3	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	8.725	745.417	284.501
2,3	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	8.725	993.889	284.501
2,3	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	8.725	1182.728	284.501
3,4	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	14.542	0.000	474.168
3,4	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	14.542	248.472	474.168
3,4	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	14.542	496.944	474.168
3,4	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	14.542	745.417	474.168
3,4	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	14.542	993.889	474.168
3,4	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	14.542	1182.728	474.168

4,5	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	20.358	0.000	663.835
4,5	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	20.358	248.472	663.835
4,5	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	20.358	496.944	663.835
4,5	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	20.358	745.417	663.835
4,5	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	20.358	993.889	663.835
4,5	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	20.358	1182.728	663.835
5,6	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	26.175	0.000	853.502
5,6	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	26.175	248.472	853.502
5,6	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	26.175	496.944	853.502
5,6	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	26.175	745.417	853.502
5,6	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	26.175	993.889	853.502
5,6	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	26.175	1182.728	853.502
Secondary Beam											
1,2	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	2.908	47.466	36.232
1,2	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	2.908	142.397	36.232
1,2	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	2.908	237.328	36.232
1,2	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	25.565	2.908	318.495	36.232
										0.000	0.000
2,3	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	8.725	47.466	108.696
2,3	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	8.725	142.397	108.696
2,3	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	8.725	237.328	108.696
2,3	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	8.725	332.260	108.696

3,4	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	14.542	47.466	181.161
3,4	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	14.542	142.397	181.161
3,4	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	14.542	237.328	181.161
3,4	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	14.542	332.260	181.161
4,5	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	20.358	47.466	253.625
4,5	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	20.358	142.397	253.625
4,5	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	20.358	237.328	253.625
4,5	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	20.358	332.260	253.625
5,6	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	26.175		
5,6	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	26.175	142.397	326.089
5,6	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	17.844	26.175	222.298	326.089
5,6	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	25.565	26.175	318.495	326.089
1,2	D'	Secondary Beam	25	2.3901	0.23	0.4	5.497	24.213	3.505	133.102	19.269
2,3	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	8.725	413.849	108.187
3,4	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	14.542	413.849	180.311
4,5	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	20.358	413.849	252.436
5,6	D'	Secondary Beam	25	2.3901	0.23	0.4	5.497	24.213	25.578	133.102	140.607
5,6	D''	Secondary Beam	26	4.5999	0.23	0.4	11.003	28.023	26.175	308.331	287.999
5,6	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	26.175	413.849	324.560
Slab											
A-C	1,6	Slab	25	29.083	15.24	0.125	1385.078	7.620	14.542	10554.293	20141.110
C-D	1,5	Slab	25	23.2664	7.62	0.125	554.031	19.050	11.633	10554.293	6445.155

D-E	2,5	Slab	25	17.4498	7.62	0.125	415.523	26.670	14.542	11082.008	6042.333
E-F	2,3	Slab	25	5.8166	5.7912	0.125	105.266	33.376	8.725	3513.313	918.435
E-F	5,6	Slab	25	5.8166	5.7912	0.125	105.266	33.376	26.175	3513.313	2755.304
D-D'	1'-2	Slab	25	2.3114	2.7051	0.125	19.539	24.213	4.661	473.097	91.071
D-D'	5-5'	Slab	25	2.3114	2.7051	0.125	19.539	24.213	24.422	473.097	477.190
D'-E	5-5'	Slab	25	2.9083	4.9149	0.125	44.669	28.023	24.721	1251.735	1104.239
D'-E	5'-6	Slab	25	2.9083	4.9149	0.125	44.669	28.023	27.629	1251.735	1234.149
C-C'	5,6	Slab	25	5.8166	2.6543	0.125	48.247	16.567	26.175	799.316	1262.848
Wall											
1.00	A-B	Basement wall	25	6.82	0.26	3.3124	146.839	3.810	0.000	559.455	0.000
1.00	B-C	Basement wall	25	6.82	0.26	3.3124	146.839	11.430	0.000	1678.366	0.000
1.00	C-D	Basement wall	25	6.82	0.26	3.3124	146.839	19.050	0.000	2797.277	0.000
1.00	D-E	Basement wall	25	6.82	0.26	3.3124	146.839	26.670	0.000	3916.188	0.000
1,2	E	Basement wall	25	5.0166	0.26	3.3124	108.010	30.480	2.908	3292.157	314.127
2.00	E-F	Basement wall	25	4.9912	0.26	3.3124	107.464	33.376	5.817	3586.660	625.072
2,3	F	Basement wall	25	5.0166	0.26	3.3124	108.010	36.271	8.725	3917.667	942.380
3,4	F	Basement wall	25	5.0166	0.26	3.3124	108.010	36.271	14.542	3917.667	1570.633
4,5	F	Basement wall	25	5.0166	0.26	3.3124	108.010	36.271	20.358	3917.667	2198.887
5,6	F	Basement wall	25	5.0166	0.26	3.3124	108.010	36.271	26.175	3917.667	2827.140

6.00	E-F	Basement wall	25	4.9912	0.26	3.3124	107.464	23.376	29.083	2512.025	3125.362
6.00	D-E	Basement wall	25	6.82	0.26	3.3124	102.787	26.670	29.083	2741.332	2989.357
6.00	C-D	Basement wall	25	6.82	0.26	3.3124	146.839	19.050	29.083	2797.277	4270.510
6.00	B-C	Basement wall	25	6.82	0.26	3.3124	146.839	11.430	29.083	1678.366	4270.510
6.00	A-B	Basement wall	25	6.82	0.26	3.3124	146.839	3.810	29.083	559.455	4270.510
1,2	A	Basement wall	25	5.0166	0.26	3.3124	108.010	0.000	2.908	0.000	314.127
2,3	A	Basement wall	25	5.0166	0.26	3.3124	108.010	0.000	8.725	0.000	942.380
3,4	A	Basement wall	25	5.0166	0.26	3.3124	108.010	0.000	14.542	0.000	1570.633
4,5	A	Basement wall	25	5.0166	0.26	3.3124	108.010	0.000	20.358	0.000	2198.887
5,6	A	Basement wall	25	5.0166	0.26	3.3124	108.010	0.000	26.175	0.000	2827.140
1,1'	D	Main wall	19.2	3.1052	0.23	3.3124	45.421	22.860	1.953	1038.335	88.690
1,1'	D'	Main wall	19.2	3.1052	0.23	3.3124	45.421	25.565	1.953	1161.205	88.690
1,2	D'	Partition wall	19.2	2.3901	0.11	3.3124	11.704	24.255	3.505	283.892	41.026
5',6	D	Main wall	19.2	3.1052	0.23	3.3124	45.421	22.860	27.130	1038.335	1232.303
5',6	D'	Main wall	19.2	3.1052	0.23	3.3124	45.421	25.565	27.130	1161.205	1232.303
5,6	D'	Partition wall	19.2	2.3901	0.11	3.3124	11.704	24.255	25.578	283.892	299.374
							Total			Total	Total
							9720.078			168784.548	143498.503

x=	14.763
y=	17.365

Center of stiffness for mezzanine level

Stiffness(k)=	$12EI/L^3$

where

$Ec=5000*(fck)^{1/2}$			
$I=bd^3/12$	b=d=	0.8	m

I=	0.034
Ec=	25000.000

Column	I	E	k	xi	yi	k*xi	k*yi
1-A	0.034	25000	281.755	0.000	0.000	0.000	0.000
1-B	0.034	25000	281.755	0.000	7.620	0.000	2146.973
1-C	0.034	25000	281.755	0.000	15.240	0.000	4293.946
1-D	0.034	25000	281.755	0.000	22.860	0.000	6440.919
1-E	0.034	25000	281.755	0.000	30.480	0.000	8587.892
2-A	0.034	25000	281.755	5.817	0.000	1638.856	0.000
2-B	0.034	25000	281.755	5.817	7.620	1638.856	2146.973
2-C	0.034	25000	281.755	5.817	15.240	1638.856	4293.946
2-D	0.034	25000	281.755	5.817	22.860	1638.856	6440.919
2-E	0.034	25000	281.755	5.817	30.480	1638.856	8587.892
2-F	0.034	25000	281.755	5.817	36.271	1638.856	10219.592
3-A	0.034	25000	281.755	11.633	0.000	3277.712	0.000
3-B	0.034	25000	281.755	11.633	7.620	3277.712	2146.973
3-C	0.034	25000	281.755	11.633	15.240	3277.712	4293.946
3-D	0.034	25000	281.755	11.633	22.860	3277.712	6440.919
3-E	0.034	25000	281.755	11.633	30.480	3277.712	8587.892
3-F	0.034	25000	281.755	11.633	36.271	3277.712	10219.592
4-A	0.034	25000	281.755	17.450	0.000	4916.568	0.000
4-B	0.034	25000	281.755	17.450	7.620	4916.568	2146.973
4-C	0.034	25000	281.755	17.450	15.240	4916.568	4293.946
4-D	0.034	25000	281.755	17.450	22.860	4916.568	6440.919
4-E	0.034	25000	281.755	17.450	30.480	4916.568	8587.892
4-F	0.034	25000	281.755	17.450	36.271	4916.568	10219.592
5-A	0.034	25000	281.755	23.266	0.000	6555.424	0.000
5-B	0.034	25000	281.755	23.266	7.620	6555.424	2146.973
5-C	0.034	25000	281.755	23.266	15.240	6555.424	4293.946

5-D	0.034	25000	281.755	23.266	22.860	6555.424	6440.919
5-E	0.034	25000	281.755	23.266	30.480	6555.424	8587.892
5-F	0.034	25000	281.755	23.266	36.271	6555.424	10219.592
6-A	0.034	25000	281.755	29.083	0.000	8194.281	0.000
6-B	0.034	25000	281.755	29.083	7.620	8194.281	2146.973
6-C	0.034	25000	281.755	29.083	15.240	8194.281	4293.946
6-D	0.034	25000	281.755	29.083	22.860	8194.281	6440.919
6-E	0.034	25000	281.755	29.083	30.480	8194.281	8587.892
6-F	0.034	25000	281.755	29.083	36.271	8194.281	10219.592
		Total	9861.425			147497.051	179916.345

xi=	14.957
yi=	18.244

e_x=	-0.194
e_y=	-0.880

Center of mass for terrace level

Grid No.		Descriptions	Load Calculations				Total Load (KN)	Centroid(m)		WY	WX
YY	XX		Unit Wt. (KN/m3)	Length (m)	Breadth (m)	Height (m)		Y	X		
Wall											
1	A-D	Parapet wall	19.2	22.86	0.11	1.2192	58.863	11.430	0.000	672.808	0.000
2	E-F	Parapet wall	19.2	5.7912	0.11	1.2192	14.912	33.376	5.817	497.699	86.737
2,3	F	Parapet wall	19.2	5.8166	0.11	1.2192	14.977	36.271	8.725	543.250	130.677
3	E-F	Parapet wall	19.2	5.7912	0.11	1.2192	14.912	33.376	11.633	497.699	173.475
3,5	E	Parapet wall	19.2	11.6332	0.11	1.2192	20.968	30.480	17.450	639.118	365.895
5	E-F	Parapet wall	19.2	5.7912	0.11	1.2192	10.438	33.376	23.266	348.389	242.865
5,6	F	Parapet wall	19.2	5.8166	0.11	1.2192	10.484	36.271	26.175	380.275	274.421
6	D'-F	Parapet wall	19.2	10.7061	0.11	1.2192	24.811	30.918	29.083	767.104	721.576
6	A-C	Parapet wall	19.2	15.24	0.11	1.2192	27.568	7.620	29.083	210.066	801.751
1,6	A	Parapet wall	19.2	29.083	0.11	1.2192	39.242	0.000	14.542	0.000	570.641
1	D-E	Main Wall	19.2	6.82	0.23	9.1933	193.813	26.670	0.000	5168.993	0.000
1,2	E	Main Wall	19.2	5.0166	0.23	9.1933	142.563	30.480	2.908	4345.332	414.617
1,2	D	Main Wall	19.2	5.0166	0.23	9.1933	142.563	22.860	2.908	3258.999	414.617
2	D-E	Partition Wall	19.2	6.82	0.11	9.1933	92.693	26.670	5.817	2472.127	539.159
5,6	C	Main Wall	19.2	5.0166	0.23	9.1933	142.563	15.240	26.175	2172.666	3731.554
6	C-D'	Main Wall	19.2	10.3251	0.23	9.1933	293.422	20.803	29.083	6103.928	8533.595
5,6	D'	Main Wall	19.2	5.0166	0.23	9.1933	142.563	25.565	26.175	3644.647	3731.554
5	C-D'	Partition Wall	19.2	10.3251	0.11	9.1933	140.332	20.803	23.266	2919.270	3265.027

Slab											
A-C	1,6	Slab	25	29.083	15.24	0.125	1385.078	7.620	14.542	10554.293	20141.110
C-D	1,5	Slab	25	23.2664	7.62	0.125	554.031	19.050	11.633	10554.293	6445.155
D-E	2,5	Slab	25	17.4498	7.62	0.125	415.523	26.670	14.542	11082.008	6042.333
E-F	2,3	Slab	25	5.8166	5.7912	0.125	105.266	33.376	8.725	3513.313	918.435
E-F	5,6	Slab	25	5.8166	5.7912	0.125	105.266	33.376	26.175	3513.313	2755.304
D-D'	1'-2	Slab	25	2.3114	2.7051	0.125	19.539	24.213	4.661	473.097	91.071
D-D'	5-5'	Slab	25	2.3114	2.7051	0.125	19.539	24.213	24.422	473.097	477.190
D'-E	5-5'	Slab	25	2.9083	4.9149	0.125	44.669	28.023	24.721	1251.735	1104.239
D'-E	5'-6	Slab	25	2.9083	4.9149	0.125	44.669	28.023	27.629	1251.735	1234.149
C-C'	5,6	Slab	25	5.8166	2.6543	0.125	48.247	16.567	26.175	799.316	1262.848
Main Beam											
1.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	0.000	168.897	0.000
1.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	0.000	506.692	0.000
1.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	0.000	844.487	0.000
1.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	0.000	1182.281	0.000
2.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	5.817	168.897	257.850
2.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	5.817	506.692	257.850
2.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	5.817	844.487	257.850
2.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	5.817	1182.281	257.850
2.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	5.817	1082.798	188.707
3.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	11.633	168.897	515.700
3.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	11.633	506.692	515.700

3.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	11.633	844.487	515.700
3.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	11.633	1182.281	515.700
3.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	11.633	1082.798	377.414
4.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	17.450	168.897	773.550
4.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	17.450	506.692	773.550
4.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	17.450	844.487	773.550
4.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	17.450	1182.281	773.550
4.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	17.450	1082.798	566.120
5.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	23.266	168.897	1031.400
5.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	23.266	506.692	1031.400
5.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	23.266	844.487	1031.400
5.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	23.266	1182.281	1031.400
5.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	23.266	1082.798	754.827
6.00	A-B	Main Beam	25	6.82	0.4	0.65	44.330	3.810	29.083	168.897	1289.249
6.00	B-C	Main Beam	25	6.82	0.4	0.65	44.330	11.430	29.083	506.692	1289.249
6.00	C-D	Main Beam	25	6.82	0.4	0.65	44.330	19.050	29.083	844.487	1289.249
6.00	D-E	Main Beam	25	6.82	0.4	0.65	44.330	26.670	29.083	1182.281	1289.249
6.00	E-F	Main Beam	25	4.9912	0.4	0.65	32.443	33.376	29.083	1082.798	943.534
1,2	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	2.908	0.000	94.834
1,2	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	2.908	248.472	94.834
1,2	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	2.908	496.944	94.834
1,2	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	2.908	745.417	94.834

1,2	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	2.908	993.889	94.834
2,3	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	8.725	0.000	284.501
2,3	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	8.725	248.472	284.501
2,3	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	8.725	496.944	284.501
2,3	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	8.725	745.417	284.501
2,3	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	8.725	993.889	284.501
2,3	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	8.725	1182.728	284.501
3,4	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	14.542	0.000	474.168
3,4	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	14.542	248.472	474.168
3,4	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	14.542	496.944	474.168
3,4	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	14.542	745.417	474.168
3,4	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	14.542	993.889	474.168
3,4	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	14.542	1182.728	474.168
4,5	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	20.358	0.000	663.835
4,5	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	20.358	248.472	663.835
4,5	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	20.358	496.944	663.835
4,5	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	20.358	745.417	663.835
4,5	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	20.358	993.889	663.835
4,5	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	20.358	1182.728	663.835
5,6	A	Main Beam	25	5.0166	0.4	0.65	32.608	0.000	26.175	0.000	853.502
5,6	B	Main Beam	25	5.0166	0.4	0.65	32.608	7.620	26.175	248.472	853.502
5,6	C	Main Beam	25	5.0166	0.4	0.65	32.608	15.240	26.175	496.944	853.502

5,6	D	Main Beam	25	5.0166	0.4	0.65	32.608	22.860	26.175	745.417	853.502
5,6	E	Main Beam	25	5.0166	0.4	0.65	32.608	30.480	26.175	993.889	853.502
5,6	F	Main Beam	25	5.0166	0.4	0.65	32.608	36.271	26.175	1182.728	853.502
Secondary Beam											
1,2	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	2.908	47.466	36.232
1,2	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	2.908	142.397	36.232
1,2	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	2.908	237.328	36.232
1,2	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	25.565	2.908	318.495	36.232
										0.000	0.000
2,3	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	8.725	47.466	108.696
2,3	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	8.725	142.397	108.696
2,3	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	8.725	237.328	108.696
2,3	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	8.725	332.260	108.696
3,4	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	14.542	47.466	181.161
3,4	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	14.542	142.397	181.161
3,4	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	14.542	237.328	181.161
3,4	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	14.542	332.260	181.161
4,5	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	20.358	47.466	253.625
4,5	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	20.358	142.397	253.625
4,5	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	19.050	20.358	237.328	253.625
4,5	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	26.670	20.358	332.260	253.625
5,6	A'	Secondary Beam	25	5.4166	0.23	0.4	12.458	3.810	26.175		
5,6	B'	Secondary Beam	25	5.4166	0.23	0.4	12.458	11.430	26.175	142.397	326.089

5,6	C'	Secondary Beam	25	5.4166	0.23	0.4	12.458	17.844	26.175	222.298	326.089
5,6	D'	Secondary Beam	25	5.4166	0.23	0.4	12.458	25.565	26.175	318.495	326.089
1,2	D'	Secondary Beam	25	2.3901	0.23	0.4	5.497	24.213	3.505	133.102	19.269
2,3	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	8.725	413.849	108.187
3,4	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	14.542	413.849	180.311
4,5	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	20.358	413.849	252.436
5,6	D'	Secondary Beam	25	2.3901	0.23	0.4	5.497	24.213	25.578	133.102	140.607
5,6	D"	Secondary Beam	26	4.5999	0.23	0.4	11.003	28.023	26.175	308.331	287.999
5,6	E'	Secondary Beam	25	5.3912	0.23	0.4	12.400	33.376	26.175	413.849	324.560
Column											
1-D		Column	25	0.8	0.8	2.1948	35.117	22.860	0.000	802.770	0.000
1-E		Column	25	0.8	0.8	2.1948	35.117	30.480	0.000	1070.360	0.000
2-D		Column	25	0.8	0.8	2.1948	35.117	22.860	5.817	802.770	204.260
2-E		Column	25	0.8	0.8	2.1948	35.117	30.480	5.817	1070.360	204.260
5-C		Column	25	0.8	0.8	2.1948	35.117	15.240	23.266	535.180	817.042
5-D		Column	25	0.8	0.8	2.1948	35.117	22.860	23.266	802.770	817.042
6-C		Column	25	0.8	0.8	2.1948	35.117	15.240	29.083	535.180	1021.302
6-D		Column	25	0.8	0.8	2.1948	35.117	22.860	29.083	802.770	1021.302
							Total			Total	Total
							7042.976			129250.540	105597.487

x=	14.993
y=	18.352

Center of stiffness for terrace level

Stiffness(k)=	$12EI/L^3$

where

$Ec=5000*(fck)^{1/2}$			
$I=bd^3/12$	b=d=	0.8	m

I=	0.034
Ec=	25000.000

Column	I	E	k	xi	yi	k*xi	k*yi
1-D	0.034	25000	968.535	0.000	22.860	0.000	22140.699
1-E	0.034	25000	968.535	0.000	30.480	0.000	29520.932
2-D	0.034	25000	968.535	5.817	22.860	5633.578	22140.699
2-E	0.034	25000	968.535	5.817	30.480	5633.578	29520.932
5-C	0.034	25000	968.535	23.266	15.240	22534.311	14760.466
5-D	0.034	25000	968.535	23.266	22.860	22534.311	22140.699
6-C	0.034	25000	968.535	29.083	15.240	28167.889	14760.466
6-D	0.034	25000	968.535	29.083	22.860	28167.889	22140.699
		Total	7748.276			112671.557	177125.592

xi=	14.542
yi=	22.860

e_x=	0.452
e_y=	-4.508

7. DESIGN AND DETAILING

7.1. Design of Slab

Slab is a reinforced concrete structure used in RCC buildings as flooring systems and ceilings. It bears the loads of the structure and transfers it to beams and columns and finally to foundation. A slab may be supported by beams or walls or continuous over one or more supports. The transfer of gravity loads from slab to beams is done through one-way or two-way action.

One-way slabs (length more than twice of breadth) span in one direction while two-way slabs (length to breadth ratio below two) span in both directions. In one way slab, the reinforcement bars are placed in only one (shorter) direction as considerable bending moment develops only in that direction. The slab is designed to resist bending only in one direction. In two-way slab, the reinforcements are placed in both directions as both spans contribute to carry load. The slab is designed to resist bending in both directions.

In our project, we have come across both one way and two-way slabs. Slabs are categorized according to the end conditions and conditions of the corner restraint and their spanning either in one direction or in the both directions.

Design Criteria for Slab:

1. Determine effective depth of Slab by deflection control criteria. According to IS 456:2000, Clause.23.2.1
2. Find the overall depth of the slab

   Overall depth of the slab= effective depth +normal cover + Φ/2
3. Calculate the effective span of the slab

   Effective span= clear span +effective depth or width of the support (whichever is smaller)
4. Check for the ratio of the longer to shorter span, IS456:2000, Cl.24.3
5. Determine total service load

   Total service load= self-weight of slab +live load +floor finish +partition load
6. Calculate design load,

   Design load= 1.5* Total service load
7. Considering unit strip width.
8. Find the bending moment coefficients from, IS456:2000, Annex D Table 26.9
9. Calculate moments

   $M_x = \alpha_x * Wl_x^2$

   $M_y = \alpha_y * Wl_x^2$
10. Check for the effective depth:

    M_{max}= 0.1338*fck*b*d^2 (for Fe 500)
11. Find area of steel and spacing of reinforcement

    Mux = 0.87*fy* Ast*d*(1-fy*Ast/ (fck*b*d))
12. Check for Ast_{min}= 0.12%bd from IS 456:2000, Cl.26.3.3.b,1
13. Check for shear

    τv <= Kτc

    τc= nominal shear stress

    τv= design shear strength of concrete (Table19 IS456:2000)

    K= IS456:2000, Cl. 40.2.1.1
14. Check for deflection
15. Check for development length
16. Detailing arrangement of bar

Design of two-way slab

Interior panel: Slab 2-3 A'-B

1. Geometry

Short clear span = 3.495 m

Long clear span = 5.417 m

Total depth of slab, D = 125 mm

Assume clear cover = 15 mm

Assume bar diameter =10 mm

Effective depth of slab in x direction, dx=125-15-10/2=105 mm

Effective depth of slab in y direction, dy=125-15-10/2-10=95 mm

2. Check for one way and two-way slab

Effective length for short span lx = lesser of (3.495+0.4, 3.495+0.105)

$lx_{eff} = 3.6m$

Effective length for long span ly = lesser of (5.417 +0.4, 5.417 +0.095)

$ly_{eff} = 5.512m$

Ratio ly/lx = 1.531 < 2

So, two-way slab is to be designed.

3. Design load

Dead load = 0.125*25 = 3.125 kN/m^2

Live load = 5 kN/m^2

Floor finish = 1.5 kN/m^2

Total load (W) = 9.625 kN/m^2

Factor of Safety (FOS) = 1.5

Design load (Wu) = 1.5*9.625 = 14.4375 kN/m^2

4. Moment calculation

Considering unit width of slab (b) = 1000mm

From IS 456:2000, Table 26

For interior panel,

+ve BM Coefficient:

α_x+ = 0.0415

α_y+ = 0.024

-ve BM Coefficient:

α_x^- = 0.0539

α_y^- = 0.032

From IS 456:2000 Annex D-1.1,

Mx = αx*Wu*lx^2

My = αy*Wu*lx^2

Mx+ = 0.0415*14.4375*3.6^2 = 7.765 KN-m

Mx- = 0.0539*14.4375*3.6^2 = 10.08 KN-m

My+ = 0.024*14.4375*3.6^2 = 4.491 KN-m

My- = 0.032*14.4375*3.6^2 = 5.988 KN-m

Checking for depth at maximum moment,

From IS 456:2000 Annex G-1.1

Depth of slab = $(M_{max}/0.134*b*fck)^{1/2}$

= 54.853mm < 95mm (ok)

5. Calculation of tension steel

From IS 456:2000 Annex G-1.1

$Mu= 0.87f_y A_{st} req * d (1 - \frac{fy\ Ast\ req}{fck\ bd})$

For Ast x+:

$7.765*10^6 = 0.87*500*Ast*105*(1 - \frac{500*\ Ast\ req}{25*1000*105})$

A_{st} req = 172.61mm^2

From IS 456:2000 Cl 26.5.2.1,

A_{st} min = 0.12% of bD = 150 mm^2

For 10mm Ø bars, A_b = 78.54 mm^2

Spacing req = $\frac{\text{Ab}}{\text{Ast req}}$ * b = 455.167 mm

Spacing provided = 250 mm

A_{st} provided = $\frac{\text{Ab}}{\text{spacing}}$ * b = 314.286 mm^2

Provide 10mmØ bars @ 250mm c/c, Ast provided = 314.286 mm^2

Similarly for moment in other directions, the reinforcements have been designed as:

Φ (mm)	Moment (KN-m)		Ast req (mm^2)	Ast min (mm^2)	Spacing req (mm)	Spacing provided (mm)	Ast provided (mm^2)
10	Mx+	7.765	172.6213	150	455.1666	250	314.2857
10	Mx-	10.08	227.6361	150	345.1624	250	314.2857
10	My+	4.491	107.6944	150	729.5775	250	314.2857
10	My-	5.988	144.7545	150	542.7911	250	314.2857

6. Check for shear

Shear force due to design loads;

Vu max= (Wu*lx)/2 = 25.9875 kN

From IS 456:2000 Cl 40.1,

Shear stress, τv =Vu/bd= 0.2475 N/mm^2

τcmax = 3.1 N/mm^2 (IS 456: 2000 Table 20)

For (100*Ast/bd) = 0.299%,

τc = 0.385 N/mm^2 (IS 456: 2000 Table 19)

and K=1.3 (IS 456: 2000 Cl 40.2.1.1)

So, τc' = 1.3*0.385= 0.501 N/mm^2

Hence τcmax > τc' > τv, so design is safe in shear.

7. Check for deflection

From IS 456:2000 CL. 23.2.1

To be safe in deflection,

(lx/d) < = αβγδλ

α = 26

β = 1

For γ:

$fs = 0.58*f_y*\frac{Ast,req}{Ast\ provided} = 159.282\ N/mm^2$

% steel in tension = Ast *100/(bd) = 0.299%

So, modification factor (γ) = 2 (from graph)

δ = 1

λ = 1

lx/d = 3600/105 = 34.286

αβγδλ = 26*1*2*1*1 = 52

(lx/d) < = αβγδλ

Hence, safe in deflection control criteria.

8. Check for development length

From IS 456:2000 Cl 26.2

$L_d = \frac{0.87fy\emptyset}{4\tau bd} = \frac{0.87*500*10}{4*1.6*1.4} = 485.491$ mm

Where τbd = 1.4 for M25 (IS 456:2000 Cl 26.2.1.1)

M_1= 0.87fy*Ast(d-0.42x)

Where x= (0.87fyAst)/(0.36f_{ck}b)

Ast = 314.286 mm^2

M_1 = 13.482 KN-m

V = 25.9875 kN

$1.3M_1/V + L_0$= 1.3*13.482/25.9875 m (taking L_0=0)

= 674.42 mm

> L_d (ok)

9. Torsional reinforcement

All edges are continuous and held down, so no torsion reinforcement is required.

Design of one-way slab

Two adjacent edges discontinuous: Slab 5-6 C-C’

1. Geometry

Short clear span = 2.339 m

Long clear span = 5.417 m

Total depth of slab, D = 125 mm

Assume clear cover = 15 mm

Assume bar diameter =10 mm

Effective depth of slab d=125-15-10/2=105 mm

2. Check for one way and two-way slab

Effective length for short span lx = lesser of (2.339 +0.4, 2.339 +0.105)

lx_{eff} = 2.444 m

Effective length for long span ly = lesser of (5.417 +0.4, 5.417 +0.105)

ly_{eff} = 5.417 m

Ratio ly/lx = 2.259 > 2

So, one way slab is to be designed.

3. Design load

Dead load = 0.125*25 = 3.125 kN/m^2

Floor finish = 1.5 kN/m^2

Sum DL = 4.625 KN/m^2

Live load = 5 kN/m^2

Sum LL = 5 KN/m^2

Factor of Safety (FOS) = 1.5

Design dead load (W_{DL}) = 1.5*4.625 = 6.9375 kN/m^2

Design live load (W_{LL}) = 1.5*5= 7.5 kN/m^2

4. Moment and SF calculation

Considering unit width of slab (b) = 1000mm

From IS 456:2000 Table 12 and 13

Max –ve BM = -(W_{DL}/10 + W_{LL}/9) *L^2

= -(6.9375/10 + 7.5/9) * 2.444^2

= -9.124 KN-m

Max +ve BM = (W_{DL}/12 + W_{LL} /10)*L^2

= (6.9375 /12 + 7.5/10) * 2.444^2

= 7.935 KN-m

Max SF = (0.6* W_{DL} +0.6* W_{LL})/*L

= (0.6* 6.9375 +0.6* 7.5)/* 2.444

= 21.174 KN

Checking for depth at maximum moment,

From IS 456:2000 Annex G-1.1

Depth of slab = $(M_{max}/0.134*b*fck)^{1/2}$ = 52.187 mm < 105mm (ok)

5. Calculation of tension steel

From IS 456:2000 Annex G-1.1

Mu= 0.87f_y A_{st} req $*$ d (1 - $\frac{\text{fy Ast req}}{\text{fck bd}}$)

For Ast +:

9.124 *10^6 = 0.87*500*Ast*105*(1 - $\frac{500*\text{ Ast req}}{25*1000*105}$)

A_{st} req = 208.041 mm^2

From IS 456:2000 Cl 26.5.2.1,

A_{st} min = 0.12% of bD = 150 mm^2

For 10mm Ø bars, A_b = 78.54 mm^2

Spacing req = $\frac{\text{Ab}}{\text{Ast req}}$ * b = 377.673 mm

Spacing provided = 260 mm

A_{st} provided = $\frac{\text{Ab}}{\text{spacing}}$ * b = 302.198 mm^2

Provide 10mmØ bars @ 260mm c/c, Ast provided = 302.198 mm^2

For Ast ⁻ :

$7.935 * 10^6 = 0.87*500*Ast*105*(1 - \frac{500* \text{Ast req}}{25*1000*105})$

A_{st} req = 179.927 mm^2

From IS 456:2000 Cl 26.5.2.1,

A_{st} min = 0.12% of bD = 150 mm^2

For 10mm Ø bars, A_b = 78.54 mm^2

Spacing req = $\frac{\text{Ab}}{\text{Ast req}}$ * b = 436.685 mm

Spacing provided = 260 mm

A_{st} provided = $\frac{\text{Ab}}{\text{spacing}}$ * b = 302.198 mm^2

Provide 10mmØ bars @ 260mm c/c, Ast provided = 302.198 mm^2

Design summary of main bar reinforcement:

Φ (mm)	Moment (KN-m)		Ast req (mm^2)	Ast min (mm^2)	Spacing req (mm)	Spacing provided (mm)	Ast provided (mm^2)
10	M+	9.124	208.041	150	377.673	260	302.198
10	M-	7.935	179.927	150	436.685	260	302.198

6. Check for shear

Shear force due to design loads;

From IS 456:2000 Table 13

Vu max = (0.6* W_{DL} +0.6* W_{LL})/*L = 21.174 kN

From IS 456:2000 Cl 40.1,

Shear stress, τv =Vu/bd= 0.202 N/mm^2

τcmax = 3.1 N/mm^2 (IS 456: 2000 Table 20)

For (100*Ast/bd) = 0.288%,

τc = 0.388 N/mm^2 (IS 456: 2000 Table 19)

and K=1.3 (IS 456: 2000 Cl 40.2.1.1)

So, τc' = 1.3*0.388= 0.504 N/mm^2

Hence τcmax > τc' > τv, so design is safe in shear.

7. Check for deflection

From IS 456:2000 CL. 23.2.1

To be safe in deflection,

(lx/d) < = αβγδλ

α = 23 (avg of simply supported and continuous)

β = 1 (span < 10m)

For γ:

$fs = 0.58*f_y*\frac{\text{Ast,req}}{\text{Ast provided}}$ = 199.644 N/mm^2

% steel in tension = Ast *100/(bd) = 0.288%

So, modification factor (γ) = 1.8 (from graph)

δ = 1, λ = 1

lx/d = 2444/105 = 23.279

αβγδλ = 23*1*1.8*1*1 = 41.4

(lx/d) < = αβγδλ

Hence, safe in deflection control criteria.

8. Check for development length

From IS 456:2000 Cl 26.2

$L_d = \frac{0.87 fy Ø}{4τbd} = \frac{0.87*500*10}{4*1.6*1.4}$ = 485.491 mm

Where τbd = 1.4 for M25 (IS 456:2000 Cl 26.2.1.1)

M_1= 0.87fy*Ast(d-0.42x)

Where x= (0.87fyAst)/(0.36f_{ck}b), Ast = 302.198 mm^2

M_1 = 12.996 KN-m

From IS 456:2000 Table 13

SF at support, V = (0.4 W_{DL} + 0.45 W_{LL})*L

= (0.4*6.938 + 0.45*7.5)*2.444 = 15.032 kN

1.3M_1/V + L_0= 1.3*12.996 /16.594 m (taking L_0=0)

= 1123.928 mm > L_d (ok)

7.2. Design of Beam

A flexural member, the beam supports the applied load. It carries weight by bending. The beam may have a rectangle shape and be made of L and T sections with single and double reinforcement. To meet both serviceability and strength requirements, the cross-sectional dimensions and reinforcement details for beams must be determined. The effective span to effective depth ratio regulates the serviceability requirement for deflection. The depth of the beam is typically substantial and determined by the strength requirement. The reinforcement's spacing determines how serviceable a crack must be. The spacing of reinforcement bars in beams is minimal and dictated by minimum rather than maximum spacing requirements for crack control. To meet the demands for strength, reinforcements are offered. The transverse and longitudinal bars' detailing should be satisfactory.

There are two types of reinforced concrete beams in our case:

a. Singly Reinforced Beams

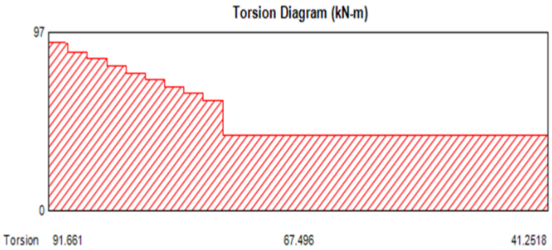
b. Doubly Reinforced Beams

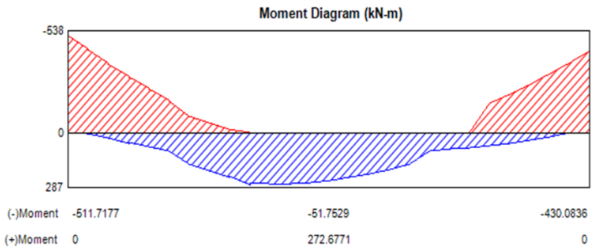
Beam Detailed Design

Load Combination: Envelope

Reference	Step	Calculation	Remarks
IS 456:2000 CL 22.2.b.1	1	**Known data:** characteristics strength of concrete (f_{ck})=25MPa grade of steel(f_y)=500MPa overall depth of beam , D=650mm width of beam ,b=400mm clear cover=30mm take 20mm dis. Bar effective depth=650-30-20/2=610mm Effective span of beam = clear span =7620-800=6820mm	
IS13290:1993 cl.6.1.3 cl.6.1.2 cl.6.1.4	2	**Check for member size** width of beam ,b=400mm>200mm b/D=400/650=0.62 >0.3 clear length ,L=7.62-0.8/2-0.8/2=6.82m L/D=6.82/0.65=10.5 >4	ok ok ok
cl 6.1.1	3	**Check for axial stress:** axial stress =P/A=(0*1000)/(400*650) 0N/mm^2 < o.1f_{ck}(2.5N/mm^2)	ok
IS 456:2000 CL.26.5.1.1 IS13920:2016 CL.6.2.1	4	**Minimum are required ($A_{st,min}$)** $A_{st,min}$=0.85*b*d/f_y =0.85*400*610/500 =414.8mm^2 $A_{st,min}$= 0.24*√fck*b*d/fy =0.24*√25*400*610/500=585.6 mm^2	adopt maximum $A_{st,min}$=585.6mm^2
IS 456:2000 CL.26.5.1.1 CL.26.5.1.2 IS13920:2016	5	**Maximum area required** Tension steel ,$A_{st, max}$=0.04bD=0.04*400*650 =10400mm^2 compression steel , $A_{sc,max}$=0.04bD=0.04*400*650 =10400mm^2 $A_{st,max}$=0.025bD=0.025*400*650=6500mm^2	adopt mimimum $A_{st,max}$=6500mm^2

IS 456:2000 CL.G-1.1 C	6	**Limiting moment ($M_{u/lim}$)** $M_{u,lim}=0.36\frac{X_{u,max}}{d}(1-0.42\frac{X_{u,max}}{d})bd^2 f_{ck}$ $M_{u,lim}$=0.36*0.46*(1-0.42*0.46)*400*610^2*25 =497.15KNm where, $X_{u,max}$=0.46 (cl.38.1)	





IS 456:2000 cl.41.4 **IS 456: 2000** **Table 55**	7	**Design for moments** **for left end** hogging moment ,M_u=511.72kNm torsional moment ,T_u=91.66KNm moment due to torsion ,M_t= $T_u(\frac{1+D/b}{1.7})$ =91.66(1+650/400)/1.7=141.53KNm equivalent bending moment ,$M_e=M_u+M_t$ =653.26KNm here $M_e > M_{u,lim}$, so design as doubly reinforced section. d'/d=40/610=0.066 adopt nearest higher ratio i.e. 0.1 M_e/bd^2=4.4 P_t=1.219 A_{st}=2974.36mm^2 P_c=0.298 A_{sc}=727.12mm2 But Asc must be 50% of Ast at the least Adopt A_{sc}=1487.18mm2 sagging moment , Mu=0	> $A_{st.min}$ <$A_{s,min}$

		torsional moment, Tu=91.66KNm	
		Moment due to torsion=141.53KNm equivalent bending moment, Me=141.53KNm Here M_e $<M_{u,lim}$, so design as singly reinforced section.	
IS 456:2000 **table 3**		Me/bd2=0.095 P_t=0.229	
		Area of steel ,Ast=558.76mm2 adopt Ast=Asc=585.6mm2	$<A_{st,min}$
		for mid span hogging moment ,Mu=51.75kNm torsional moment , Tu= 67.5KNm moment due to torsion , M_t=67.5*(1+650/400)/1.7 =104.23KNm equivalent bending moment ,Me=Mu+Mt = 155.98KNm Here Me $<M_{u,lim}$ so design as singly reinforced section.	
IS 456:2000 **table 3**		Me/bd2=1.05 Pt=0.255	
		Area of steel ,A_{st}=622.2mm^2 provide Asc= maximum of (50%of Ast or Ast,min) =585.6mm2	$>A_{st,min}$
		sagging moment ,Mu=272.68kNm	
IS 456:2000 **CL 41.4**		torsional moment , Tu= 67.5KNm moment due to torsion , M_t=67.5*(1+650/400)/1.7 =104.23KNm equivalent bending moment ,Me=Mu+Mt = 376.91KNm Here Me $<M_{u,lim}$ so design as singly reinforced section.	
IS 456:2000 **table 3**		Me/bd2=1.05 Pt=0.673 Area of steel ,A_{st}=1642.12mm^2 provide Asc= maximum of (50%of Ast or Ast,min) =821.06mm2	
		for right end hogging moment ,Mu=430.08kNm	
IS 456:2000 **CL 41.4**		torsional moment , Tu= 41.25KNm moment due to torsion , M_t=41.25*(1+650/400)/1.7	

		=63.69KNm equivalent bending moment ,Me=Mu+Mt = 493.75KNm	
IS456:2000 table 3 **IS 456:2000 CL.41.4** **IS 456:2000 table 3**		Here Me <$M_{u,lim}$ so design as singly reinforced section. Me/bd2=3.32 Pt=0.942 Area of steel ,A_{st}=2298.48mm^2 provide Asc= maximum of (50%of Ast or Ast,min) =1149.24mm2 sagging moment ,Mu=0kNm torsional moment , Tu= 67.5KNm moment due to torsion , M_t=67.5*(1+650/400)/1.7 =104.23KNm equivalent bending moment ,Me=Mu+Mt = 104.23KNm Here Me <$M_{u,lim}$ so design as singly reinforced section. Me/bd2=0.7 Pt=0.167 Area of steel ,A_{st}=407.48mm^2 provide , Ast=Ast,min=585.6mm2 provide Asc= maximum of (50%of Ast or Ast,min) =585.6mm2	>Ast, min <Ast,min

Summary of longitudinal reinforcement detailing:

Position	**Area Required**	**Bars**	**Area Provided**
Left Top	2974.36	4-25Φ+4-20Φ	3220.13
Left Bottom	1487.18	4-25Φ	1963.5
Mid Top	821.06	4-20Φ	1256.64
Mid Bottom	1642.12	4-25Φ	1963.5
Right Top	2298.48	4-25Φ+4-20Φ	3220.13
Right Bottom	1149.24	4-25Φ	1963.5

IS 13290:2016 cl. 6.3.3	8	**Shear force due to formation of plastic hinge at both ends of beam plus factored gravity load on span** **for sway to right** $V_{u,a} = V_{u,a}^{D+L} - 1.4\,\frac{M_u^{As}+M_u^{Bh}}{L_{AB}}$ and $V_{u,b} = V_{u,b}^{D+L} + 1.4\,\frac{M_u^{As}+M_u^{Bh}}{L_{AB}}$	
		for sway to left $V_{u,a} = V_{u,a}^{D+L} - 1.4\,\frac{M_u^{Ah}+M_u^{Bs}}{L_{AB}}$ $V_{u,b} = V_{u,b}^{D+L} + 1.4\,\frac{M_u^{Ah}+M_u^{Bs}}{L_{AB}}$ here, $V_{u,a}^{D+L}$=185.5KN $V_{u,b}^{D+L}$=183.2KN $M_u^{AH}=M_u^{BH}$=591.27KNm $M_u^{AS}=M_u^{BS}$=435.89KNm L_{AB}=7.62m at left end ,Vu,a=-3.21KN or 371.92KN at right end , Vu,b=-3.21KN or 371.92KN at mid span , Vu= 188.72KN	From Etabs From Etabs hogging/sagging moments of resistance at Aand B from above eqations from above eqations from above eqations
is 456:2000 cl.41.3.1	9	**Design shear force** at left end, Vu=maximum of (347.46, 371.92)=371.92KN Tu=91.66KNm equivalent shear Ve=Vu+ 1.6*Tu/b=738.56KN at mid span , Vu= maximum of(285.09, 188.72)=285.09 Tu=67.5KNm equivalent shear Ve=Vu+ 1.6*Tu/b=555.09KN at right end , Vu=maximum of (335.44,371.92)=371.92	

		Tu=41.25KNm equivalent shear Ve=Vu+ 1.6*Tu/b=536.92KN	
IS 456:2000 **table 19** **table 20**	10	**Check for shear** **left end** Ast provided =3220.13mm2 Ast*100/bd=1.32 design shear strength ,τ_c=0.711N/mm2 maximum shear strength , $\tau_{c,max}$=3.1N/mm2 equivalent nominal shear stress ,τ_{ve}=Ve/bd=3.02/mm2 $\tau ve > \tau c$, transverse reinforcement should be provided.	 $< \tau c,max$
  cl.41.4.3 **IS 13920:2016 cl.6.3.5** **IS 456:2000** **table 19** **table20**		Let us consider 10mmφ-2legged vertical stirrups so Asv=157.08mm2 spacing of stirrups is given by , $S_v = \frac{0.87 f_y A_{sv} b_1 d_1}{T_u + 0.4 V_u b_1}$ where , b1=400-2*30-2*10-25=295mm d1=650-2*30-2*10-25=545mm so Sv=81.05mm also Sv=0.87fyAsv/(τve-τc)b=73.76mm spacing of stirrups over a length of 2d (1220mm) should be smaller than a. d/4=152.5mm b. 8dia$_{\text{smallest log. Bar}}$=8*20=160mm c. 100mm so , provide Sv=70mm **at mid span** Ast provided =1963.5mm2 Ast*100/bd=0.8 design shear strength ,τ_c=0.585N/mm2 maximum shear strength , $\tau_{c,max}$=3.1N/mm2 equivalent nominal shear stress ,τ_{ve}=Ve/bd=2.275mm2 $\tau ve > \tau c$, transverse reinforcement should be provided.	 $<\tau c,max$

		Let us consider 10mmφ-2legged vertical stirrups so Asv=157.08mm2 spacing of stirrups is given by , $S_v = \frac{0.87 f_y A_{sv} b_1 d_1}{T_u + 0.4 V_u b_1}$ where , b1=400-2*30-2*10-25=295mm d1=650-2*30-2*10-25=545mm so Sv=108.08mm also Sv=0.87fyAsv/(τve-τc)b=101.08mm spacing of stirrups over the remaining length of beam should be smaller than d/2 (i.e.305mm)	
		so , provide Sv=100mm **right end** Ast provided =3220.13mm2 Ast*100/bd=1.32 design shear strength ,τ_c=0.711N/mm2 maximum shear strength , $\tau_{c,max}$=3.1N/mm2 equivalent nominal shear stress ,τ_{ve}=Ve/bd=2.2/mm2 τve>τc , transverse reinforcement should be provided. Let us consider 10mmφ-2legged vertical stirrups so Asv=157.08mm2 spacing of stirrups is given by , $S_v = \frac{0.87 f_y A_{sv} b_1 d_1}{T_u + 0.4 V_u b_1}$ where , b1=400-2*30-2*10-25=295mm d1=650-2*30-2*10-25=545mm so Sv=129.03mm also Sv=0.87fyAsv/(τve-τc)b=114.7mm spacing of stirrups over a length of 2d (1220mm)	$<\tau c,max$

		should be smaller than a. d/4=152.5mm b. 8dia$_{smallest\ log.\ Bar}$=8*20=160mm c. 100mm so , provide Sv=100mm	
	11	**provision for shear reinforcement** Provide 2-legged 10mmφ stirrup @ c/c upto a length of 2d=1220mm from left end =70 mm Provide 2legged 10mmφ stirrup @ c/c at midspan =100mm Provide 2-legged 10mmφ stirrup @ c/c upto a length of 2d=1220mm from right end =70 mm	
IS 456:2000 CL.23.2.1	12	**check for deflection** L/D < α β γ δ λ α=26 β=1 *For* γ, fs=0.58*fy*Ast,req/Ast,prov=0.58*500*1642.12/1963.5 =242.5N/mm2 Ast(%)=0.8% so , γ=1.05 for δ Asc(%)=1256.64*100/(400*610)=0.5% so δ=1.15 λ=1 for rectangular beam now α β γ δ λ =31.395 for effective span of beam= c/c distance of beam=6820mm L/D =6820/650=10.5	< α β γ δ λ ,ok
IS 456:2000 CL.26.2.1.1	13	**Check for development length** τbd=1.4N/mm2 Ld=0.87fyØ/4τbd=0.87*500*25/(4*1.4*1.6)=1214mm	

CL.26.2.1 **CL26.2.3.3**		now M1=591.27KNm V=738.56KN Lo=12Φ=12*25=300mm so , 1.3*M1/V+Lo=1340.7mm	>Ld, ok
IS 456:2000 **CL 26.5.1.7** **CL 26.5.1.3**	14	**Provision of side reinforcement** For depth of beam > 450mm, additional longitudinal bar should be provided . Total area of side reinforcement > 0.1%*web area =260mm2 Provide 2-16mm bars on both sides of beam .	

7.3. Design of Column

Columns are vertical structural components that are primarily affected by axial forces. They are structural elements that transmit loads from a structure's slab (the roof or upper floors) to its foundation and the ground beneath it.

Column may be categorized as either a short column or a long column based on slenderness ratio. A lengthy column typically fails through buckling while a short column typically fails by direct compression. The ratio of the effective length to the column's least lateral dimension is used to represent slenderness.

Columns can be also be categorized as either axially loaded, uniaxially loaded, or biaxially loaded depending on how they are loaded.

According to IS Code 456:2000, the design of biaxially loaded column members can be obtained by following equation,

$(Mux/Mux1)^{\alpha n} + (Muy/Muy1)^{\alpha n} \leq 1.0$ where,

Mux, Muy = Moments about x and y axes respectively due to design loads

Mux1, Muy1= Maximum uniaxial moment capacities with an axial load Pu, bending about x and y axes respectively,

αn is related to Pu/Puz

Puz = 0.45 fck*Ac + 0.75 fy *Asc

Ac= Gross Cross-section area of column

Asc = Area of reinforcement

fy = Characteristic strength of reinforcement bar

fck = Characteristic strength of concrete

Column Detailed Design

Column A6 (First Floor)

(0.9(SW+WL+FF+LDL+EP+SDL) +1.5EQy)

Reference	Calculation	Output	Unit	Remark
	1. Material Properties			
	Grade of concrete used (fck)	M25		
	Grade of steel used (fy)	Fe500		
IS 13920:2016 CL.7.1	**2.Check for Axial Stress**			
	Max. Factored Load	2729.17	kN	
	Max. axial stress	4.26	N/mm^2	
	0.1fck	2.5	N/mm^2	
	Axial stress>0.1fck, OK.			
IS 13920:2016 Cl 7.1.2	**3.Check for Member Size**			
	Depth of column(Dy)	800	mm	>300mm
	Width of column(Dx)	800	mm	>300mm
	Dx/Dy	1	>0.4	
	Hence, design as a column member.			
	4. Member Properties			
	Length of column	3.9624	m	
	Depth of beam	0.65	m	
	Effective length factor (Kx)	0.96		
	Effective length factor (Ky)	0.96		
	Unsupported length of column	3.3124	m	
	Effective length of column(Lex)	3.179	m	
	Effective length of column(Ley)	3.179	m	
	Width of column (Dx)	0.8	m	
	Depth of column (Dy)	0.8	m	
	$\varphi_{l,max}$	28	mm	
	Effective cover	60	mm	(clear cover>= 40mm)
	5. Load Data			
	Axial load of column(Pa)	2729.17	kN	
	Moment about X- axis	330.42	kN -m	
	Moment about Y- axis	10.185	kN -m	

IS456:2000 Cl.25.1.2	**6. Slenderness Check** Lex/Dx Ley/Dy MOI of column=bd^3/12 MOI of beam section=bd^3/12 Length of adjoining beam Height of column Flexural stiffness: For column, kc=MOI*E/L For beams, kb=MOI*E/L	 3.9748 3.9748 0.0239 0.00283 7.62 3.3124 0.0072 0.00037	 <12 <12 m^4 m^4 m m	Design as short column x0.7 x0.35
Clause 25.2 Annex E	So, $\beta_1=\beta_2=\Sigma$ Kc / (Σ Kc +Σ Kb) =2*Kc/(2Kc+2Kb) Type of Frame (Sway or Non-sway) Stability index (Qx=0.00738 ,Qy=0.00633) It is non-sway frame as per calculated For non-sway frame	0.951	 <0.04	0.7 and 0.35 taken as modifier for cracked section
Fig 26	Effective length ratio for both axes Slenderness ratio=kL/d	0.96 5.29984	 <12	column is short
IS456:2000 CL.25.4	**7. Check for Ecentricity** minimum ecentricities ex, min ey, min Hence, e,min moment due to ecentricity Muxe Muye Now, Design Moment Mux Muy	 34.59 34.59 34.59 94.4 94.4 330.42 94.4	 >20mm mm kN -m kN -m kN -m kN -m	

	8. Longitudinal Reinforcement Limiting Longitudinal Reinforcement			
	Min. Reinforcement=0.8%of Area	5120	mm^2	
	Max. Reinforcement=4% of Area	25600	mm^2	
	But in extreme cases;			
	Max. Reinforcement=6% of Area	38400	mm^2	
	Assume percentage of steel(Pt)	1.50%	(0.8-4)	
	Area of steel required (Asc req)	9600	mm^2	
	Let us provide ,16 bars of 28mmdia			
	Area of steel provided	9856	mm^2	
	Let us provide ,16 bars of 28mmdia			
	d'/D	0.075=0.1		
	Trial 1: take p=1.5%			
	p/ f_{ck}	0.06		
	Pu/(fck*Dx*Dy)	0.17		
	Mux1/(fck*Dx2*Dy)	0.09		
	Muy1/(fck*Dy2*Dx)	0.09		
Sp-16 Chart 48	Mux1	1152	kN -m	
	Muy1	1152	kN -m	
IS456:2000 CL.39.6	Puz=0.45fckAc+0.75fyAsc	10710	kN	
	Pu/Puz=	0.23		
	αn=	1.04		
	(Mux/Mux1)αn+(Muy/Muy1)αn=	0.36	<1	
	9. Design for shear			
	Percentage steel provided in tension=	1.52	%	
	Design shear strength of concrete, τc =	0.74	N/mm^2	
IS 456:2000 Cl 40.2.2	Shear strength of members under axial compression			
	δ=1+3Pu/(Agfck)	1.511	>1.5	Take 1.5
	Actual τc=	1.11		
	Shear capacity of the section, Vcx=Vcy =	710.4	kN	
	End moment of the beam	M_R^{LS}	M_R^{LH}	
	Moment from Etabs kNm(X axis)	102.4578	102.4578	
	Moment from Etabs kNm(Y axis)	0	0	

IS13920:2016 Cl 7.5	End moment of the beam Moment from Etabs kNm(X axis) Moment from Etabs kNm(Y axis) Shear force due to plastic hinge $1.4(M_R^{LS}+M_R^{RH})/H$ or $1.4(M_R^{RS}+M_R^{LH})/H$ V_{px1} V_{py1} Design shear forces Vu_x= Vu_y=	M_R^{RS} 0 102.4578 72.4 72.4 72.4 72.4	M_R^{RH} 0 102.4578 kN kN kN kN	 >Vu from etabs >Vu from etabs
IS456:2000 Table 20 IS 456:2000 CL.40.3	Maximum shear stress: τ_{cmax} for M25= τ_{vx}=Vdx/A τ_{vy}=Vdy/A τ_{cdx} τ_{cdy} Minimum shear reinforcement $A_{svmin}/S_v=0.4*b/0.87*f_y$ f_y is taken as 415N/mm^2 as per Cl 26.5.1.6	 3.1 0.113125 0.113125 1.11 1.11 886.3	 N/mm^2 N/mm^2 N/mm^2 N/mm^2 N/mm^2 mm2/m	
IS 456:2000 cl.26.5.3.2 (C.2) NBC105AnnexA Cl 4.2.3 IS 456:2000 Cl 26.5.3.2c	**10. Design of Transverse Reinforcement** **Diameter of ties** φ_t must be greater than equal to a) 6mm b)1/4*28mm (we used 28mm for longitudinal bars) Hence adopt ties of 8mm φ Area of tie (two legged)= **Spacing of the ties** S_v <= 1/2 least lateral dimension of the compression member ie = S_v <= 16 times the dia of smallest longitudinal bar	 7 8 100.57 400 448	 mm mm mm^2 mm mm	
	Sv <=	300	mm	

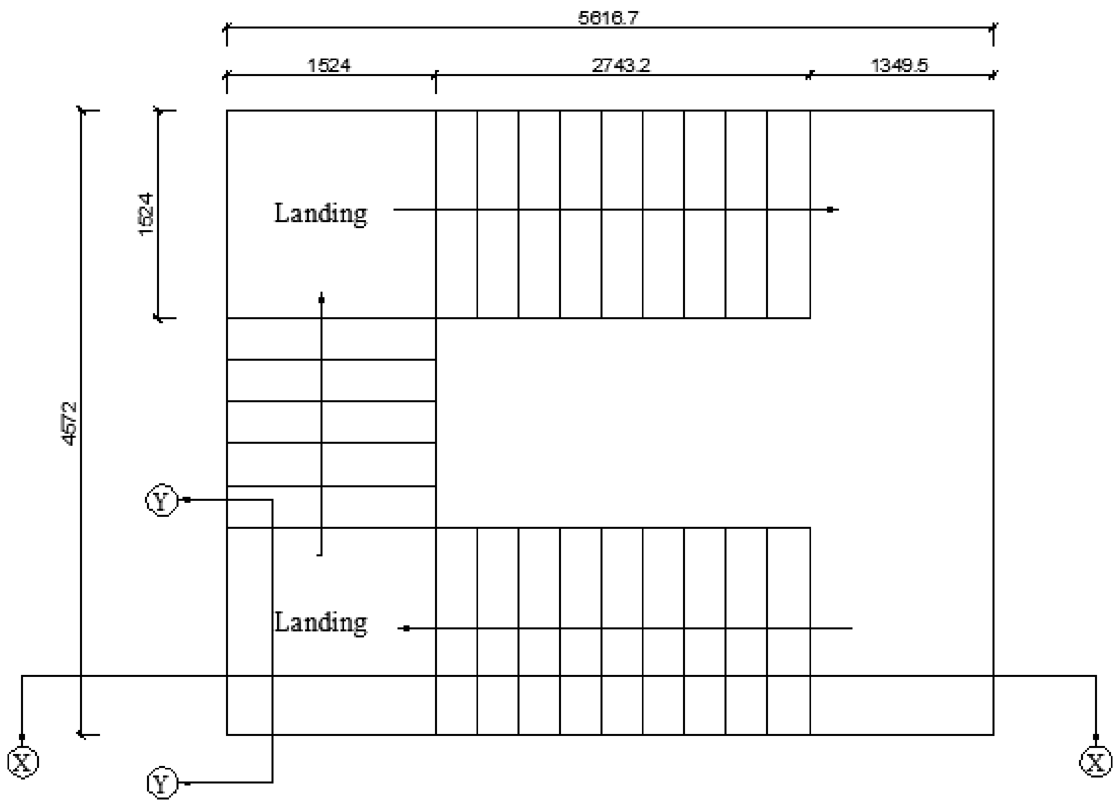
	Spacing of the ties= Area/Asvmin/Sv Thus provide 8mm φ lateral ties @ 110mm c/c in the central part	113.471	mm	
IS456:2000 CL.26.2.1	**11. Splicing of vertical bars** Maximum of 50% bars should be spliced at a section and the clear overlap of the spliced section should be more than development length (Ld) of the largest bars clear length of lap, maxm of: Ld=0.87fyφ/(4τbd) 24f Thus, clear length of lap splice	 1087.5 672 1100	 mm mm mm	 f=nominal bar diameter
IS13920:2016 Cl.8.1.b **IS13920:2016 Cl.8.1.a**	**12. Design of Special confining hoops** Spacing of hoop a) <=100mm b) <=min of (Dx/4 or Dy/4) c) 6*dia of smallest longitudinal reinforcement Lo shall not be less than a) Larger lateral dimension b) 1/6 of clear span c) 450mm Thus, Lo	 100 200 168 800 552.33 450 800	 mm mm mm mm mm mm mm	
IS13920:2016 **Cl.8.1.c**	**13. Check for Special confinement reinforcement** Ash=0.18*S*h*fck/fy(Ag/Ak -1) Dx' Dy' Ak=Dx'*Dy' Ag=Dx*Dy h Ash=pf^2/4 Hence, Sc Provide Spacing	 680 680 462400 640000 169 50.286 101 100	 mm^2 mm^2 mm mm^2 mm mm	 <300 mm OK

7.4. Design of Staircase

Stairs are a set of steps which make it possible to access each floor of the building. The place of the staircase has to be carefully considered, given that it is often the only means by which all floors of a building can communicate. Stairs consists of flight and landing. Flight is the inclined slab consisting of risers and trades whereas the landing is the horizontal slab. The design of flight is similar to one way slab.

The design of staircase requires proportioning of its different component, determination of reinforcement and its detailing to satisfy both the serviceability and strength requirement. The geometrical forms of staircases may be quite different depending on the individual circumstances involved. The geometrical shape and structural arrangement of a staircase depends upon the functional usage, number of floors and the availability of staircase space.

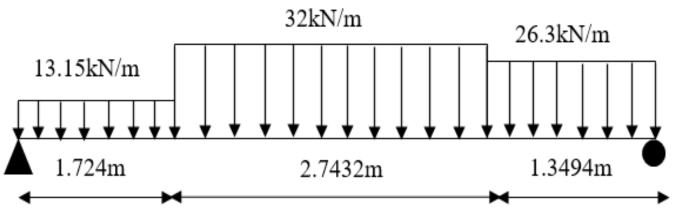
In our building, open well staircase is used.



OPEN WELL STAIRCASE- PLAN

Staircase Detailed Design

Reference	Steps	Calculation	Output/Remarks
IS 456: 2000 Clause 33.1(c)	**1**	**Known data:** Floor height= 13' (3.9624m) Tread width(T)= 1' (304.8mm) Riser height (R)= 6" (152.4mm) Number of risers= 10 Number of treads= 9 Length of going= 9' (2.7432m) Width of flight= 5' (1.524m) Beam thickness= 400mm Wall thickness= 260mm Total effective span= 5.8166m **Assumed data:** Depth of waist slab (D)= 200mm Clear cover (CC)= 20mm Diameter of main bars= 16mm Diameter of distribution bars= 10mm Effective depth(d)= 164mm	
IS 456: 2000 Cl. 33.2	**2**	**Load calculation** Imposed load= 5kN/m^2 Floor finishes= 1.5kN/m^2 $cos\,\theta = \frac{T}{\sqrt{R^2 + T^2}}$ cosΘ= 0.8944 Total load on landing= 11.5kN/m^2 Self-weight of waist slab= 25*0.2/0.8944= 5.5902kN/m^2 Self-weight of steps= 0.5*25*0.1524= 1.905kN/m^2 Total load on going= 14kN/m^2 Factored load on landing= 11.5*1.5= 17.25kN/m^2 Factored load on going= 14*1.5= 21kN/m^2 Load intensity on landing= 17.25* 1.524= 26.289kN/m Load intensity for common landing area = 26.289/2= 13.1445kN/m	

		Load intensity on going= 21*1.524= 32kN/m	
	3	**Analysis**  Calculation of reactions: Reaction at lower support(beam)= 81.425kN Reaction at upper support(wall)= 64.473kN Position of zero shear from upper support= 3.03m Maximum bending moment(M)= 118.94kNm	
IS 456: 2000 ANNEX G-1.1 **IS 456: 2000 Cl. 26.3.3(b)(1)**	**4**	**Design** Main bars/ Longitudinal bars: Effective depth from BM criteria: $d = \sqrt{\frac{M}{0.138 * f_{ck} * b}}$ d= 137.30mm Area of steel required Ast: $M = 0.87 f_y A_{st} \left(d - 0.416 * \frac{0.87 * f_y \times A_{st}}{0.36 * f_{ck} \times b} \right)$ Ast= 1910.67mm^2 Area of each bar= 201.09mm^2 Required spacing= (201.09/1910.67)*1524= 160.39mm Maximum spacing= 300mm or 3d= 300mm or 492mm Provide spacing= 150mm Area of steel provided= 2043.05mm^2 **Provide 16mm bars @150mm c/c** Distribution bars:	fck= 30N/mm2 fy= 500N/mm2 <164mm, OK

IS 456: 2000 Cl. 26.3.3(b)(2)		Area of distribution bar required =0.12% of bD= 365.76mm2 Area of each bar= 78.55mm^2 Required spacing= (78.55/365.76)*1000= 327.29mm Maximum spacing= 450mm or 5d= 450mm or 820mm Provide spacing= 300mm **Provide 10mmφ bar @300mm c/c**	
IS 456: 2000 Clause 40.1	5	**Check for shear** Nominal shear stress: $\tau_v = \frac{V_u}{bd}$ τ_v=0.33N/mm^2 Percentage of steel= 100* 2043.05/(1524*164)= 0.82%	
IS 456: 2000 Table 19		τ_c= 0.61N/mm^2	For 0.82% steel and M30 grade concrete
IS 456: 2000 Clause 40.2.1.1		k= 1.20	For overall depth of slab 200mm
		Design shear stress: τ_{ck}= 0.61*1.20= 0.73N/mm^2	> 0.33N/mm^2, OK
IS 456: 2000 Table 20		Maximum shear stress, $\tau_{c\,max}$= 3.5N/mm^2	>0.73N/mm^2, OK
IS 456: 2000 Clause 26.2.1	6	**Development length** $L_d = \frac{0.87 fy Ø}{4\tau_{bd}}$	
IS 456: 2000 Clause 26.2.1.1		τ_{bd}= 1.6*1.5 L_d= (0.87*500*16)/(4*1.6*1.5)= 725mm Provide L_d= 750mm	

7.5. Design of Mat Foundation

Foundations are the subsurface structure that transfers loads from the buildings or individual to the earth. Foundations must be designed to transfer the loads without exceeding the safe bearing capacity. Additionally, it must prevent excessive settlement, and minimize differential settlement. Most of the foundations used in structures are classified as:

- Footing
- Combined footing
- Raft or mat foundation.
- Pile foundation
- Isolated

The type of foundations to be used in a given situation depends on a number of factors, like:

- Soil strata
- Bearing capacity of soil
- Type of structure
- Type of loads
- Permissible differential settlement and
- Economy

Normally, in residential buildings load from superstructure are small enough to be transmitted by isolated footings, spread footings and combined footings. However, in large commercial buildings the loads to be transmitted from the superstructure are heavy to the extent that the individual footings might overlap or require more than 50% of total area. In such cases, a large area footing called raft footing is required. This footing is preferred even in cases of low soil bearing pressure or high settlement.

Raft foundation is designed using rigid foundation design method where foundation is assumed to be rigid and pressure distribution on soil is linearly varying. The analysis requires determination of contact pressure under the raft, which is done as per IS 2950(Part I) – 1981 Appendix D. The raft is analyzed as a whole in each of the two perpendicular directions. In case of uniform conditions when the variations in adjacent column loads and column spacing do not exceed 20% of the higher value, raft may be divided into perpendicular strips of widths equal to the distance between mid-spans and each strip may be analyzed as an independent beam with known column loads and known contact pressures. Such beams will not normally satisfy statics due to shear transfer between adjacent strips and the design maybe based on moment distribution (IS 2950(Part I) 1981).

Design Methodology

Collection of known data and assumed data

↓

Extraction of reaction forces from ETABS to excel for desired load combinations

↓

Calculation of C.G from the plan of the building

↓

Calculation of the centre of forces from the reaction forces

↓

Calculation of eccentricity (ex, ey)

↓

Calculation of soil pressure at extreme points and comparison with allowable soil pressure for service load combination

↓

Calculation of soil pressure under columns for design load combination

↓

Division of raft into design strips in each direction and calculation of design moment for top and

↓

Calculation of depth of foundation from moment consideration and check for two way shear

↓

Calculation of reinforcements for the design bending moment

Known Data:

Unit weight of the soil (γ) = 18 kN/m^3

Service Load (P) = 115632.62kN (1.5(DL + LL))

Grade of the Concrete = M25

Grade of the Steel = Fe500

Bearing Capacity of the Soil (q) = 165 kN/m^2

Angle of repose of the soil (Φ) = 30°

As per IS 1893:(Part 1): 2016, CL 6.3.5.2, when earthquake forces are included, net bearing pressure in soil can be increased depending on the type of the foundation and type of soil. For the raft foundation and stiff soil, this can be increased upto 25 %.

Therefore, for load cases, including earthquake force:

q =1.25*165 = 206.25 kN/m^2

Depth of the raft foundation shall not be less than 1m (IS 2950 (Part 1) - 1981, CL 4.3):

$Df = \frac{q}{\gamma}$ = 0.987 m < 1 m

So, depth of raft foundation should be at least 1m.

Considering axial transfer of the load to the foundation, the area of the soil required to sustain the foundation load is given as:

Area of the soil required = (service load transferred + self wt. of the foundation) / safe bearing capacity of the soil

= 1.1 * (115632.62/1.5)/165

= 513.92 m^2

Plinth area of the building = 1019.29 m^2

Area of the soil required > 50% of Plinth area.

So, Mat Foundation is designed.

Label	FZ kN	Global X mm	Global Y mm	MX kN-m	MY kN-m	p*x	p*y
1	1178.7842	5.8166	0	67.3859	-24.575	6856.516	0
2	3370.316	5.8166	7.62	-0.3634	-7.9011	19603.78	25681.81
3	3427.7271	5.8166	15.24	-0.063	-8.2325	19937.72	52238.56
4	4024.1342	5.8166	22.86	29.0155	-18.6932	23406.78	91991.71
5	1556.4684	5.8166	30.48	-99.9299	-79.1436	9053.354	47441.16
6	794.3753	5.8166	36.2712	11.2019	-18.1395	4620.563	28812.95
7	1182.0767	11.6332	0	65.6275	-23.5735	13751.33	0
8	3455.1878	11.6332	7.62	-0.58	-12.6691	40194.89	26328.53
9	3454.833	11.6332	15.24	-0.1588	-12.9564	40190.76	52651.65
10	3482.8627	11.6332	22.86	-1.3582	-13.462	40516.84	79618.24
11	3282.5151	11.6332	30.48	3.5418	-11.6603	38186.15	100051.1
12	906.428	11.6332	36.2712	-66.5317	-26.5102	10544.66	32877.23
13	1186.2304	17.4498	0	65.4854	-23.559	20699.48	0
14	3454.7363	17.4498	7.62	-0.7463	-12.0926	60284.46	26325.09
15	3480.7455	17.4498	15.24	-1.4525	-11.3392	60738.31	53046.56
16	3494.2625	17.4498	22.86	-0.5068	-11.6483	60974.18	79878.84
17	2996.2899	17.4498	30.48	20.3349	-12.8479	52284.66	91326.92
18	706.6633	17.4498	36.2712	-114.1342	-20.9757	12331.13	25631.53
19	1251.928	23.2664	0	66.5569	-16.4055	29127.86	0
20	3381.5739	23.2664	7.62	-0.2405	-16.3675	78677.05	25767.59
21	4085.5426	23.2664	15.24	-13.678	-13.8212	95055.87	62263.67
22	4291.7399	23.2664	22.86	-24.5252	-14.6362	99853.34	98109.17
23	3334.8506	23.2664	30.48	2.9667	-13.8546	77589.97	101646.2
24	933.7766	23.2664	36.2712	-66.4808	-15.6307	21725.62	33869.2
25	1784.9304	29.083	0	65.3162	-41.8172	51911.13	0
26	1677.8449	29.083	7.62	-65.8876	-10.0824	48796.76	12785.18
27	1444.609	29.083	15.24	-3.4162	-14.2703	42013.56	22015.84
28	1563.5589	29.083	22.86	0.5872	-7.7912	45472.98	35742.96
29	1120.8463	29.083	30.48	-8.3272	-12.1076	32597.57	34163.4
30	1227.7803	29.083	36.2712	7.5829	-40.8118	35707.53	44533.06
31	1056.8331	0	0	-11.4185	-9.5221	0	0
32	1107.8822	0	7.62	2.9842	-72.9002	0	8442.062
33	1150.0453	0	15.24	-2.2322	-73.8222	0	17526.69
34	1319.1975	0	22.86	-7.0268	-61.3653	0	30156.85
35	1378.9773	0	30.48	17.5199	-2.138	0	42031.23
80	91.4289	6.2044	36.2712	-1.8417	-0.899	567.2615	3316.236
81	95.1753	6.5921	36.2712	-4.6783	-1.0665	627.4051	3452.122
82	94.9233	6.9799	36.2712	-7.1716	-1.0685	662.5551	3442.982
83	95.0623	7.3677	36.2712	-8.9212	-1.1296	700.3905	3448.024
84	95.5823	7.7555	36.2712	-10.0287	-1.1686	741.2885	3466.885

86	96.0811	8.1432	36.2712	-10.6614	-1.205	782.4076	3484.977
88	96.5283	8.531	36.2712	-10.9459	-1.2227	823.4829	3501.197
90	96.9318	8.9188	36.2712	-10.9488	-1.2543	864.5153	3515.833
91	97.4793	9.3066	36.2712	-10.6778	-1.2718	907.2009	3535.691
92	97.6599	9.6943	36.2712	-10.0824	-1.2785	946.7444	3542.242
93	98.018	10.0821	36.2712	-9.0545	-1.3198	988.2273	3555.23
94	97.8427	10.4699	36.2712	-7.4478	-1.3019	1024.403	3548.872
95	97.2335	10.8577	36.2712	-5.169	-1.381	1055.732	3526.776
96	101.9167	11.2454	36.2712	-2.6429	-1.2118	1146.094	3696.641
97	189.3054	0	23.368	-0.4431	-4.4561	0	4423.689
98	191.2022	0	23.876	-0.3939	-8.593	0	4565.144
99	193.9089	0	24.384	-0.3122	-11.7667	0	4728.275
100	196.1971	0	24.892	-0.1681	-13.8306	0	4883.738
101	202.8046	0	25.4	0.4244	-15.2575	0	5151.237
102	211.4019	0	25.908	0.1033	-16.3503	0	5477
103	211.9617	0	26.416	0.169	-17.2066	0	5599.18
104	206.9716	0	26.924	-0.1495	-17.7657	0	5572.503
105	199.1519	0	27.432	0.4084	-17.8669	0	5463.135
106	198.3721	0	27.94	0.6119	-17.2967	0	5542.516
107	197.4962	0	28.448	0.6785	-15.8071	0	5618.372
108	202.262	0	28.956	1.3782	-13.1207	0	5856.698
109	207.0455	0	29.464	0.9942	-8.9885	0	6100.389
110	209.555	0	29.972	1.0037	-3.9313	0	6280.782
111	155.5224	0.3878	30.48	-1.8865	-0.2593	60.31159	4740.323
112	155.8133	0.7755	30.48	-5.1602	-0.3817	120.8332	4749.189
113	155.5983	1.1633	30.48	-8.3088	-0.4933	181.0075	4742.636
114	152.5456	1.5511	30.48	-10.8185	-0.4294	236.6135	4649.59
115	150.3931	1.9389	30.48	-12.6461	-0.7396	291.5972	4583.982
116	150.786	2.3266	30.48	-13.8357	-0.8427	350.8187	4595.957
117	150.959	2.7144	30.48	-14.4283	-0.9423	409.7631	4601.23
118	151.1663	3.1022	30.48	-14.446	-1.0653	468.9481	4607.549
119	151.5884	3.49	30.48	-13.8949	-1.1785	529.0435	4620.414
120	151.5221	3.8777	30.48	-12.7644	-1.286	587.5572	4618.394
121	151.63	4.2655	30.48	-11.0242	-1.485	646.7778	4621.682
122	150.5821	4.6533	30.48	-8.6371	-1.6399	700.7037	4589.742
123	149.3237	5.0411	30.48	-5.6399	-2.0268	752.7557	4551.386
124	157.5508	5.4288	30.48	-2.5511	-1.9682	855.3118	4802.148
125	149.9699	5.8166	30.8661	-0.288	-2.6811	872.3149	4628.986
126	144.6204	5.8166	31.2522	-0.0381	-5.2022	841.199	4519.706
127	139.9057	5.8166	31.6382	0.2911	-7.514	813.7755	4426.365
128	135.7162	5.8166	32.0243	0.4775	-9.1509	789.4068	4346.216
129	131.0148	5.8166	32.4104	0.6185	-10.2035	762.0607	4246.242

130	126.4429	5.8166	32.7965	0.6902	-10.8155	735.4678	4146.885
131	121.8203	5.8166	33.1826	0.7271	-11.0966	708.58	4042.314
132	117.4294	5.8166	33.5686	0.772	-11.0997	683.0398	3941.941
133	113.3496	5.8166	33.9547	0.7947	-10.8204	659.3093	3848.752
134	109.1539	5.8166	34.3408	0.8051	-10.1966	634.9046	3748.432
135	105.0505	5.8166	34.7269	0.8362	-9.1077	611.0367	3648.078
136	100.8934	5.8166	35.113	0.8401	-7.396	586.8566	3542.67
137	96.5657	5.8166	35.499	0.8614	-4.9625	561.6841	3427.986
138	96.6354	5.8166	35.8851	0.7162	-2.2378	562.0895	3467.771
139	105.8866	23.6542	36.2712	-2.6299	-0.7088	2504.663	3840.634
140	110.5959	24.0419	36.2712	-5.1289	-0.8698	2658.936	4011.446
141	112.249	24.4297	36.2712	-7.3698	-0.8902	2742.209	4071.406
142	113.9002	24.8175	36.2712	-8.936	-0.9679	2826.718	4131.297
143	115.7782	25.2053	36.2712	-9.929	-1.0354	2918.224	4199.414
144	117.429	25.593	36.2712	-10.5021	-1.1021	3005.36	4259.291
145	118.8806	25.9808	36.2712	-10.768	-1.1731	3088.613	4311.942
146	120.1596	26.3686	36.2712	-10.78	-1.2612	3168.44	4358.333
147	121.4011	26.7564	36.2712	-10.5316	-1.3469	3248.256	4403.364
148	122.1829	27.1441	36.2712	-9.9555	-1.425	3316.545	4431.72
149	123.0437	27.5319	36.2712	-8.9212	-1.553	3387.627	4462.943
150	123.2901	27.9197	36.2712	-7.2526	-1.6239	3442.223	4471.88
151	123.7219	28.3075	36.2712	-4.8262	-1.8246	3502.258	4487.542
152	133.0373	28.6952	36.2712	-2.0061	-1.6344	3817.532	4825.423
153	98.1349	12.021	36.2712	-2.7289	-1.3741	1179.68	3559.471
154	101.2902	12.4087	36.2712	-5.3787	-1.6261	1256.88	3673.917
155	98.314	12.7965	36.2712	-7.8267	-1.5982	1258.075	3565.967
156	95.6053	13.1843	36.2712	-9.6328	-1.6308	1260.489	3467.719
157	93.4539	13.5721	36.2712	-10.8567	-1.6219	1268.366	3389.685
158	91.3136	13.9598	36.2712	-11.6155	-1.6044	1274.72	3312.054
159	89.3029	14.3476	36.2712	-11.9995	-1.5655	1281.282	3239.123
160	87.4396	14.7354	36.2712	-12.0524	-1.5312	1288.457	3171.539
161	85.8375	15.1232	36.2712	-11.7732	-1.4835	1298.138	3113.429
162	84.1609	15.5109	36.2712	-11.1166	-1.4213	1305.411	3052.617
163	82.7499	15.8987	36.2712	-9.9895	-1.3838	1315.616	3001.438
164	81.093	16.2865	36.2712	-8.273	-1.3048	1320.721	2941.34
165	79.1243	16.6743	36.2712	-5.8992	-1.2955	1319.342	2869.933
166	81.9449	17.062	36.2712	-3.3354	-1.0865	1398.144	2972.24
167	79.2469	17.8376	36.2712	-3.3349	-0.9542	1413.575	2874.38
168	82.8038	18.2253	36.2712	-5.8986	-1.0782	1509.124	3003.393
169	82.3525	18.6131	36.2712	-8.2727	-1.0038	1532.835	2987.024
170	82.1883	19.0009	36.2712	-9.9896	-0.9797	1561.652	2981.068
171	82.6415	19.3887	36.2712	-11.1173	-0.9414	1602.311	2997.506

172	83.3548	19.7764	36.2712	-11.7746	-0.9013	1648.458	3023.379
173	84.3272	20.1642	36.2712	-12.0545	-0.8568	1700.391	3058.649
174	85.5734	20.552	36.2712	-12.0024	-0.8239	1758.705	3103.85
175	87.2841	20.9398	36.2712	-11.6192	-0.7874	1827.712	3165.899
176	89.0733	21.3275	36.2712	-10.8611	-0.7407	1899.711	3230.795
177	91.3355	21.7153	36.2712	-9.6377	-0.729	1983.378	3312.848
178	93.7059	22.1031	36.2712	-7.8318	-0.6764	2071.191	3398.825
179	96.1414	22.4909	36.2712	-5.3833	-0.6965	2162.307	3487.164
180	101.4853	22.8786	36.2712	-2.7315	-0.5949	2321.842	3680.994
181	124.2213	29.083	30.8661	-0.3834	-0.5331	3612.728	3834.227
182	124.0579	29.083	31.2522	-0.3961	-0.5042	3607.976	3877.082
183	125.5137	29.083	31.6382	-0.33	-0.5155	3650.315	3971.028
184	126.5856	29.083	32.0243	-0.2942	-0.5322	3681.489	4053.815
185	127.3761	29.083	32.4104	-0.2284	-0.5508	3704.479	4128.31
186	128.1124	29.083	32.7965	-0.1883	-0.5639	3725.893	4201.638
187	128.4619	29.083	33.1826	-0.1408	-0.5689	3736.057	4262.7
188	128.8165	29.083	33.5686	-0.0726	-0.5665	3746.37	4324.19
189	129.135	29.083	33.9547	-0.0221	-0.5606	3755.633	4384.74
190	129.2266	29.083	34.3408	0.0328	-0.5581	3758.297	4437.745
191	129.4298	29.083	34.7269	0.1065	-0.5685	3764.207	4494.696
192	129.8475	29.083	35.113	0.16	-0.6036	3776.355	4559.335
193	131.0639	29.083	35.499	0.2107	-0.6593	3811.731	4652.637
194	134.268	29.083	35.8851	0.1708	-0.7366	3904.916	4818.221
195	206.9858	29.083	23.368	0.6066	-1.0279	6019.768	4836.844
196	199.0387	29.083	23.876	0.873	-1.3896	5788.643	4752.248
197	189.3062	29.083	24.384	1.1145	-1.9206	5505.592	4616.042
198	178.8462	29.083	24.892	1.1949	-2.4534	5201.384	4451.84
199	168.2696	29.083	25.4	1.3014	-2.8828	4893.785	4274.048
200	158.3498	29.083	25.908	1.116	-3.1474	4605.287	4102.527
201	149.5658	29.083	26.416	0.9403	-3.2266	4349.822	3950.93
202	143.3021	29.083	26.924	0.6065	-3.128	4167.655	3858.266
203	139.4748	29.083	27.432	0.2113	-2.8741	4056.346	3826.073
204	138.6724	29.083	27.94	-0.1111	-2.4967	4033.009	3874.507
205	140.5389	29.083	28.448	-0.4423	-2.0367	4087.293	3998.051
206	144.4669	29.083	28.956	-0.6547	-1.5515	4201.531	4183.184
207	150.4213	29.083	29.464	-0.7785	-1.1154	4374.703	4432.013
208	155.034	29.083	29.972	-0.7623	-0.8415	4508.854	4646.679
209	202.514	29.083	15.748	-0.0915	-0.8451	5889.715	3189.19
210	200.6514	29.083	16.256	-0.0283	-1.039	5835.545	3261.789
211	198.8053	29.083	16.764	-0.0461	-1.3438	5781.855	3332.772
212	197.1066	29.083	17.272	-0.0071	-1.6404	5732.451	3404.425
213	199.2928	29.083	17.78	0.355	-1.8617	5796.033	3543.426

214	206.8679	29.083	18.288	-0.0638	-1.9761	6016.339	3783.2
215	206.7074	29.083	18.796	-0.2376	-1.9826	6011.671	3885.272
216	203.3981	29.083	19.304	-0.7407	-1.8957	5915.427	3926.397
217	196.0104	29.083	19.812	-0.4962	-1.7365	5700.57	3883.358
218	197.956	29.083	20.32	-0.4683	-1.5286	5757.154	4022.466
219	201.0104	29.083	20.828	-0.5742	-1.2967	5845.985	4186.645
220	210.7714	29.083	21.336	0.015	-1.0727	6129.865	4497.019
221	221.1644	29.083	21.844	-0.4663	-0.8915	6432.124	4831.115
222	224.3236	29.083	22.352	-0.2932	-0.8296	6524.003	5014.081
223	231.3759	29.083	8.128	-0.3461	-0.7489	6729.105	1880.623
224	222.8146	29.083	8.636	-0.0262	-0.8693	6480.117	1924.227
225	215.8145	29.083	9.144	0.2294	-1.0757	6276.533	1973.408
226	209.3014	29.083	9.652	0.3683	-1.2942	6087.113	2020.177
227	203.2836	29.083	10.16	0.3018	-1.4851	5912.097	2065.361
228	198.4775	29.083	10.668	0.2672	-1.6219	5772.321	2117.358
229	195.0518	29.083	11.176	0.1004	-1.6926	5672.691	2179.899
230	193.0267	29.083	11.684	0.0069	-1.6929	5613.796	2255.324
231	192.3279	29.083	12.192	-0.174	-1.6227	5593.472	2344.862
232	192.8232	29.083	12.7	-0.2439	-1.4866	5607.877	2448.855
233	194.3175	29.083	13.208	-0.3901	-1.2968	5651.336	2566.546
234	196.5218	29.083	13.716	-0.39	-1.0812	5715.444	2695.493
235	199.4888	29.083	14.224	-0.4451	-0.8817	5801.733	2837.529
236	201.509	29.083	14.732	-0.3682	-0.7819	5860.486	2968.631
237	142.2851	23.6542	0	2.3976	-0.6494	3365.64	0
238	147.5597	24.0419	0	4.9666	-0.749	3547.616	0
239	150.1739	24.4297	0	7.2655	-0.707	3668.703	0
240	152.8202	24.8175	0	8.8903	-0.7088	3792.615	0
241	155.9511	25.2053	0	9.935	-0.717	3930.794	0
242	159.2696	25.593	0	10.5501	-0.7138	4076.187	0
243	162.5857	25.9808	0	10.8469	-0.7246	4224.107	0
244	166.1819	26.3686	0	10.8803	-0.7721	4381.984	0
245	170.0692	26.7564	0	10.6481	-0.8163	4550.44	0
246	173.6441	27.1441	0	10.0899	-0.8831	4713.413	0
247	177.7021	27.5319	0	9.0861	-1.0323	4892.476	0
248	181.1662	27.9197	0	7.4738	-1.1394	5058.106	0
249	184.9986	28.3075	0	5.1372	-1.4352	5236.848	0
250	196.3269	28.6952	0	2.4517	-1.3941	5633.64	0
251	118.7169	0.3878	0	1.8464	-0.4827	46.03841	0
252	121.6551	0.7755	0	4.6819	-0.6145	94.34353	0
253	122.7271	1.1633	0	7.1695	-0.6747	142.7684	0
254	124.0029	1.5511	0	8.9094	-0.7727	192.3409	0
255	125.384	1.9389	0	10.0046	-0.8608	243.107	0

256	126.5701	2.3266	0	10.6231	-0.9338	294.478	0
257	127.4522	2.7144	0	10.8916	-0.9931	345.9563	0
258	128.1483	3.1022	0	10.8772	-1.067	397.5417	0
259	128.8109	3.49	0	10.5875	-1.118	449.55	0
260	128.9499	3.8777	0	9.9719	-1.1525	500.029	0
261	129.0775	4.2655	0	8.9223	-1.2186	550.5801	0
262	128.6678	4.6533	0	7.2907	-1.2238	598.7299	0
263	127.7232	5.0411	0	4.985	-1.3005	643.8654	0
264	131.8943	5.4288	0	2.4115	-1.1453	716.0278	0
265	128.6531	6.2044	0	2.3979	-1.2419	798.2153	0
266	131.9612	6.5921	0	4.9464	-1.4517	869.9014	0
267	129.9886	6.9799	0	7.2168	-1.4147	907.3074	0
268	128.3723	7.3677	0	8.8069	-1.414	945.8086	0
269	127.3585	7.7555	0	9.8138	-1.3999	987.7288	0
270	126.7256	8.1432	0	10.3903	-1.3738	1031.952	0
271	126.2235	8.531	0	10.6495	-1.3301	1076.813	0
272	126.0024	8.9188	0	10.6482	-1.3079	1123.79	0
273	126.2053	9.3066	0	10.3862	-1.2705	1174.542	0
274	126.2526	9.6943	0	9.8069	-1.2294	1223.931	0
275	126.6978	10.0821	0	8.7971	-1.2315	1277.38	0
276	126.8603	10.4699	0	7.2039	-1.1828	1328.215	0
277	126.7255	10.8577	0	4.9303	-1.2288	1375.947	0
278	131.3299	11.2454	0	2.3769	-1.0676	1476.857	0
279	129.3207	12.021	0	2.3768	-1.1894	1554.564	0
280	132.7251	12.4087	0	4.9307	-1.3999	1646.946	0
281	131.0239	12.7965	0	7.2048	-1.3739	1676.647	0
282	129.6102	13.1843	0	8.7985	-1.3857	1708.82	0
283	128.7266	13.5721	0	9.8086	-1.3815	1747.09	0
284	128.1415	13.9598	0	10.3876	-1.3644	1788.83	0
285	127.6435	14.3476	0	10.6487	-1.3282	1831.378	0
286	127.3808	14.7354	0	10.6485	-1.3127	1877.007	0
287	127.5124	15.1232	0	10.387	-1.2805	1928.396	0
288	127.4598	15.5109	0	9.8077	-1.2424	1977.016	0
289	127.7808	15.8987	0	8.7975	-1.2465	2031.549	0
290	127.8116	16.2865	0	7.2037	-1.1983	2081.604	0
291	127.5255	16.6743	0	4.9294	-1.2424	2126.398	0
292	132.0297	17.062	0	2.3754	-1.0775	2252.691	0
293	129.8913	17.8376	0	2.3747	-1.1813	2316.949	0
294	133.3006	18.2253	0	4.9281	-1.3832	2429.443	0
295	131.634	18.6131	0	7.2016	-1.3465	2450.117	0
296	130.2859	19.0009	0	8.7947	-1.3438	2475.549	0
297	129.5182	19.3887	0	9.8043	-1.3226	2511.19	0

298	129.1262	19.7764	0	10.3832	-1.2853	2553.651	0
299	128.9051	20.1642	0	10.6446	-1.2253	2599.268	0
300	129.0332	20.552	0	10.6453	-1.1827	2651.89	0
301	129.6793	20.9398	0	10.3852	-1.1185	2715.459	0
302	130.2939	21.3275	0	9.8079	-1.0462	2778.843	0
303	131.4754	21.7153	0	8.8002	-1.0092	2855.028	0
304	132.6743	22.1031	0	7.2093	-0.9188	2932.513	0
305	133.769	22.4909	0	4.938	-0.9017	3008.585	0
306	138.4555	22.8786	0	2.3879	-0.7438	3167.668	0
307	156.4855	0	0.508	-0.7529	-3.9512	0	79.49463
308	156.4267	0	1.016	-0.7636	-8.3406	0	158.9295
309	159.3153	0	1.524	-0.659	-11.4972	0	242.7965
310	161.9145	0	2.032	-0.508	-13.2411	0	329.0103
311	163.7168	0	2.54	-0.4427	-14.0931	0	415.8407
312	165.0608	0	3.048	-0.2874	-14.4584	0	503.1053
313	165.8019	0	3.556	-0.2372	-14.576	0	589.5916
314	166.0441	0	4.064	-0.0905	-14.5553	0	674.8032
315	165.8057	0	4.572	-0.0567	-14.4041	0	758.0637
316	165.0406	0	5.08	0.069	-14.0307	0	838.4062
317	163.9842	0	5.588	0.0884	-13.2201	0	916.3437
318	162.3806	0	6.096	0.1745	-11.6008	0	989.8721
319	160.6051	0	6.604	0.2041	-8.6846	0	1060.636
320	159.0776	0	7.112	0.2184	-4.6574	0	1131.36
321	154.4357	0	8.128	0.2672	-4.6564	0	1255.253
322	152.3246	0	8.636	0.2833	-8.6793	0	1315.475
323	149.6709	0	9.144	0.2076	-11.5879	0	1368.591
324	147.685	0	9.652	0.1772	-13.196	0	1425.456
325	146.2852	0	10.16	0.0617	-13.9915	0	1486.258
326	145.5681	0	10.668	0.0045	-14.3464	0	1552.92
327	145.5336	0	11.176	-0.1176	-14.4771	0	1626.484
328	146.2164	0	11.684	-0.175	-14.4793	0	1708.392
329	147.5274	0	12.192	-0.2865	-14.3526	0	1798.654
330	149.4356	0	12.7	-0.3092	-14.0012	0	1897.832
331	151.7953	0	13.208	-0.3909	-13.2083	0	2004.912
332	154.4637	0	13.716	-0.3592	-11.6021	0	2118.624
333	157.5314	0	14.224	-0.3758	-8.6946	0	2240.727
334	159.7478	0	14.732	-0.2951	-4.673	0	2353.405
335	161.1047	0	15.748	-0.0284	-4.671	0	2537.077
336	159.7302	0	16.256	0.0128	-8.6879	0	2596.574
337	158.3022	0	16.764	-0.0068	-11.5883	0	2653.778
338	157.2235	0	17.272	0.0002	-13.1864	0	2715.564
339	156.4829	0	17.78	-0.098	-13.9705	0	2782.266

340	156.3527	0	18.288	-0.143	-14.3124	0	2859.378
341	156.9246	0	18.796	-0.2737	-14.4282	0	2949.555
342	158.3164	0	19.304	-0.3443	-14.4129	0	3056.14
343	160.5259	0	19.812	-0.4847	-14.2656	0	3180.339
344	163.5894	0	20.32	-0.5377	-13.8898	0	3324.137
345	167.4056	0	20.828	-0.6609	-13.0685	0	3486.724
346	171.9416	0	21.336	-0.6617	-11.4304	0	3668.546
347	177.3545	0	21.844	-0.7285	-8.492	0	3874.132
348	181.345	0	22.352	-0.6433	-4.439	0	4053.423
	115632.62			-115.9691	-1801.23	1736937	2061633

Data for design (from ETABS):

Load combination: 1.5 (DL+LL)

Calculations:

Response for factored load combination i.e 1.5 (DL + LL):

∑P = 115632.32 kN

∑Mx = -115.9691 kN-m

∑My = -1801.23 kN-m

∑(P * X) = 1736937

∑(P * Y) = 2061633

Location of centre of resultant forces:

$\bar{x}F = \frac{\sum(P*X)}{\sum P} =$ 15.022m

$\bar{y}F = \frac{\sum(P*Y)}{\sum P} =$ 17.82916m

Location of Geometrical centroid: $(\bar{x}, \bar{y})$ = (14.695m, 17.665m)

Eccentricity:

ex = $\bar{x}F - \bar{x}$ = 0.927m

ey = $\bar{y}F - \bar{y}$ = 0.16416m

Area MOI

$I_{xx} = (L*B^3)/12$ =134128.7217 m^4

$I_{yy} = (B*L^3)/12$ = 86963.044 m^4

Stress at different coordinates:

$\sigma = \frac{\sum P}{A} \pm \frac{Myy}{Iyy}*x \pm \frac{Mxx}{Ixx}*y$

(x , y) = Coordinates w.r.t geometric centre = (X - $\bar{x}$,Y - $\bar{y}$)

M_{xx}=∑P*e_y + ∑M_x

M_{yy}=∑P*e_x + ∑M_y

For bearing pressure check (Serviceability condition):

∑P =77,088.41KN

M_{xx}= 12,577.52

M_{yy}= 70,260.13

For design of mat foundation (Factored):

∑P =115632.62KN

M_{xx}= 18866.2818kN-m

M_{yy}= 105390.208kN-m

Design stress under different columns: (1.5(DL+LL)):

Column	x	y	x dash	y dash	stress
35	1	31.48	15.692	18.6409	85.31381
34	1	23.86	15.692	18.6409	84.24205
33	1	16.24	15.692	18.6409	83.1703
32	1	8.62	15.692	18.6409	82.09855
31	1	1	15.692	18.6409	81.0268
6	6.8166	37.2712	15.692	18.6409	93.17224
5	6.8166	31.48	15.692	18.6409	92.35771
4	6.8166	23.86	15.692	18.6409	91.28596
3	6.8166	16.24	15.692	18.6409	90.2142
2	6.8166	8.62	15.692	18.6409	89.14245
1	6.8166	1	15.692	18.6409	88.0707
12	12.6332	37.2712	15.692	18.6409	100.2161
11	12.6332	31.48	15.692	18.6409	99.40161
10	12.6332	23.86	15.692	18.6409	98.32986
9	12.6332	16.24	15.692	18.6409	97.25811
8	12.6332	8.62	15.692	18.6409	96.18635
7	12.6332	1	15.692	18.6409	95.1146
18	18.4498	37.2712	15.692	18.6409	107.26
17	18.4498	31.48	15.692	18.6409	106.4455
16	18.4498	23.86	15.692	18.6409	105.3738
15	18.4498	16.24	15.692	18.6409	104.302
14	18.4498	8.62	15.692	18.6409	103.2303

13	18.4498	1	15.692	18.6409	102.1585
24	24.2664	37.2712	15.692	18.6409	114.304
23	24.2664	31.48	15.692	18.6409	113.4894
22	24.2664	23.86	15.692	18.6409	112.4177
21	24.2664	16.24	15.692	18.6409	111.3459
20	24.2664	8.62	15.692	18.6409	110.2742
19	24.2664	1	15.692	18.6409	109.2024
30	30.083	37.2712	15.692	18.6409	121.3479
29	30.083	31.48	15.692	18.6409	120.5333
28	30.083	23.86	15.692	18.6409	119.4616
27	30.083	16.24	15.692	18.6409	118.3898
26	30.083	8.62	15.692	18.6409	117.3181
25	30.083	1	15.692	18.6409	116.2463

For design, raft is divided in 6 strips in X- direction and 6 strip in Y- direction, and each strip is treated as continuous beam. Bending moments are obtained using coefficients suggested by IS 456: 2000, Table 12. For calculation of bending moment, the maximum value of stress under column for each strip is used and calculations are done for both X and Y directions.

Bending moment for support: $(q*l^2)/10$ kN-m

Bending moment at mid span: $(q*l^2)/12$ kN-m

Where, q = maximum stress under column for a strip

Along X- direction:

Strip Name	Width (m)	Maximum Length (m)	q(kN/m^2)	Support Moment (m)	Span Moment (m)	Remarks
1 --1	3.89	5.8166	121.3479	410.5543546	342.1286289	
2--2	6.7056	5.8166	120.5333	407.7983318	339.8319432	
3--3	7.62	5.8166	119.4616	404.1724669	336.810389	
4--4	7.62	5.8166	118.3818	400.5191973	333.7659977	
5--5	7.62	5.8166	117.3181	396.9203986	330.7669988	
6--6	4.81	5.8166	116.2463	393.2941952	327.7451627	
			Max	410.5543546	342.1286289	

Along Y- direction:

Strip Name	Width (m)	Maximum Length (m)	q(kN/m^2)	Support Moment (m)	Span Moment (m)	Remarks
A-A	3.9083	7.62	85.3181	495.3944286	412.8286905	
B-B	5.8166	7.62	93.172	540.9976277	450.8313564	
C-C	5.8166	7.62	100.2161	581.8987717	484.9156431	

D-D	5.8166	7.62	107.26	622.7987544	518.998962	
E-E	5.8166	7.62	114.304	663.6993178	553.0827648	
F-F	3.9083	7.62	121.3479	704.5993005	587.1660837	
			Max	704.5993005	587.1660837	

Manual Design:

References	Step	Calculations	Output/ Remarks
	1.a) b)	**In X direction** Upward soil pressure : q = 210.8 kN/m2 Maximum span length: l = 5.81 m In Y direction Upward soil pressure: q = 210.84 kN/m2 Maximum span length, l = 7.62 m	 q = 210.84 kN/m2 /m l = 7.315 m q = 210.84 kN/m2 /m l = 7.62 m
S 456-2000 Table 12	2. a) b)	**Moment Calculation** In X direction Max. support moment $M_s = (q*l^2)/10$= 410.55kN-m per m width Max. span moment: $M_m = (q*l^2)/12$ = 342.12 kN-m per m width In Y- direction Max. support moment $M_s = (q*l^2)/10$= 704.6 kN-m per m width Max. span moment: $M_m = (q*l^2)/12$ =587.16 kN-m per m width	 M_s = 410.55kN-m per m width M_m = 342.12 kN-m per m width M_s= 704.6 kN-m per m width M_m = 587.16 kN-m per m width
SP-16 Table C	3.	**Depth from moment consideration** Depth of footing: d = √($\sqrt{\frac{M}{0.133*fck*b}}$ =460.33mm	 Maximum moment is used i.e for Y-strip
SP- 34	4.	**Setting depth of foundation** Since footing is critical in shear, not in bending moment D = 1000mm Clear cover = 75mm Provide 20 mm dia. Bars Effective cover = 75 + 10 = 85mm Therefore, d = 1000 – 85 = 915mm	 d = 915mm D = 1000mm

IS 456 – 2000 **Cl. 31.6.2.1** **IS 456 – 2000** **Cl 3.6.3.1**	5.	**Check for two way shear** Nominal shear stress: $\tau_v = \frac{v}{bd}$ b = perimeter $\tau v \leq ks\ \tau c$; $ks = (0.5+\beta c) \leq 1$; $\beta c = L/B$ $\tau c = 0.25*\sqrt{fck}$ βc : 1 ks : 1 fck : 25 τc : 1.25 N/mm2 b = 4(d+800) mm = 7060mm Maximum load: P = 4291.7399 kN $\tau_v = \frac{4291.7399*1000}{7060*915}$ = 0.664 N/mm2 <τc. Hence, safe	d = 915 (ok)
IS 456-2000 Annex G	6. a) i)	**Area of steel** Minimum area of steel: $A_{st,min}$ = 0.12% of bD $A_{st,min}$ = 0.12% of bD = 1200mm^2 **In X direction** **Area of steel at support (Bottom bars)** $A_{st} = 0.5 * \frac{fck}{fy} *bd*(1 - \sqrt{}(1 - \frac{4.6M}{fck*bd2})$ M = 410.55 kN-m/m b = 1000 mm d = 915 mm fck = 25 N/mm2 fy = 500 N/mm2 On solving, we get: Ast = 1056.37 mm2 < Ast,min For 20 mm bars Ab = 314.15mm2 Spacing of bars: sv = (A_b/A_{st})*1000 = 261.791mm Provide 20 mm φ bars at 150 mm c/c $A_{st,provided}$ = 2094.39 mm2 $p_{st} = (A_{st}/bd)$* 100% =0.209%	20 mm φ bars at 150 mm c/c
	ii)	**Area of steel at mid span (Top bars)** M = 342.12 kN-m/m On solving we get Ast = 876.77mm2 < Ast,min	

		For 20 mm bars Spacing of bars: sv = (A_b/A_{st})*1000 = 358.3 mm Provide 20 mm φ bars at 150 mm c/c 20 mm φ @ 150 mm c/c Ast,provided = 2094.39 mm2 p_{st} = (A_{st}/bd)* 100% =0.209%	20 mm φ bars at 150 mm c/c
IS 456-2000 Annex G	b) i)	**In Y direction** **Area of steel at support (Bottom bars)** Area of steel at support (Bottom bars) $A_{st} = 0.5 * \frac{fck}{fy} *bd*(1 - \sqrt{(1 - \frac{4.6M}{fck*bd2}})$ M = 704.6 kN-m/m b = 1000 mm d = 915 mm fck = 25 N/mm2 fy = 500 N/mm2 On solving, we get: Ast = 1845.57mm2 > Ast,min For 20 mm bars Ab = 314.15mm2 Spacing of bars: sv = (A_b/A_{st})*1000 = 170.21 Provide 20 mm φ bars at 150 mm c/c 20 mm φ @ 150 mm c/c Ast,provided = 2094.39 mm2 p_{st} = (A_{st}/bd)* 100% =0.209%	20 mm φ bars at 150 mm c/c
	ii)	**Area of steel at mid span (Top bars)** M = 587.16 kN-m/m On solving we get Ast = 1526.88 mm2 > Ast,min For 20 mm bars Spacing of bars: sv = (A_b/A_{st})*1000 = 205.74 Provide 20 mm φ bars at 150 mm c/c 20 mm φ @ 150 mm c/c Ast,provided = 2094.39 mm2 p_{st} = (A_{st}/bd)* 100% =0.209%	

IS 456:2000 cl 26.2.1.1 **IS 456:2000 cl 26.2.1**	7	**Check for development length** Bond stress for M25 concrete (τ_{bd}) = 1.4 N/mm^2 For deformed bar (τ_{bd}) = 1.6*1.4 = 2.24 N/mm^2 Development length (Ld) = $(\emptyset * \sigma)/4$τbd= 971mm Lo = effective depth (d) or 12 Φ whicever greater = 915mm $L_d \leq 1.3 * M_t/\vartheta + L_0$ = 1128.428 > L_d Hence ok.	
IS 456:2000 Cl 34.4	8.	**Load transfer from column to footing** Nominal bearing stress in column = $\frac{Pu}{Ac}$ =(4291.74 * 10^3)/800*800 = 6.7 N/mm^2 Allowable bearing stress = 0.45 f_{ck} = 11.25 N/mm^2 > nominal ok. Footing doesn't require dowel bars. However, the column bars have been extended inside the footing.	
IS 456:2000 Cl 34.5.2	9.	**Design of side reinforcement** No need for side reinforcement for footing depth less or equal to 1m	
SP 34	10.	**Chair bars** As per SP-34, suggested spacing of chair bars is 30 times its diameter with at least 12 mm as its diameter. Providing 16 mm chair bars @ 480 mm c/c	
From manual design: **Along X direction, provide 20 mm φ bars @ 150 mm c/c at top and @ 150 mm c/c at bottom** **Along Y direction, provide 20 mm φ bars @ 150 mm c/c at top and @ 150 mm c/c at bottom** **Chair bars 16 mm @ 480 mm c/c**			

Overall Design Summary of Mat Foundation:

Concrete Grade: M25, Steel: Fe500 (TMT)

Total depth of foundation: 1000 mm

Clear cover: 75 mm

Reinforcement provided: Uniform

Reinforcement along X direction: 20 mm Φ @ 150 mm c/c at both top and bottom

Reinforcement along Y direction: 20 mm Φ @ 150 mm c/c at both top and bottom

Chair bars: 16 mm Φ @ 480 mm c/c

7.6. Design of Basement wall

Basement wall retains the lateral earth pressure and prevents seepage of moisture into the building.Two floors of our building lie underground, namely Mezzanine Level and Basement Level. The design for basement wall of Basement Floor is shown as a representative section withstanding higher pressure.

Design of basement wall can be done as a simple cantilever slab considering that during construction, backfill is provided as the wall is being built up before its support on the slab and beams. Our design is based on the final construction with a fixed cantilever slab action, modifiedas a propped cantilever considering hinged or roller support at the top slab position for a reasonablysafer design. This is based on the assumption that the backfilling is withheld or basement wall strutted until final construction of the wall. Further, the upper basement wall is considered a simple support with slabs acting as roller/hinge at the top and bottom for conservative design subjected to predominantly lateral surcharge and soil loads.

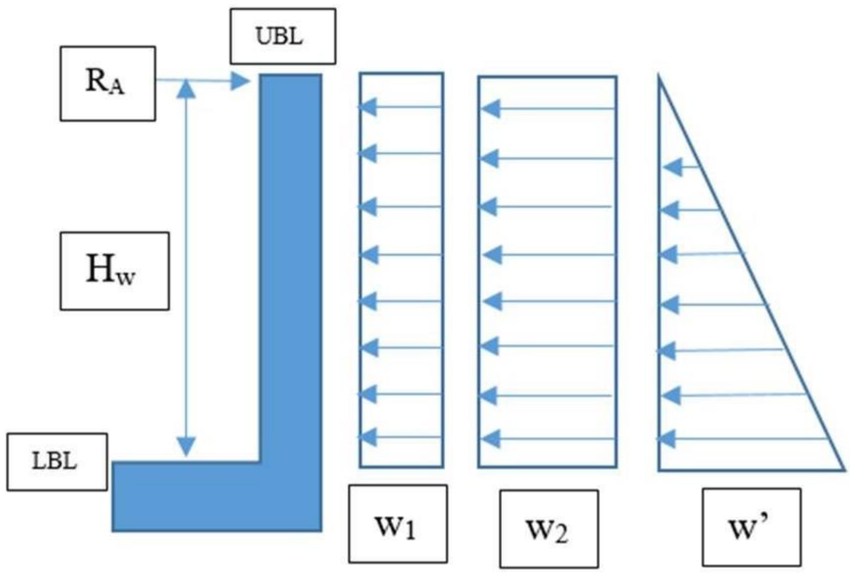


Fig: Propped Cantilever Basement Wall

Known Data:

Concrete Grade = M25

Steel Grade = Fe 500

1. Design Constants

Specific weight of Soil, γsoil' = 18 kN/m^3

Angle of internal friction, $\emptyset = 30$ deg.

Grade of concrete (fck) = 25 Mpa

Grade of steel (fy) = 500 MPa

Modulus of elasticity of steel (Es) = 25000 MPa

Surcharge load due to vehicular movement, w1 = 10 kN/m^2

Surcharge load due to soil above basement floor level, w2= γsoil'*depth of soil to mezzanine level = 18*3.9624 = 71.3232 kN/m^2

Total surcharge load, w = w1 + w2 = 81.3232 kN/m^2

Safe bearing capacity of soil, q = 150 kN/m^2 (NBC 205: Table 3.1)

Lateral earth pressure coeff. at active condition(Ka) =$\frac{1-sin\emptyset}{1+sin\emptyset}$ = 0.333

2. Basement wall data

Height of basement wall (Hw) = 3.3124m (Clear height)

Width of basement wall (b) = 1000mm (for unit length)

Clear cover (Cc) = 25mm

Effective cover (d') = 25 + 12 + 16/2 = 45mm

3. Approximate design of section

Depth of beam at upper basement floor level, D_b = 650mm

For propped cantilever, H=Hw + D_b/2 = 3.3124 + 0.650/2 = 3.6374m

Let effective depth of wall, d=H/18 = 3.6374/18 = 202mm

Overall depth, D= d + cc + $\emptyset/2$ = 202+25+8 = 235mm

Provide overall depth (D) = 260mm >100mm ok (IS 456:2000 Cl 32.1)

Effective depth (d) = D – cc - $\emptyset/2 = 260 - 25 - 16/2 = 227$mm

Effective height of basement wall, Hwe = H+d/2 = 3.6374 + 0.227/2 = 3750.9mm (IS 456:2000 Cl 22.2c)
Slenderness Ratio, Hwe/d= 3750.9/227 = 16.523 <30 ok (IS 456:2000 Cl32.2.3)

Design axial strength, (IS 456:2000 Cl 32.2.5)
Puw = 0.3(t-1.2e-2e') fck
Where,
t = thickness of the wall = 260mm
e = eccentricity of load measured at right angles to the plane of the wall determined in accordance with 32.2.2 = 0.05t = 0.05*260 = 13mm
e' = additional eccentricity due to slenderness effect taken as $Hwe^2/2500t$ = 21.645mm
Puw = 0.3(260-1.2*13-2*21.645)*25 = 1508.325 kN/m
0.04fckAg = 0.04*25*260*1000 = 260000kN/m (IS 456:2000 Cl 32.3.2)
Puw < 0.04fckAg. Hence, designed as slab.
D>200mm, so vertical and horizontal reinforcement are provided in both faces, one near each face of the wall. (IS 456:2000 Cl 32.5.1)

4. Moment Calculation

Lateral load due to surcharge load, s = Ka*w*Hwe = 0.33*81.3232*3.7509 = 101.678 kN/m
w' = Ka*Hw* γsoil' = 0.333*3.7509*18 = 22.505 kN/m^2
Lateral load due to soil pressure, Pa= 0.5*22.505*3.7509 = 42.208 kN/m
Total lateral pressure=Total lateral load/clear height = (101.678+42.208)/3.3124 = 43.439 kN/m^2 < q ok safe in bearing pressure

Reaction at roller support, $R_A = R_{UDL} + R_{UVL}$ = 3wHwe/8 + w'Hwe/10 = (3*0.333*81.3232*3.7509/8 + 22.505*3.7509/10) = 46.571 kN
Characteristic Bending Moment at the base of wall for propped cantilever (Since weight of wall gives insignificant moment, so this can be neglected in the design),
$M=-M_{udl} - M_{uvl} + R_a*Hwe= -w*l^2/8 - w'*l^2/15 + R_a*Hwe = -s*l/8 - w'*l^2/15 + R_a*Hwe$
$= -101.678*3.7509/8 - 22.505*3.3509^2/15 + 46.571*3.7509 = 105.901$ kNm
Design moment, Mu=1.5M = 158.851 kNm

5. Check for depth

Limiting value of depth of Neutral axis $x_{u,\ max}/d = 0.46$

$M_{u,\ lim} = 0.36*(x_u/d)*(1-0.412(x_u/d))*bd^2 f_{ck}$ (IS 456:2000 ANNEX G 1.1c)

$= 0.36*0.46*(1-0.412*0.46)*1000*227^2*25/10^6 = 172.0$ kNm

Mu,lim > Mu ok

Depth of wall from moment consideration,

$d = \sqrt{\frac{Mu}{0.135\times fck\times b}}$ = 216.95mm < $d_{provided}$ ok

6. Calculation of Main Steel (Vertical) Reinforcement

$Ast = 0.5\frac{fck}{fy}\left(1-\sqrt{1-4.6\frac{Mu}{fckbd^2}}\right)bd \quad = \quad 0.5\frac{25}{500}\left(1-\sqrt{1-4.6\frac{158.851*1000000}{25*1000*227*227}}\right)1000*227$ = 1941.673 mm^2

Ast,min = 0.0012bD = 312 mm2 (IS 456:2000 Cl 32.5.a.1) <Ast

Maximum dia. of bar = D/8 = 32.5mm (IS 456:2000 Cl 26.5.2.2)

Providing 16mm dia bar,

Spacing of bars, Sv= =22/7*16*16*1000/1941.673/4 = 103.593mm

Max spacing=3D (= 780mm) or 450mm (IS 456:2000 Cl 32.5.b)

Provide spacing @ 100mm c/c.

Ast provided= 22/7*16*16/4*1000/100 = 2011.429mm^2 > Ast, reqd.

Percentage of tensile rebar, pt= 2011.429 / (1000*227)*100 = 0.89%

Provide nominal vertical reinforcement 16mm@100mm c/c at the front face.

7. Check for shear force

Shear Force V= $V_{UDL} + V_{UVL}$ = 5*Ka*w*Hw/8+2*w'*Hw/5 = 5*0.333*81.3232*3.7509/8 + 2*22.505*3.7509/5 = 97.315 kN/m

Design shear force, Vu= 1.5*V = 145.973 kN/m

Nominal shear stress, τv = Vu/bd = 145.973*1000/(1000*227) = 0.643 N/mm2 (IS 456:2000 Cl 31.6.2.1)

Permissible shear stress, kτc= 1.1*0.6092 = 0.669 N/mm2 (IS 456:2000 Cl 40.2.1.1, Table 19)

Maximum shear stress, τc,max = 3.1 N/mm2 (IS 456:2000 Table 20) τc,max > kτc > τv , ok

8. Check for deflection

Allowable deflection, Δ_{all} = Hwe/250= 3.7509/250 = 15.0036mm

Actual deflection,

$\Delta = \Delta_{UDL} + \Delta_{UVL}$

$$\Delta = \left[\frac{wx}{48EI}(l^3 - 3lx^2 + 2x^3)\right] + \left[\frac{1}{EI}\left\{\frac{R_A x^3}{6} - \frac{w' x^5}{120l} + \left(\frac{w' l^3}{24} - \frac{R_A l^2}{2}\right)x\right\}\right]$$

$$\Delta' = \left[\frac{w}{48EI}(l^3 - 3 \times 3lx^2 + 4 \times 2x^3)\right] + \left[\frac{1}{EI}\left\{\frac{R_A \times 3x^2}{6} - \frac{5w' x^4}{120l} + \left(\frac{w' l^3}{24} - \frac{R_A l^2}{2}\right)\right\}\right]$$

Where,

w = 0.333*81.3232 = 27.107 kN/m^2

w' = 22.505 kN/m^2

R_A = w'Hwe/10 = 22.505*3.7509/10 = 8.4415 kN

I = 1*0.260^3/12 = 1.464*$10^{-3}$$m^4$

E = 25000 MPa

l = 3.7509m

Δ' = 0 for maximum deflection

Solving,

x = 1.4m

Δ = 0.54 mm < Δ_{all} ok

9. Calculation of Horizontal Reinforcement steel bars

Area of hor. steel reinforcement=0.2%*D*Hwe = 0.002*260*3750.9 = 1950.468mm2 (IS 456:2000 Cl 32.5.c)

As the temperature change occurs at front face of basement wall, 2/3 of horizontal reinforcement is provided at front face and 1/3 of horizontal reinforcement is provided in inner face.

Front face Horizontal Reinforcement steel=2/3rd of hor steel = 2/3*1950.468 = 1300.31 mm^2

Providing 12 mm ∅ bars,

No. of bars required, N = 1300.31/113.097 = 11.49 = 12

Spacing = (Hwe – clear cover at both sides - ∅)/ (N-1) = 335.35 mm

Maximum spacing= 3D = 3*250=750mm or 450mm

Provide 12mm ∅ bars @300mm c/c front face

Back face horizontal reinforcement steel, = 1/3rd of hor steel = 650.16 mm^2

Providing 12 mm ∅ bars,

No. of bars required, N = 650.16/113.097 = 5.74 = 6

Spacing = (Hwe – clear cover at both sides - ∅)/ (N-1) = 737.78 mm > 450mm

Provide 12mm ∅ bars @450mm c/c back face

10. Curtailment of Reinforcement

No bars can be curtailed in less than Ld distance from the bottom of stem.

Ld = (σs*Φ/4*τbd) = 0.87*500*16/ 4*1.4*1.6) = 776.78mm (IS 456:2000 Cl 26.2.1)

The curtailment of bars can be done in two layers 1/3 and 2/3 heights of the stem above the base.

Let us curtail bars at 1/3 distance i.e. 1250mm from base, h = 3.7509 – 1.250 = 2.5009m

Lateral Load due to soil pressure, Pa=0.5*Ka*h^2* γsoil' = 18.76 kN/m

Lateral Load due to surcharge load, Ps=Ka*w*h = 67.79 kN/m

Bending Moment at 1.25 m above the base of wall, M = -Pa * h/3 – Ps*h/2 + R_A*h = -18.76*2.5/3 – 67.79*2.5/2 + 46.571*2.5 = 16.055 kNm

Design Moment, Mu = 1.5*M = 24.08 kNm

Since this moment is less than half of the moment at base of stem, spacing of vertical reinforcement is doubled from 100 to 200 mm.

Provide 16mm ∅ bars @ 200mm c/c

Note: The flexural strength of the sections are found to be greater than design load along the wall for the curtailed reinforcements. These reinforcements are also found to be sufficient for extending to the upper basement wall assuming simply supported design due to the decrease in the soil surcharge at the upper basement wall.

7.7. Design of Shear Wall

Shear wall is defined as the vertical load bearing element in the building structures which is used to resist the lateral loads (wind load, earthquake load, etc.) acting on the building. Shear wall is also known as structural walls. In RC buildings shear walls are kept at the strategic location so that the structures have adequate stiffness to resist the lateral load and control drift of the overall building structure. It acts as the vertical deep cantilever beam to resist the in-plane shear and bending moments caused by the lateral loads.

The behavior of shear wall depends upon the ratio of height to length. For small height-to-length ratio in-plane shear is of primary importance which governs the behavior of shear wall. The design of slender wall which is generally provided with uniformly distributed vertical and horizontal reinforcement, will probably be controlled by flexural consideration.

IS 13920:2016 classifies shear wall as squat, intermediate and slender according to the ratio of height by length of wall as follows: $hw/ lw > 1$, $1 \leq hw/ lw \leq 2$, $hw/lw > 2$

IS 13920:2016 gives formula (in Annex A) for the moment of resistance of slender rectangular structural wall section with uniformly distributed vertical reinforcement Also, the formula doesn't apply for walls with boundary element. These constraint give rise to difficulty in design of shear wall in general case.

Known data

Length of wall (along-X) (L_w) = 3.41 m

Depth of shear wall (d_w) = 0.8L_w = 2.728m (IS 13920:1993 Cl.9.2.1)

Thickness of web (t_w) = 260mm

1. Data from ETABS

The maximum factored forces in the panel between ground level and first floor obtained from ETABS are as follows:

Max S.F. (V_u) = 1753.27 kN

Max axial force (P_u) = 7318.72 kN

Max B.M (M_u) = 9194.82 kNm

2. Check for shear strength

Shear Stress τ_v =V_u/ ($t_w \times d_w$) = 1753.27*1000/ (260*2728) = 2.4719 N/mm2 (IS 13920:1993 Cl 9.2.1)

Limiting shear stress = 0.25√fck = 0.25√25 = 1.25 N/mm2 (IS 13920:1993 Cl.9.1.5)

If τ_v > limiting shear stress or wall thickness greater than 200 mm then dual face of reinforcement bars are deployed.

Hence, **provide two layer system**.

Min. steel (P_t) = 0.25% (IS 13920:1993 Cl.9.1.4)

Shear strength of concrete (τ_c) = 0.36 N/mm2 (IS456:2000 Table 19)

Maximum shear stress ($\tau_{c\ max}$) = 3.1 N/mm2 (IS456:2000 Table 20)

$\tau_v < \tau_{c\ max}$ i.e. 2.47<3.1 ok (IS 13920:1993 Cl.9.2.3)

If $\tau_v > \tau_c$, then shear reinforcement is required. (IS 13920:1993 Cl.9.2.4)

Since 2.47>0.36, thus shear reinforcement is required.

3. Horizontal shear reinforcement calculation

Shear force to be resisted by horizontal reinforcement (V_{us}) = (V_u- $\tau_c \times t_w \times d_w$) = 1753.27*1000-0.36*260*2728 = 1497.93 kN (IS 13920:1993 Cl.9.2.5)

Assuming 2-legged 16 mm Ø bars are provided horizontally

Area of 2-legged bar (A_h) = $2\Pi \times 16^2/4$ = 402.12 mm^2

$V_{us} = (0.87\times f_y \times A_h \times dw)/S_v$ (IS 13920:1993 Cl.9.2.5)

Spacing (S_v) = $(0.87\times f_y \times A_h \times d_w)/V_{us}$ = 318.57mm

Provide spacing (S_v provided) = 300mm

Check for horizontal reinforcement area

Area of reinforcement provided per meter ($A_{h\ provided}$) = ($A_h\times1000/S_{v\ provided}$) = 1340.413 mm^2

Min. reinforcement per meter ($A_{h\ min}$) = $0.0025\times t_w\times1000$ = 0.0025*260*1000 = 650 mm2 (IS 13920:1993 Cl.9.1.4)

$A_{h\ provided} > A_h$ ok

Provide 16 mm Ø bar @ 300 mm c/c spacing in both side of wall

4. Vertical shear reinforcement calculation

Providing reinforcement same as for horizontal reinforcement, (IS 13920:1993 Cl.9.2.6)

Assuming 2-legged 16mm Ø bars,

Spacing (S_v) = 300 mm

Check for vertical reinforcement area

Area of reinforcement provided per meter ($A_{h\ provided}$) = ($A_h\times1000/S_{v\ provided}$) = 1340.413 mm^2

Min. reinforcement per meter ($A_{h\ min}$) = $0.0025\times t_w\times1000$ = 0.0025*260*1000 = 650 mm^2 (IS 13920:1993 Cl.9.1.4)

$A_{h\ provided} > A_h$ ok

Provide 16 mm Ø bar @ 300 mm c/c spacing in both side of wall

5. Check for flexural capacity of web

Load on web (P_u) = 7318.72 kN

Modulus of elasticity of steel (E_s) = 200000 N/mm^2

Providing Boundary Element of 700mm x 260mm each. (NBC 105 Cl.5.3)

From IS 13920: 1993 Annex A:

Provided V. steel per meter = 1340.413 mm^2

Total V. steel in web section, A_v = 1340.413 *(3.41-1.4) = 2694.23 mm^2

xu*/lw = 0.617

ρ = 0.00304

Φ = 0.053

λ= 0.33

xu/lw= 0.822

xu*/lw < xu/lw < 1.0

β = 0.6214

α_1= 0.354, α_2=0.1407, α_4=-0.2447, α_5=0.0426

Solving:

$\alpha_1 (xu/lw)^2 + \alpha_4 (xu/lw) - \alpha_5 = 0$

xu/lw = 0.8353

α_3= -0.0256

Muv/fck tw lw^2 = 0.0581

Moment of resistance (M_{uv}) = 4393.33 kN-m

6. Boundary Element

The axial compression at the extreme fiber due to combined axial load and bending on section is computed by $\sigma = (P_u/A) + (M_u/Z)$

Moment of inertia of wall section, I = $(t_w \times L_w^3)/12 = 0.260*3.410^3/12$ = 0.8591 m4

Gross cross sectional area (A_g) = $t_w \times L_w$ = 0.8866 m^2

Section modulus (Z) = I/y =I/1.705 = 0.5039 m^3

Axial compression (σ) = 26.502 N/mm^2

0.2×fck = 0.2×25 = 5 N/mm^2

0.2×fck<σ so boundary element is needed in the shear wall. (IS 13920:1993 Cl.9.4.1)

Axial compression due to moment in B.E. is (Mu-Muv)/Cw = 1771.77 kN (IS 13920:1993 Cl.9.4.2)

C_w = c/c distance between boundary elements = 2.71m

Fraction of Boundary Element area= (700*260)/ (3410*260) = 0.205

Total compressive load = 7318.72 kN

Factored comp. load on B.E = 0.205x7318.72 = 1500.34 kN

Factored comp. load at tension side = 7318.72/1.2x0.8 = 4879.15kN

Factored comp. load in B.E. at tension side = 0.205x4879.15 = 1000.226 kN

Total force at compression end B.E. (P_{uc}) = 1500.34 + (Mu-Muv)/Cw = 3272.107 kN

Total force at tension end B.E. (P_{uc}) = 1500.34 - (Mu-Muv)/Cw = -771.54 kN

7. Design of Boundary Element

Boundary element is designed as axially loaded short column (IS 13920:1993 Cl.9.4.2)

Min. reinforcement in boundary element (Asc min) =0.8% (IS 13920:1993 Cl.9.4.4)

Provide Asc = 2.5%

A_{sc} = 0.025x260x700 = 4550 mm2

Strength of short column = P_{ud} = 0.4×fck×Ac + 0.67× fy ×Asc = 3298.75 = 3298.75 kN >3272.107kN ok (IS 456: 2000 Cl.39.3)

Largest dia. of bar <tw/10 = 26mm (IS 13920:1993 Cl.9.1.6)

Assuming 25mm Ø bars

No. of bars reqd. = 4550/490.87=9.27 = 10

Provide 10 bars of 25mm Ø

A_{sc} (provided) = 4908.74 mm^2

Check for tension:

A_{st} (reqd.) = (771.54x1000)/ (0.87fy) = 1773.655 mm2 < 4908.74 mm^2 ok

8. Special confining reinforcement (IS 13920:1993 Cl.9.4.5)

Area of special confining reinforcement (IS 13920:1993 Cl.7.4.7)

A_{sh}' = 0.18*S*h*(f_{ck}/f_y) [(A_g/A_k)-1] Where,

h= Longer dimension of rectangular confining hoop measured to its outer face. It shall not exceed 300mm = 260-2*40 = 180mm (Taking 40mm cc)

S= Pitch of hoops = min. of ¼ of minimum member dimension and 100mm = 65 mm

A_g= Gross area of B.E. = 182000 mm2

A_k= Area of concrete core = (700-2x40+2x8) x (260-2x40+2x8) = 124656 mm2

A_{sh}' = 0.18*S*h*(f_{ck}/f_y) [(A_g/A_k)-1] = 48.44 mm2 <Area of 8mm Ø bar

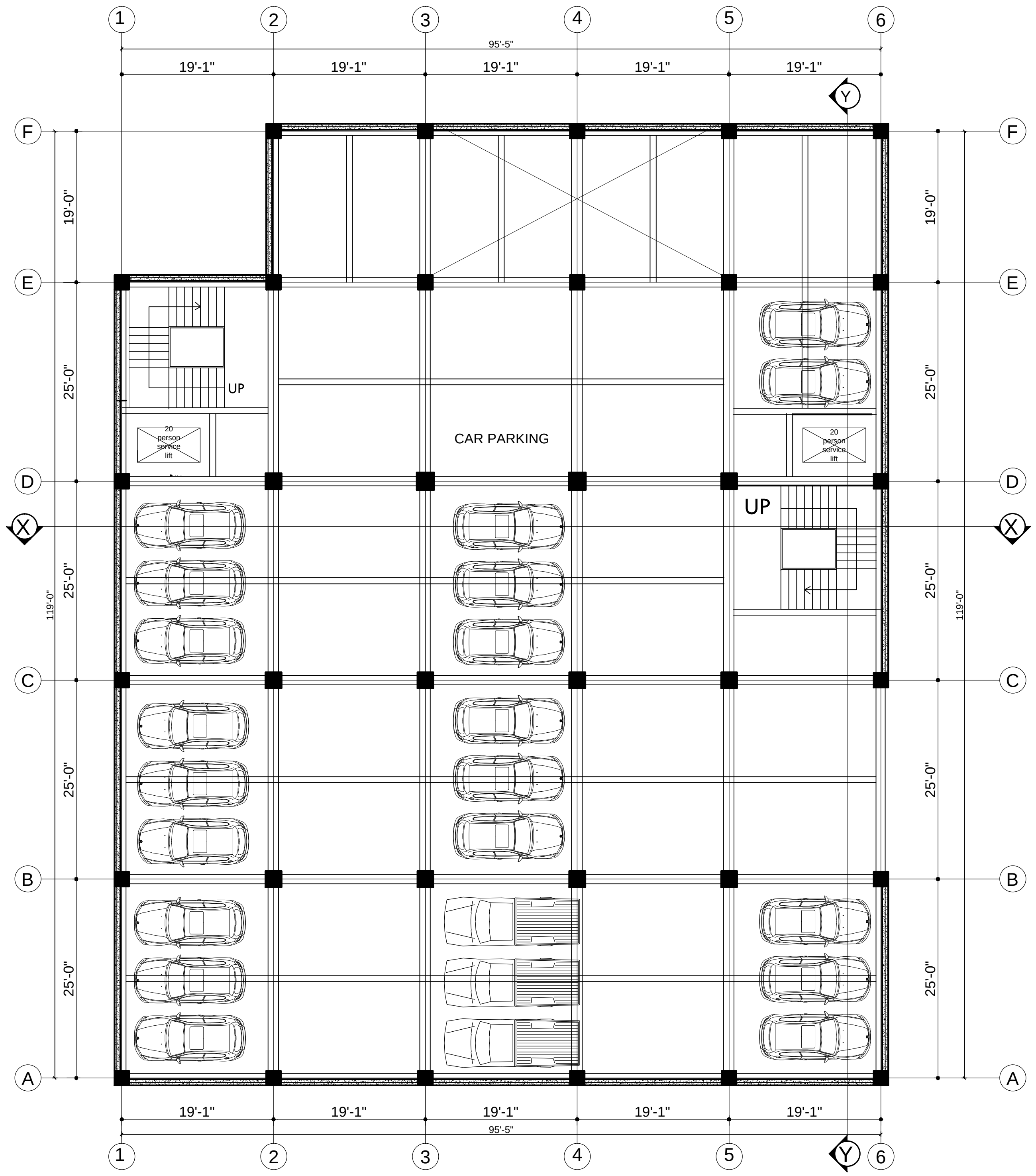
Provide 8 mm Ø @ 75mm c/c

9. Height of B.E. (IS 13920:1993 Cl.9.4.1)

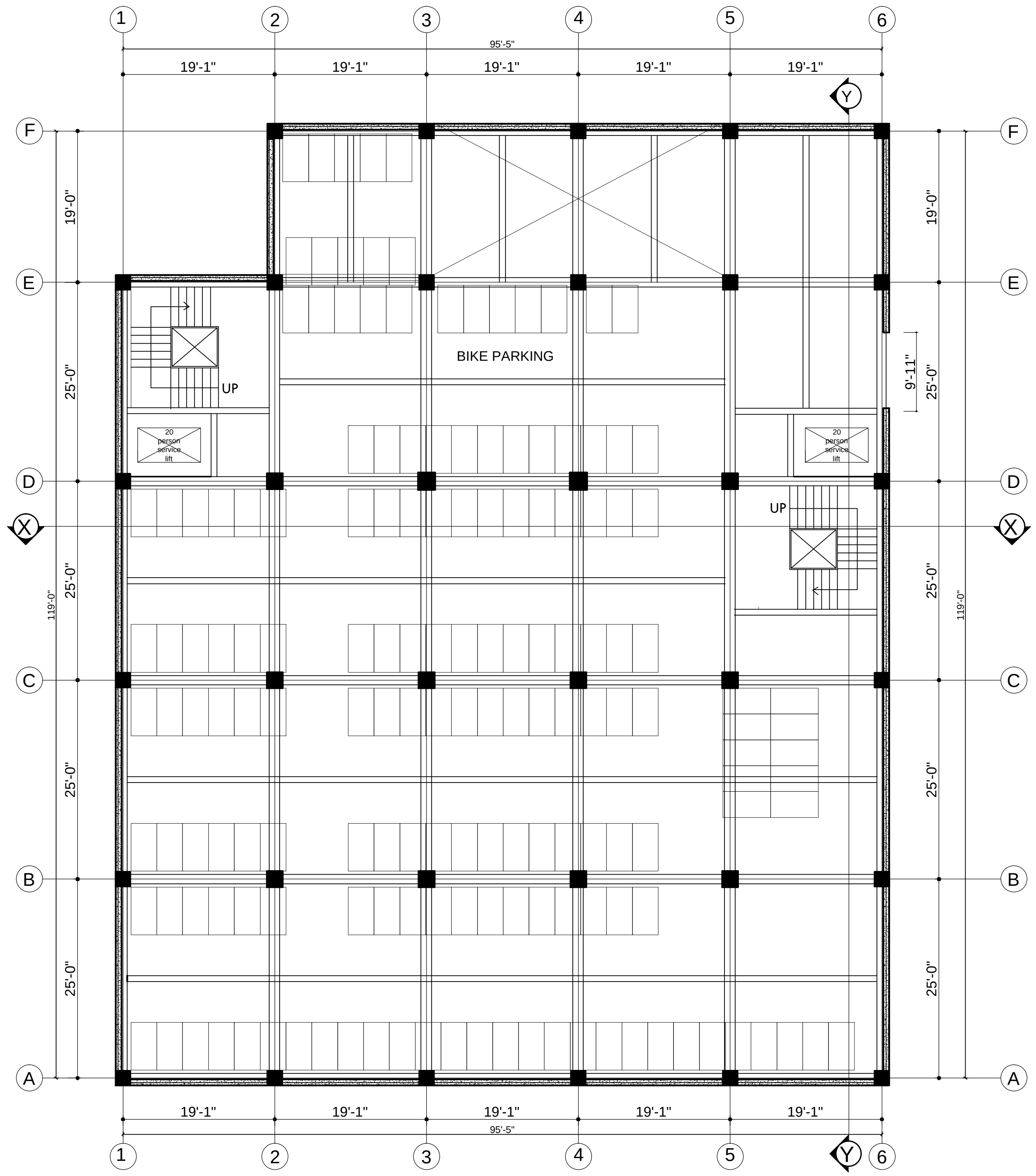
It is extended upto a point where stress in extreme fiber <0.15 f_{ck} = 3.75 N/mm^2

For conservative design **B.E. is provided throughout the height of wall**.

DRAWINGS

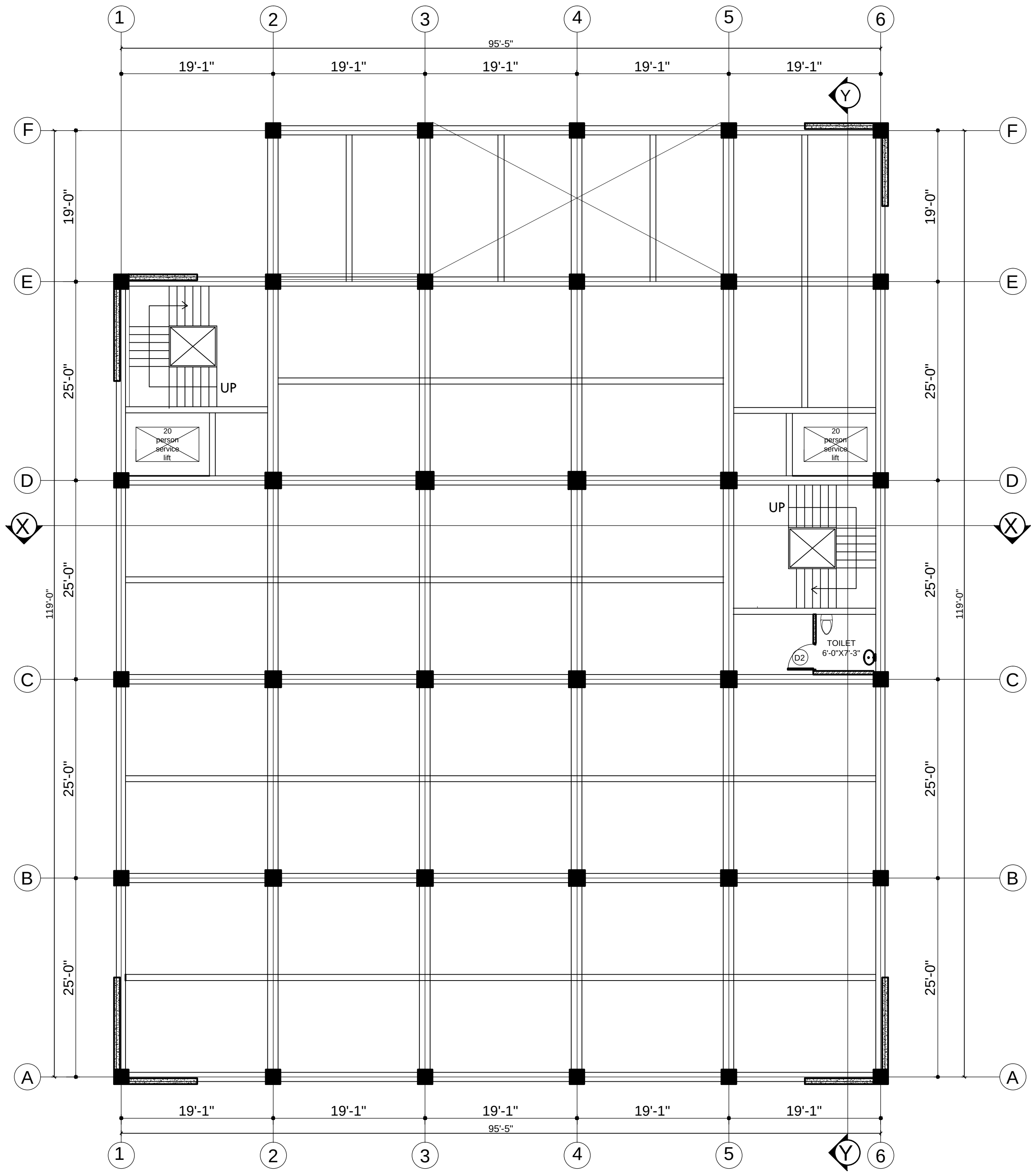


BASEMENT FLOOR PLAN

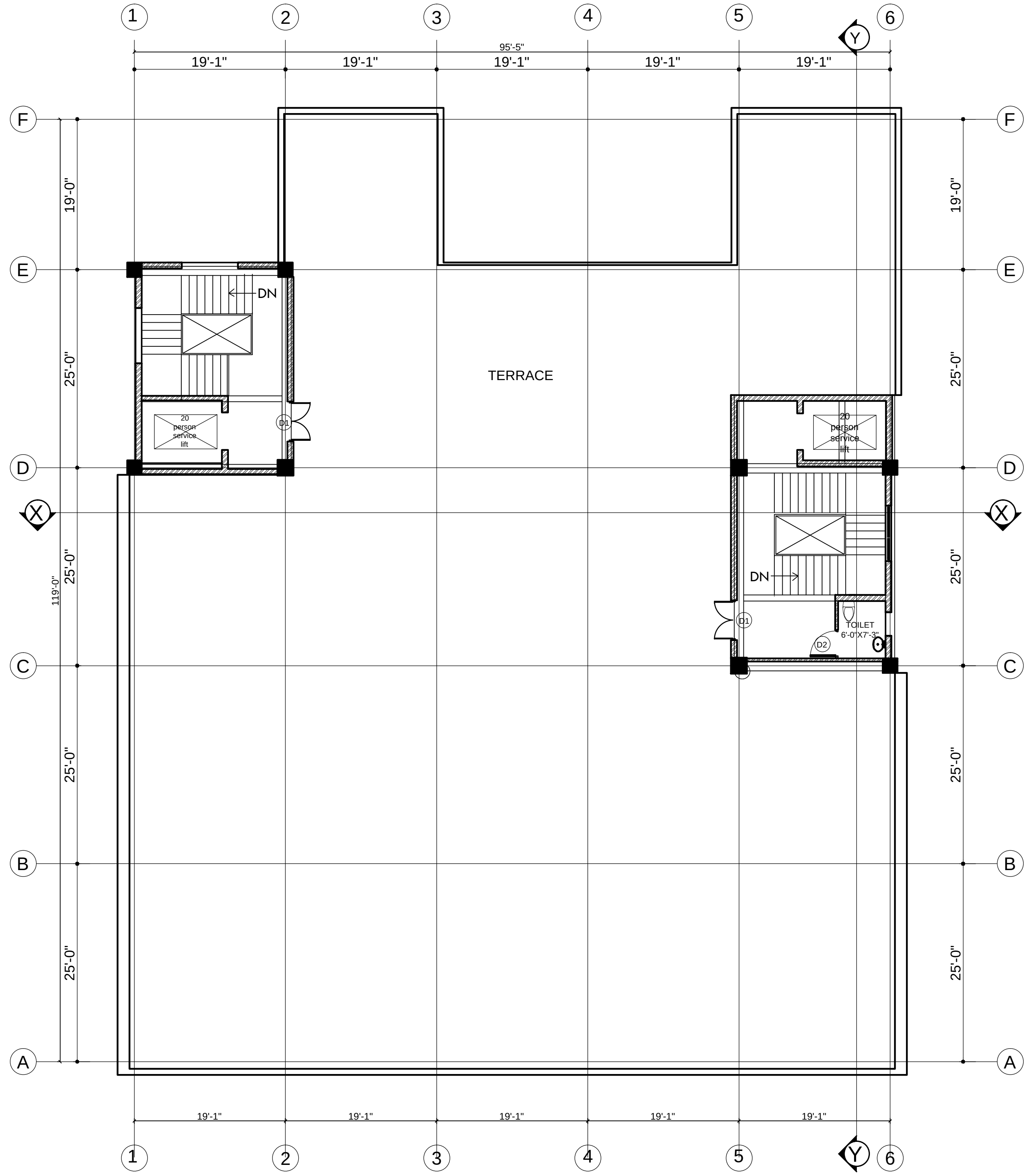


MEZZANINE FLOOR PLAN

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	FLOOR PLAN	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 01

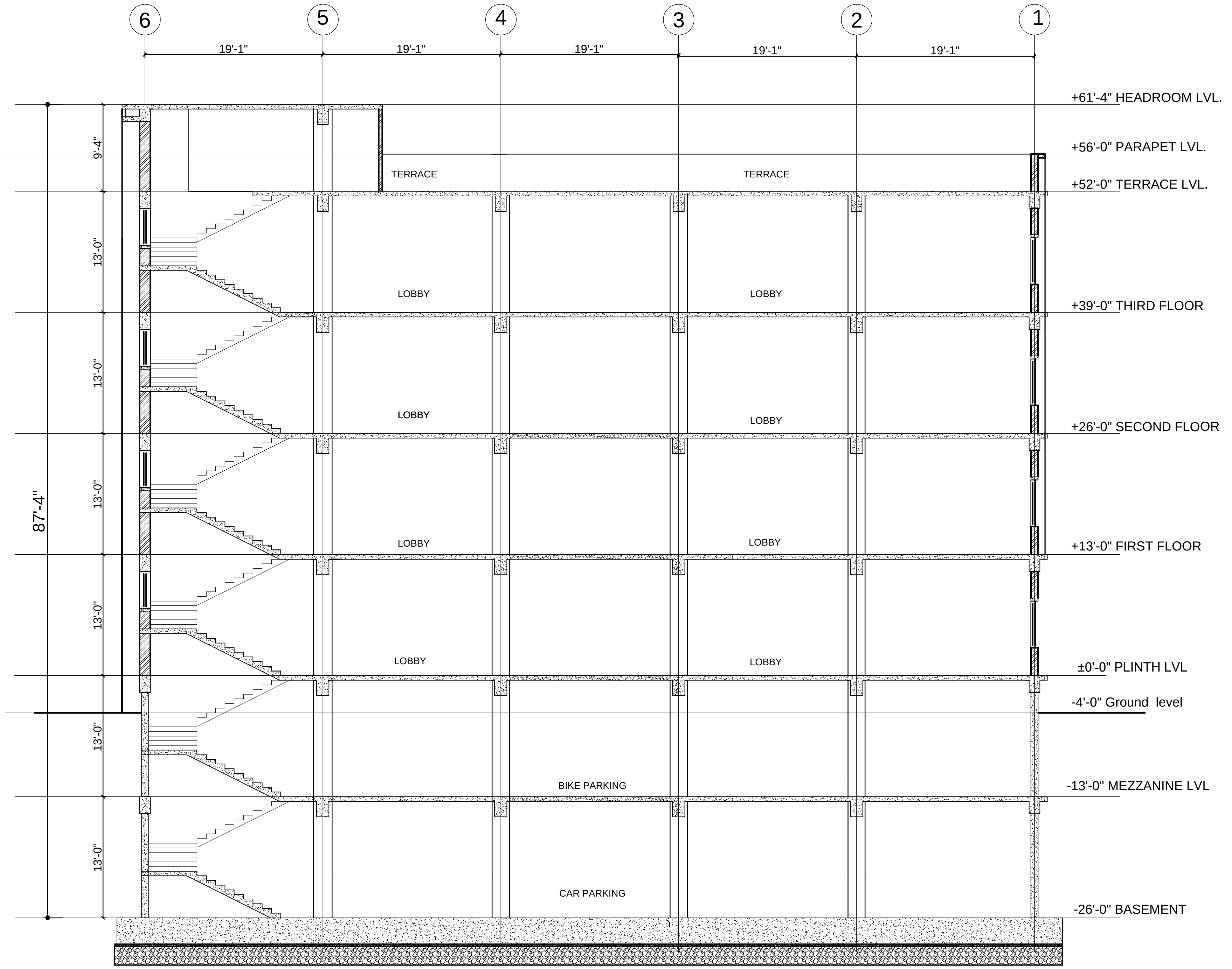


PLINTH/ FIRST/ SECOND/ THIRD FLOOR PLAN



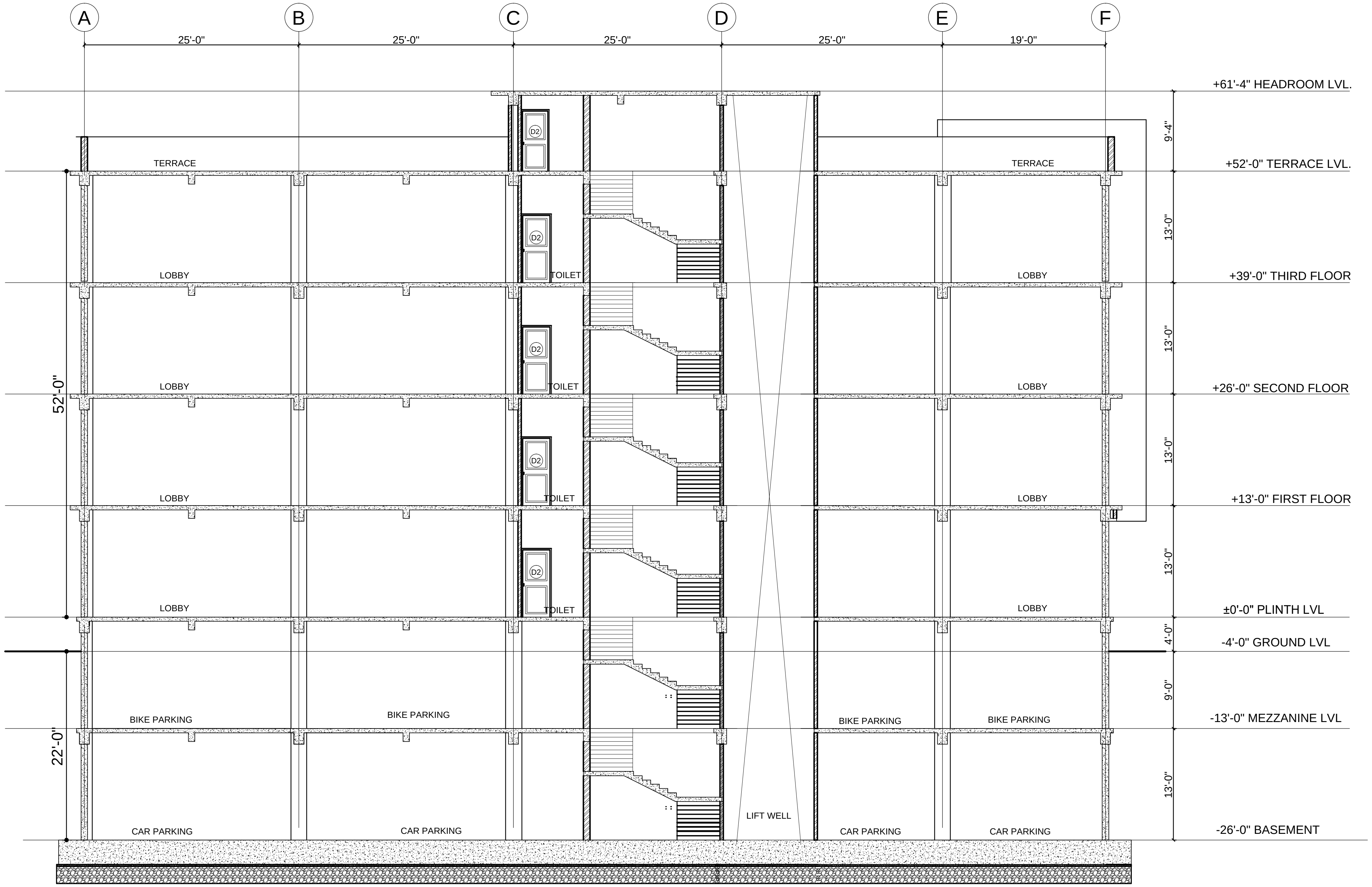
TERRACE FLOOR PLAN

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	FLOOR PLAN	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 02



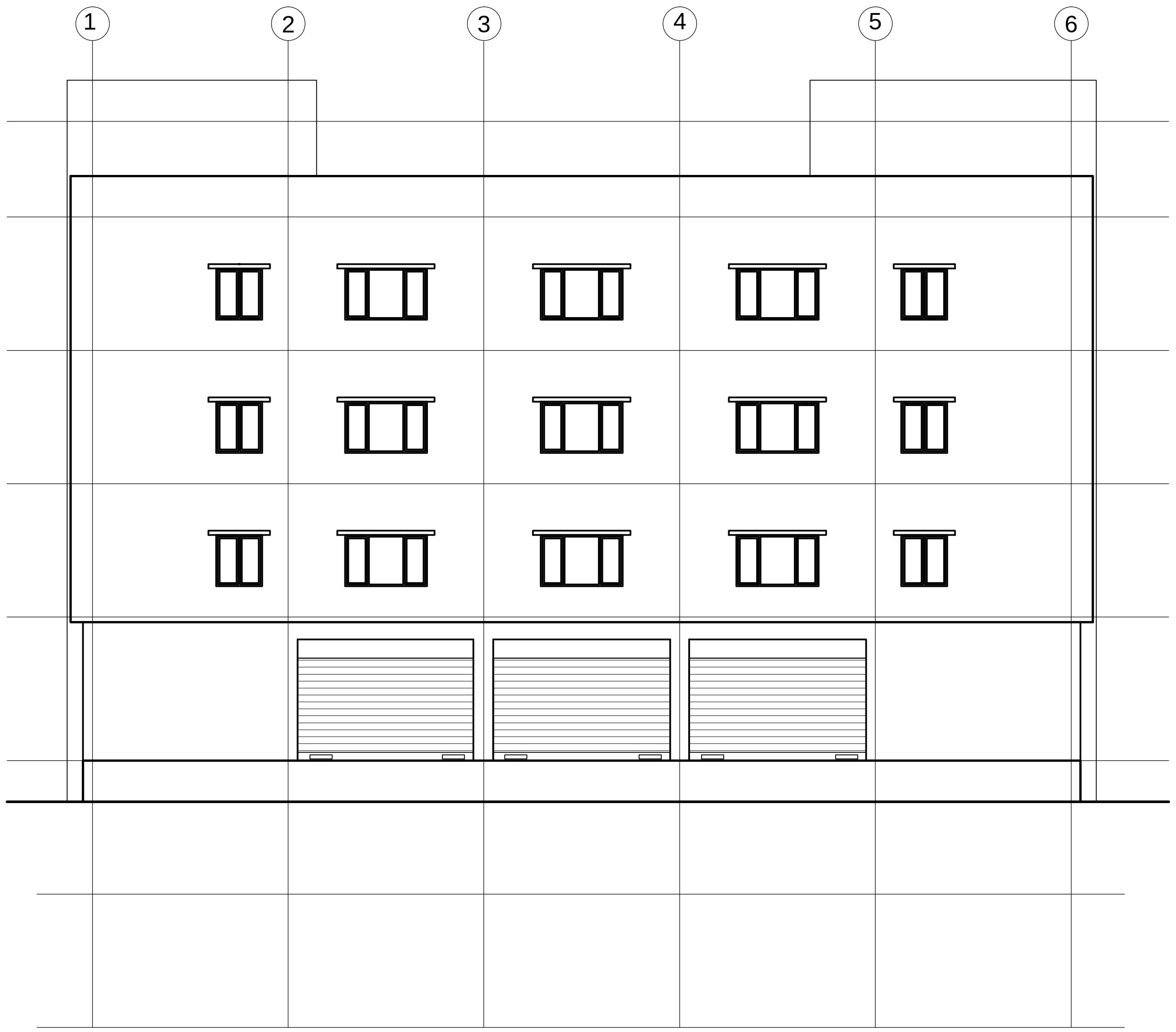
SECTION X-X

TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	PROJECT TITLE "STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	SHEET TITLE SECTION	GROUP MEMBERS RABIN LAMSAL 075BCE110 SHREEJA RAJBAHAK 075BCE157 SINAM ADHIKARI 075BCE162 SNEHA NEOPANE 075BCE164 SUSMITA TIMALSINA 075BCE182 TIMILA MAHARJAN 075BCE187	PROJECT SUPERVISOR ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	SCALE FIT TO SCALE SHEET NO. 03

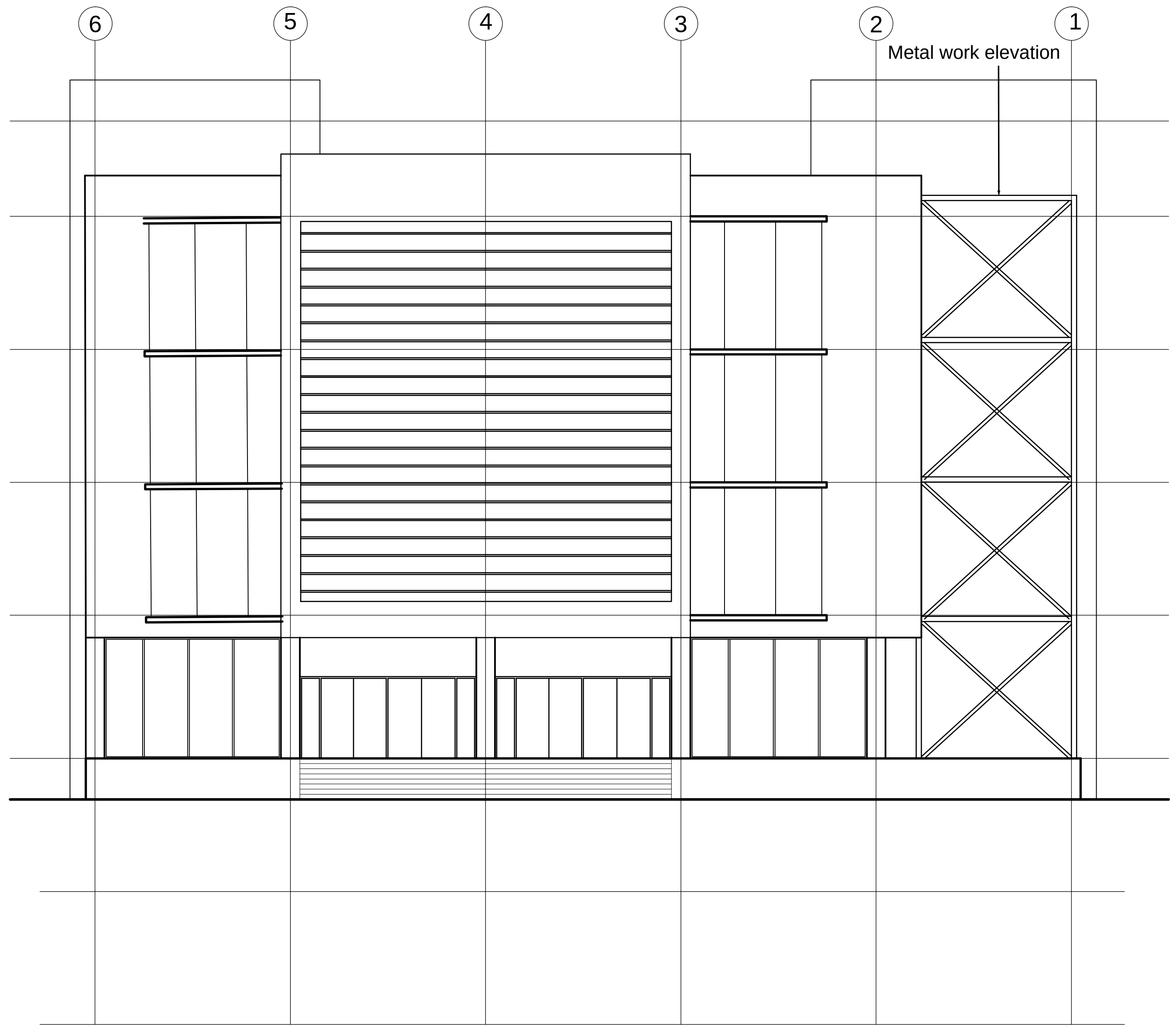


SECTION Y-Y

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	SECTION	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 04

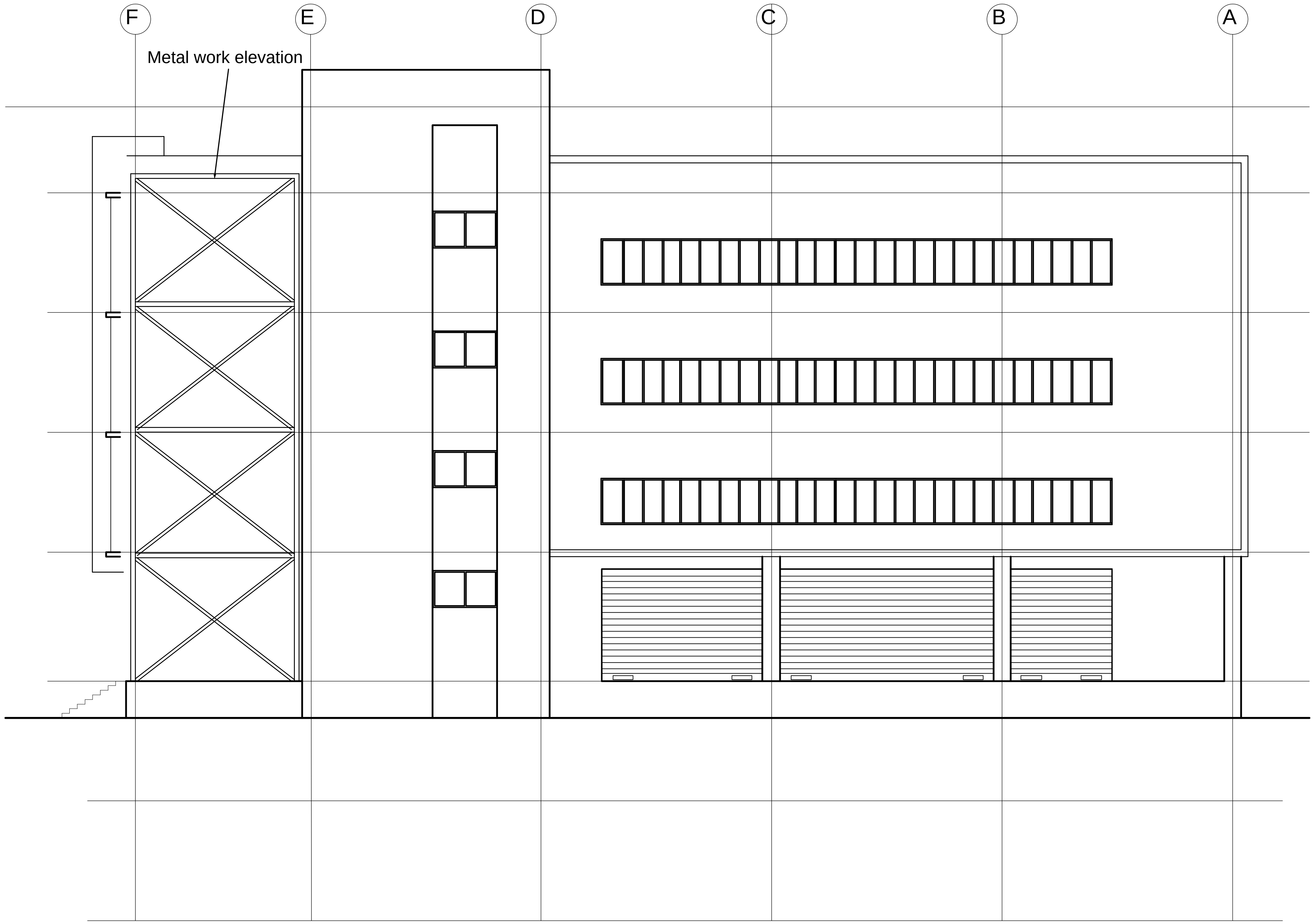


SOUTH ELEVATION



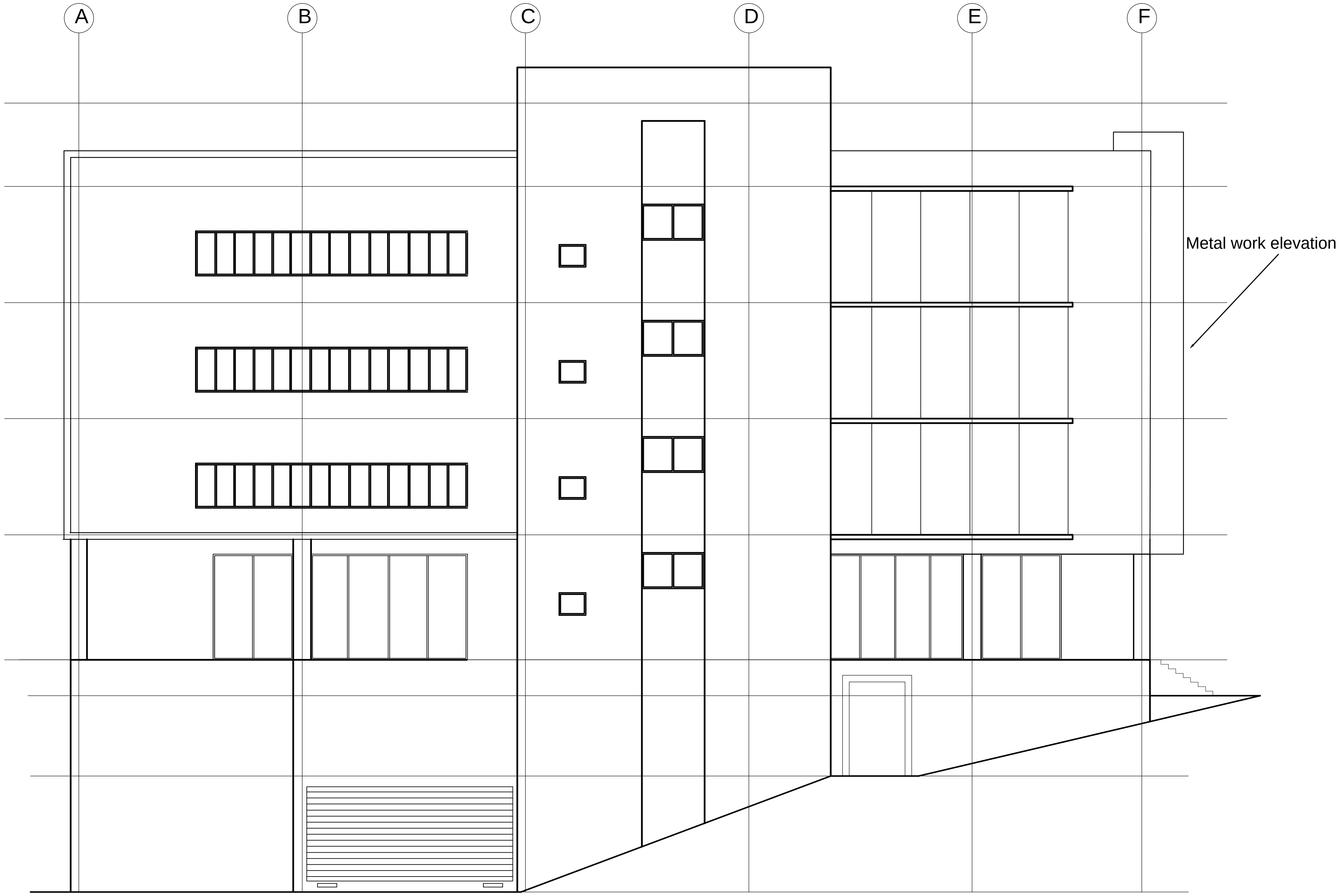
NORTH ELEVATION

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	ELEVATION	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 05



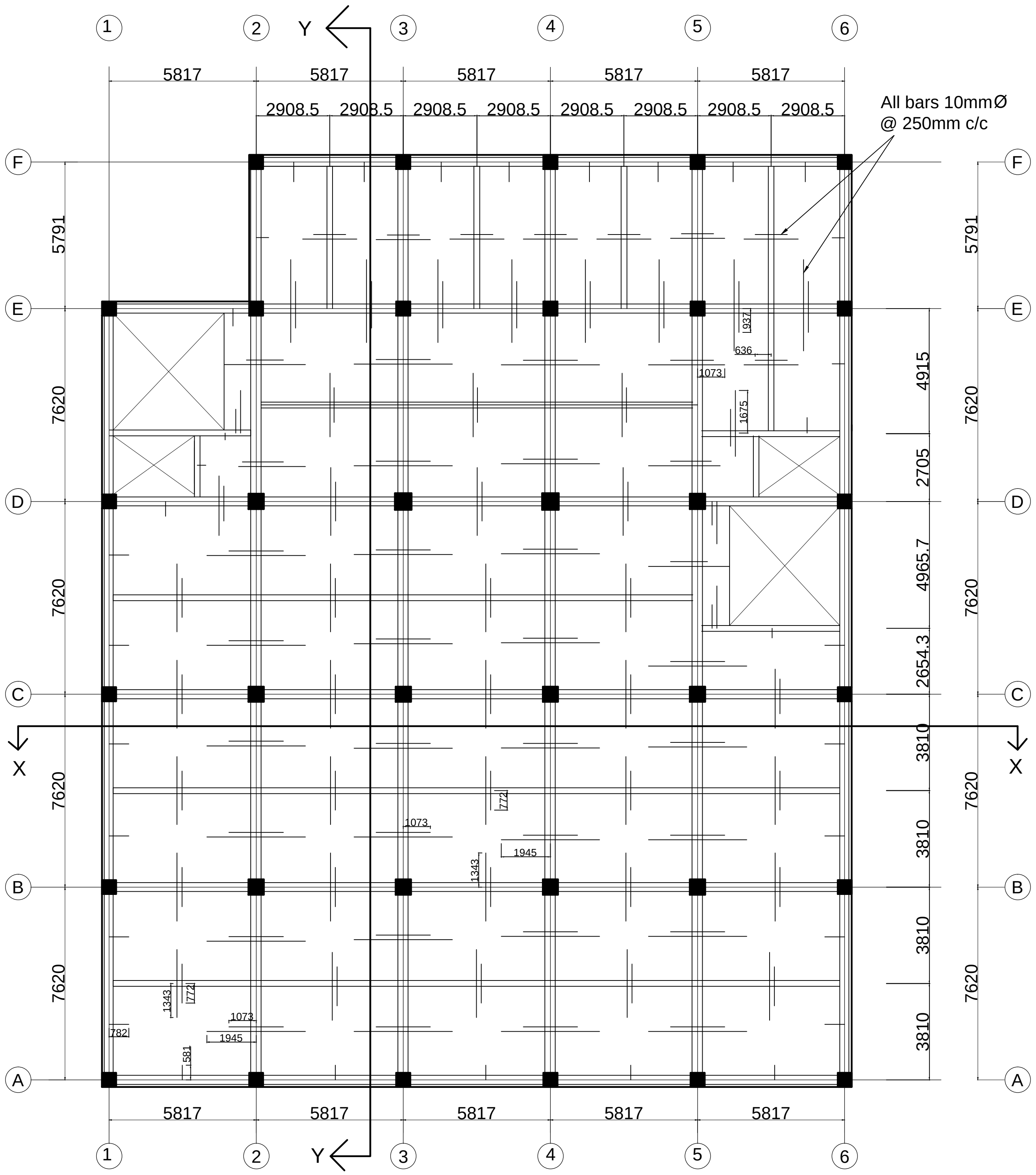
WEST ELEVATION

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	ELEVATION	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 06

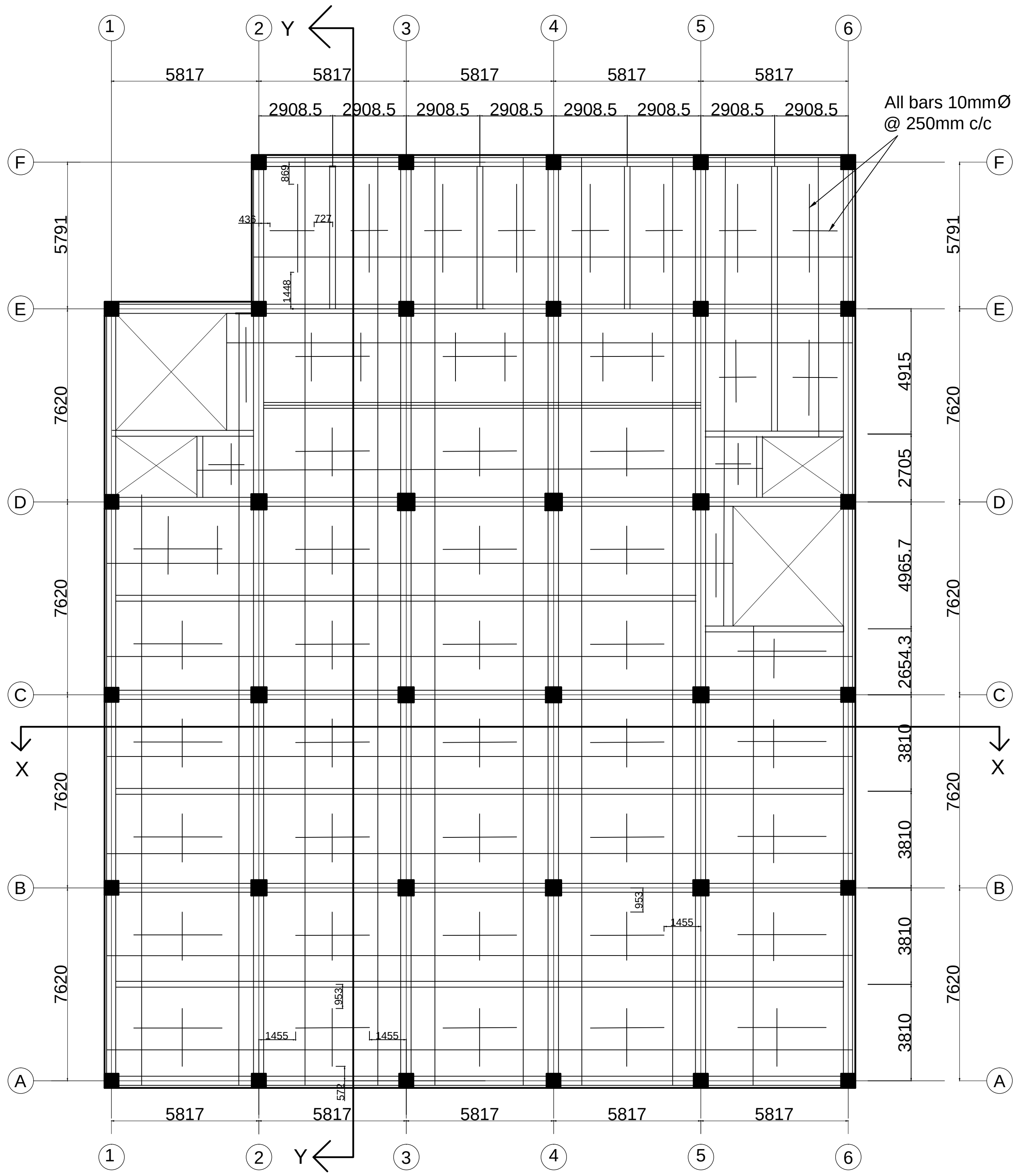


EAST ELEVATION

TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	PROJECT TITLE "STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	SHEET TITLE ELEVATION	GROUP MEMBERS RABIN LAMSAL 075BCE110 SHREEJA RAJBAHAK 075BCE157 SINAM ADHIKARI 075BCE162 SNEHA NEOPANE 075BCE164 SUSMITA TIMALSINA 075BCE182 TIMILA MAHARJAN 075BCE187	PROJECT SUPERVISOR ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	SCALE FIT TO SCALE SHEET NO. 07

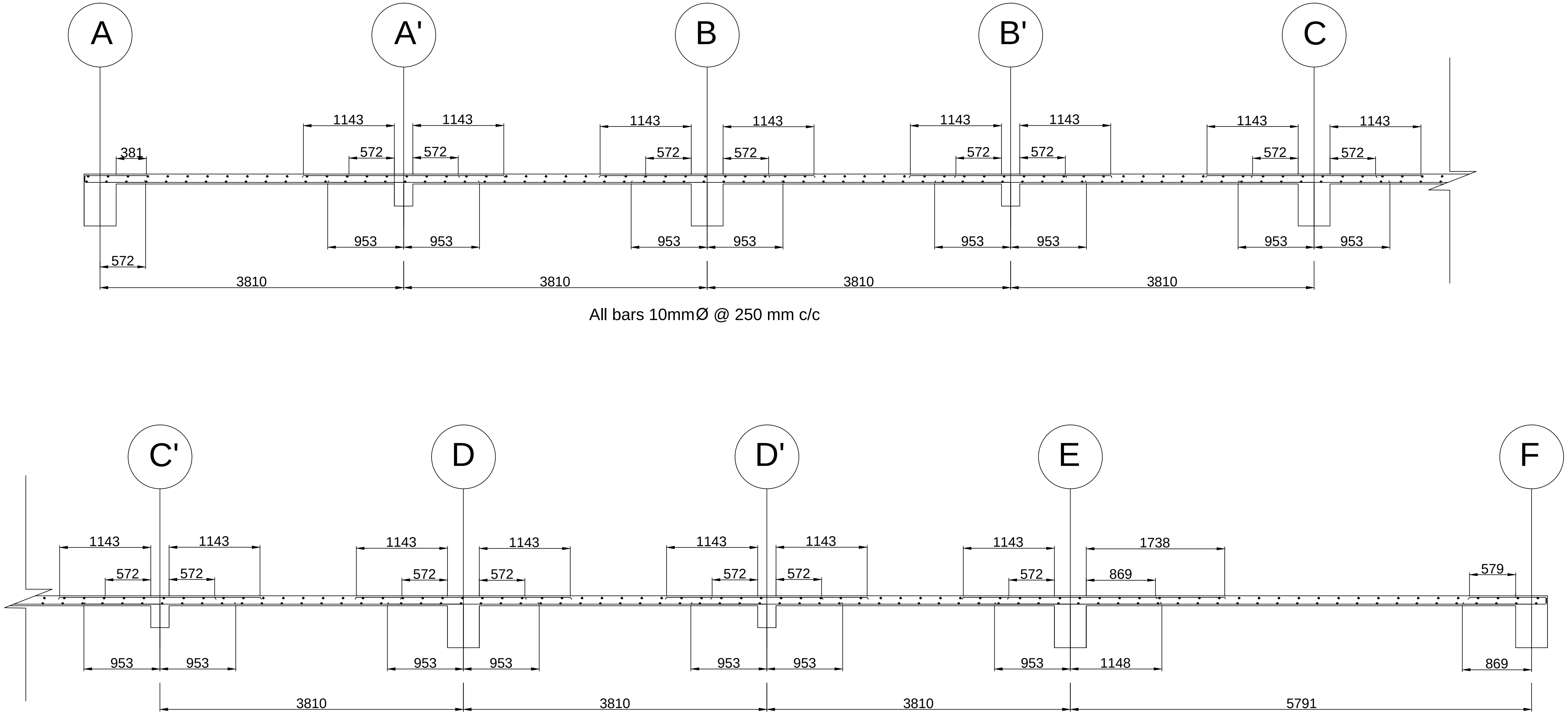


TOP REINFORCEMENT OF TYPICAL SLAB



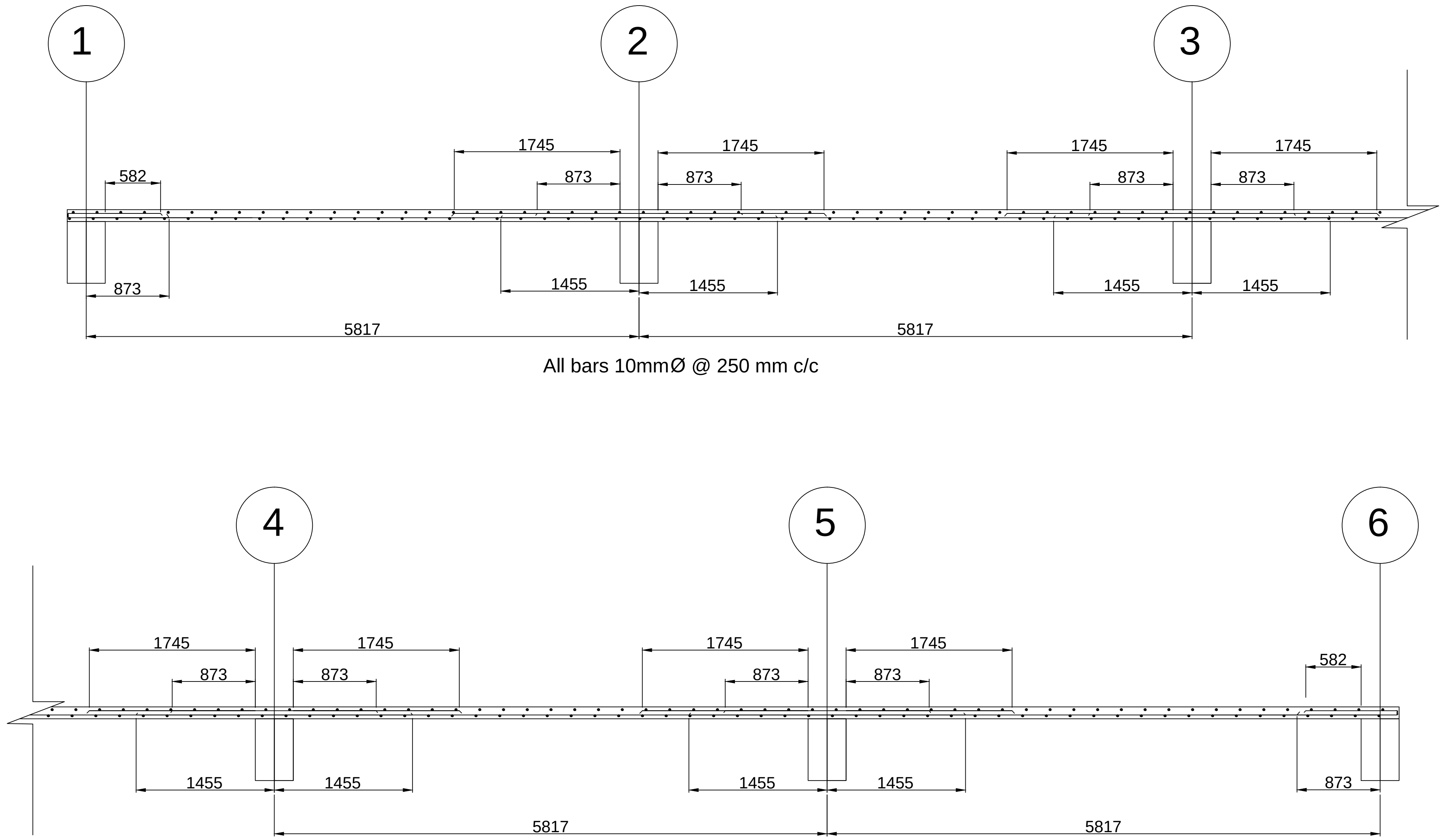
BOTTOM REINFORCEMENT OF TYPICAL SLAB

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF SLAB	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 08



SECTION ALONG Y-Y AXIS

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF SLAB	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 09



SECTION ALONG X-X AXIS

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
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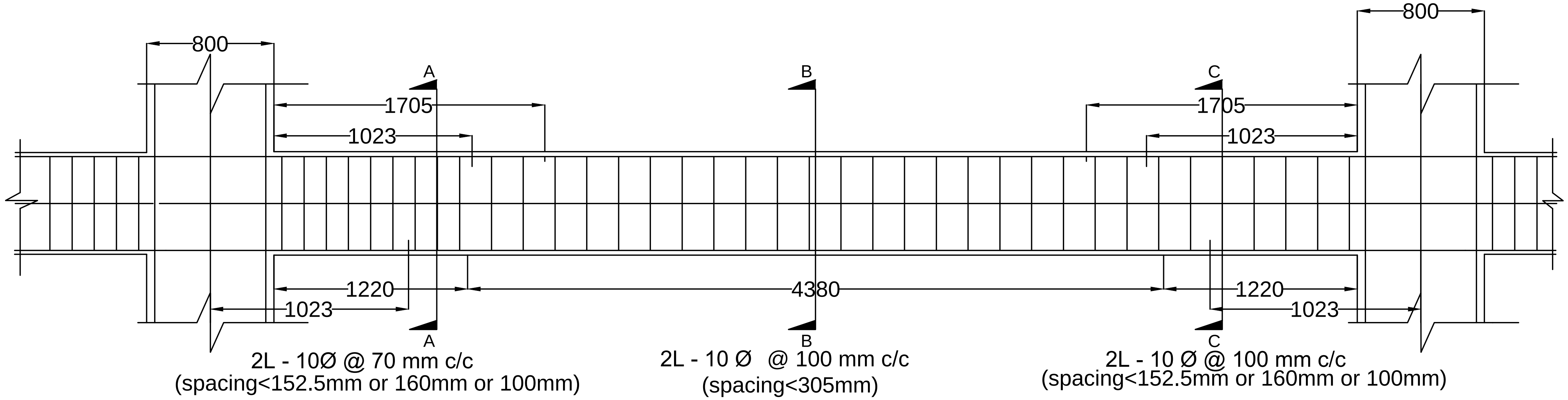
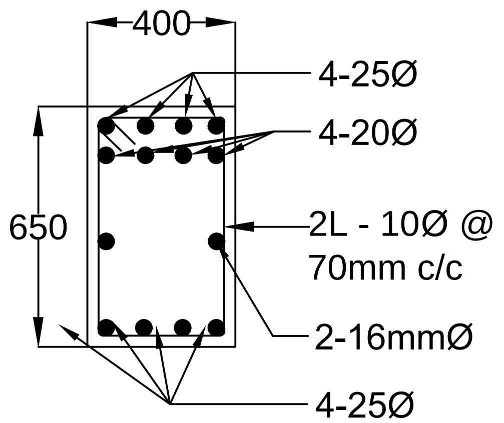
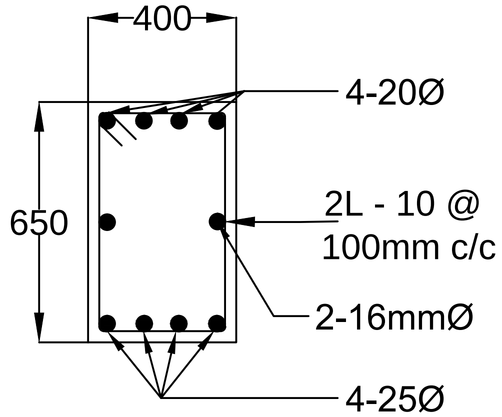


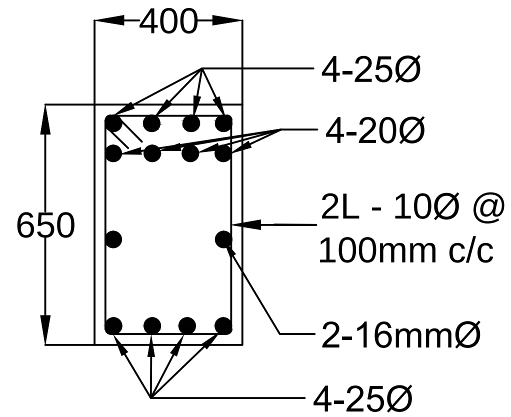
LONGITUDINAL SECTION OF PRIMARY BEAM



SECTION A-A



SECTION B-B



SECTION C-C

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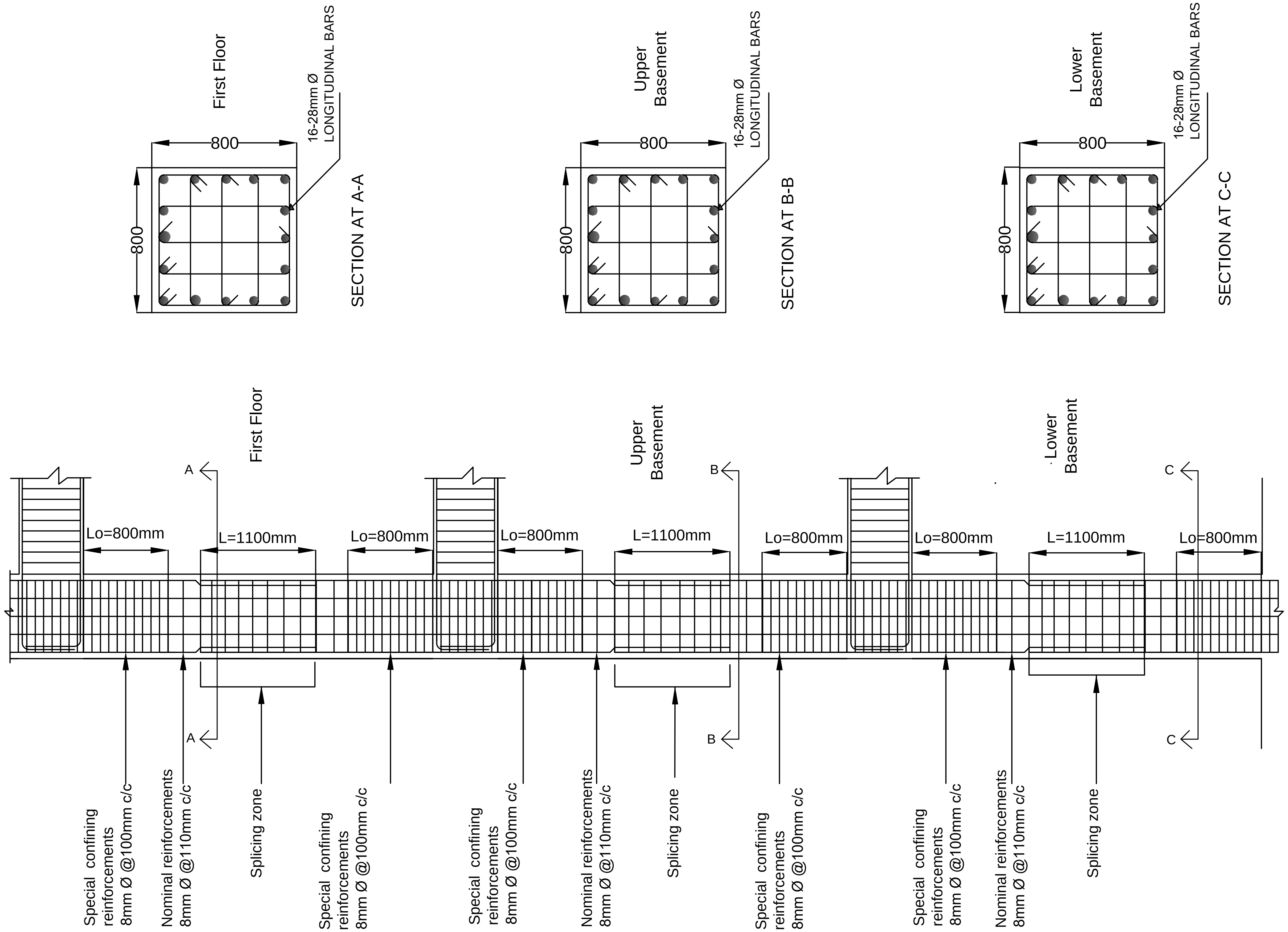
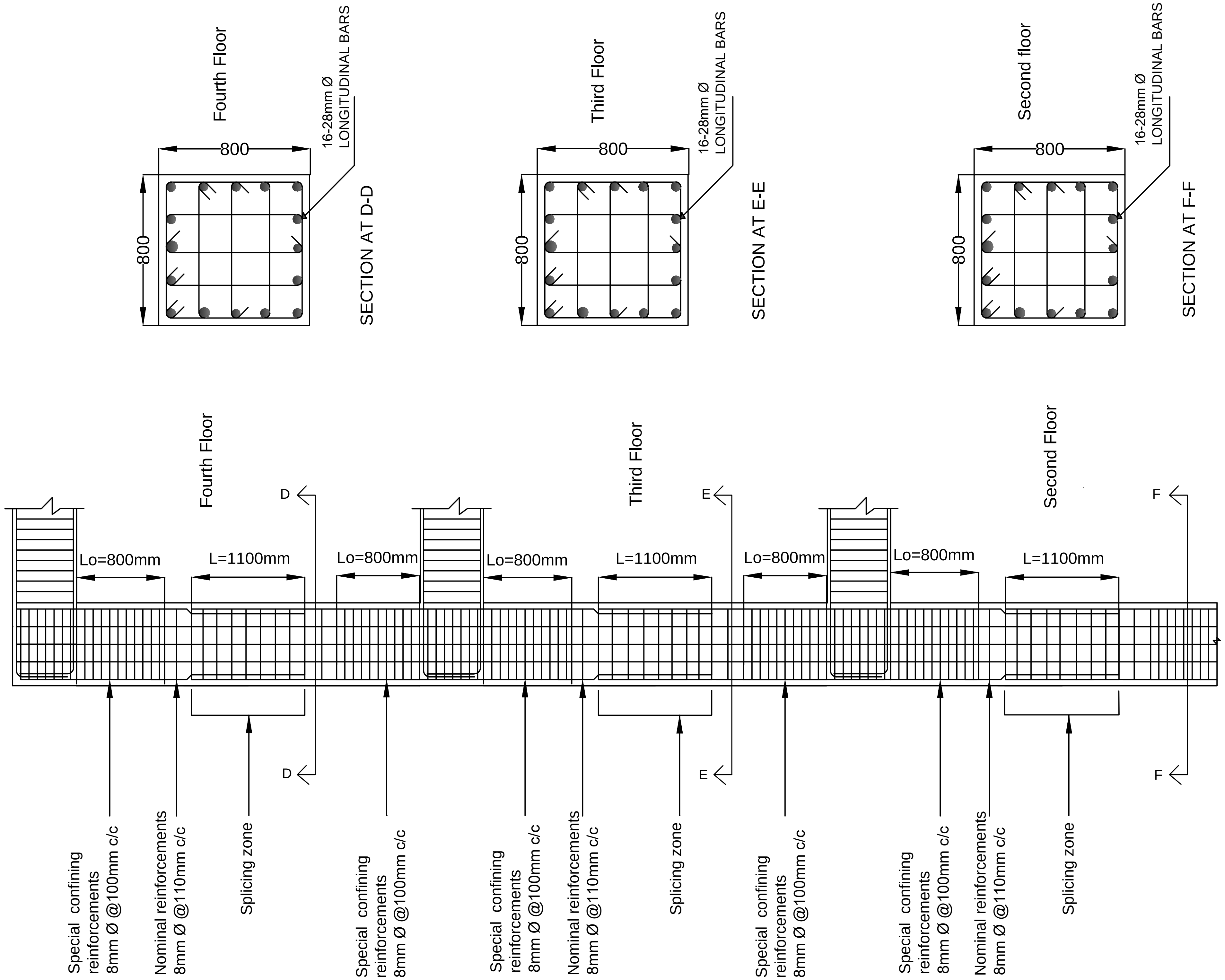


	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF COLUMN	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 12



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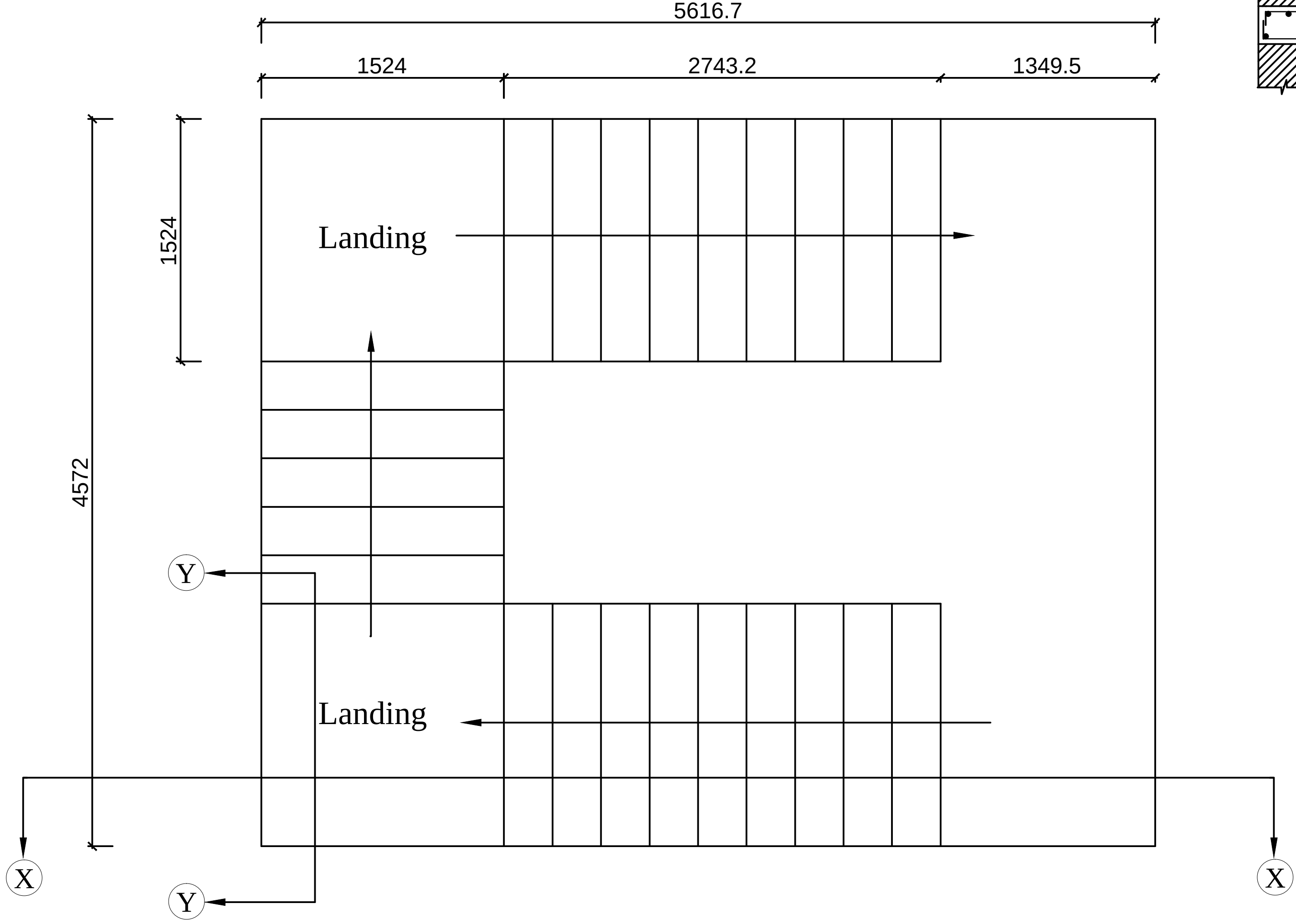
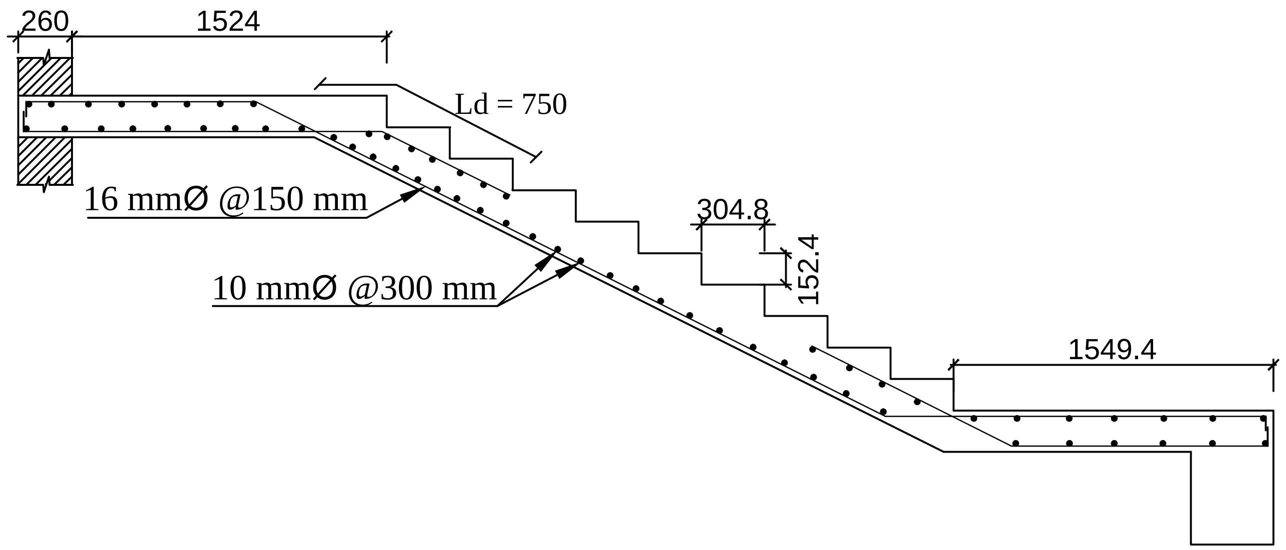
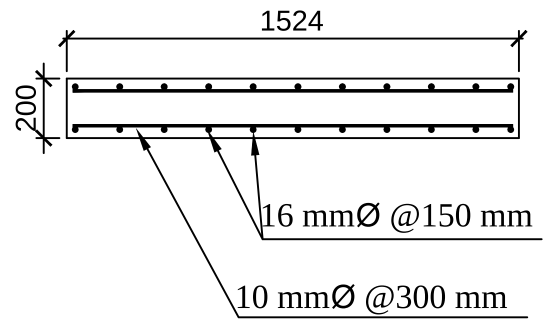
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF COLUMN	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 13



OPEN WELL STAIRCASE- PLAN



CROSS SECTION AT X-X



CROSS SECTION AT Y-Y

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
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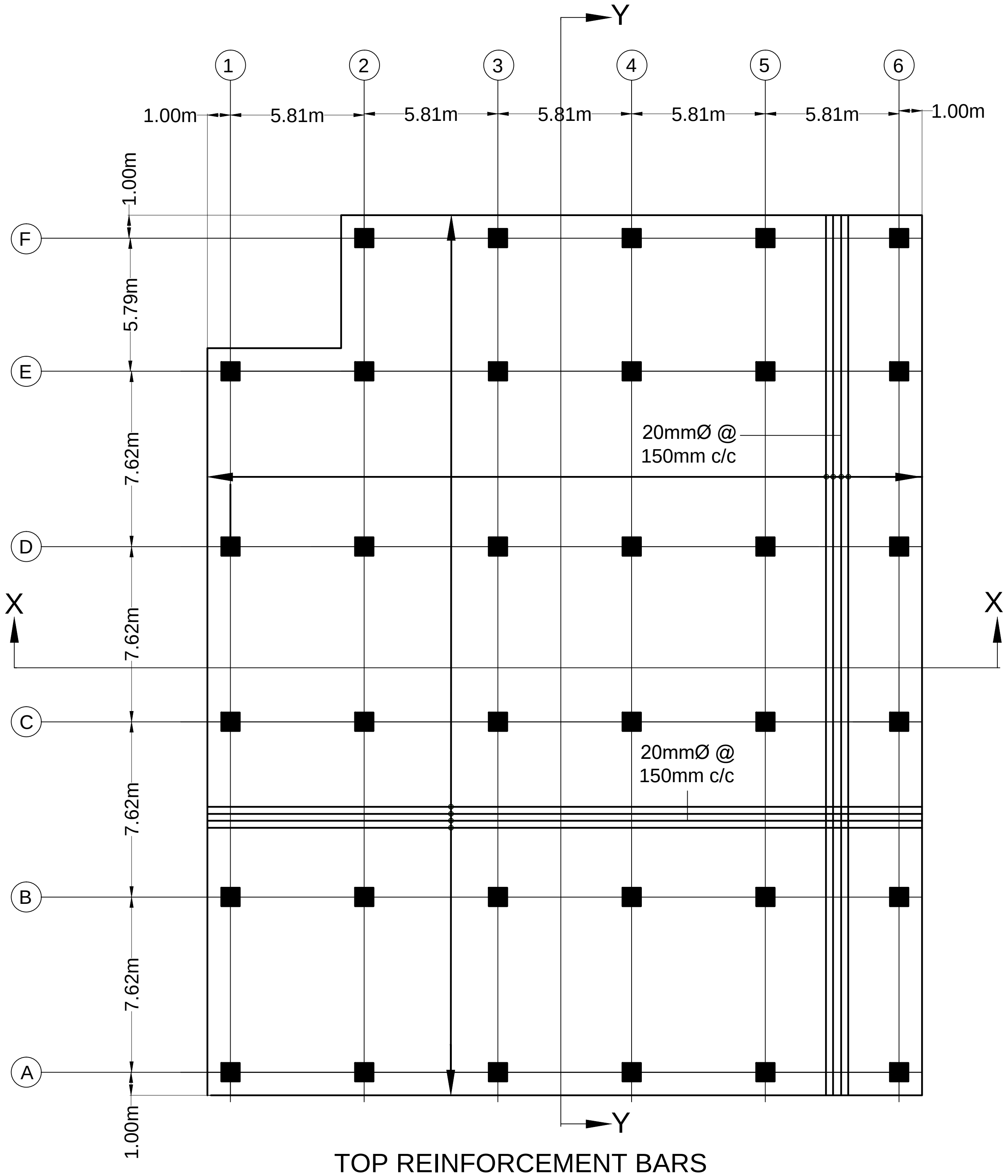
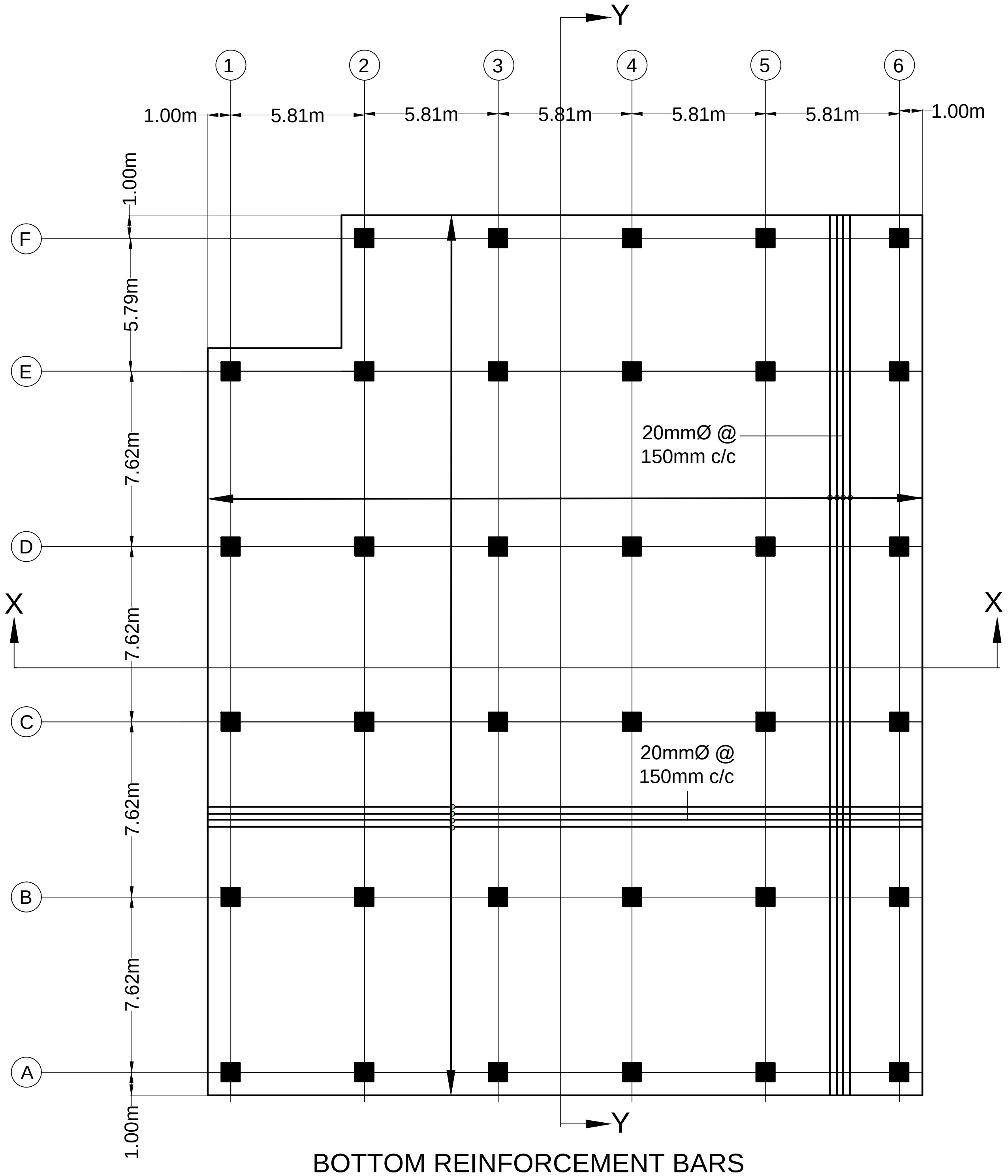
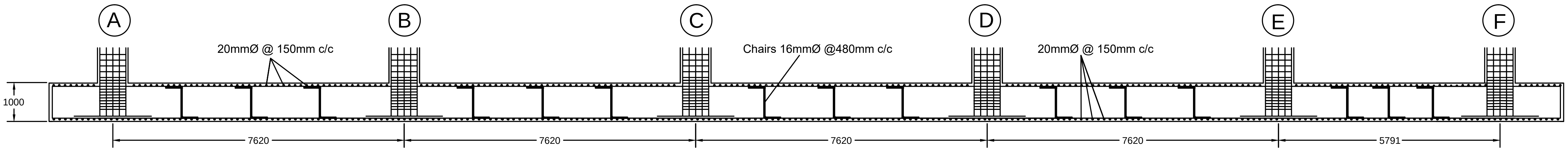


TOP REINFORCEMENT BARS

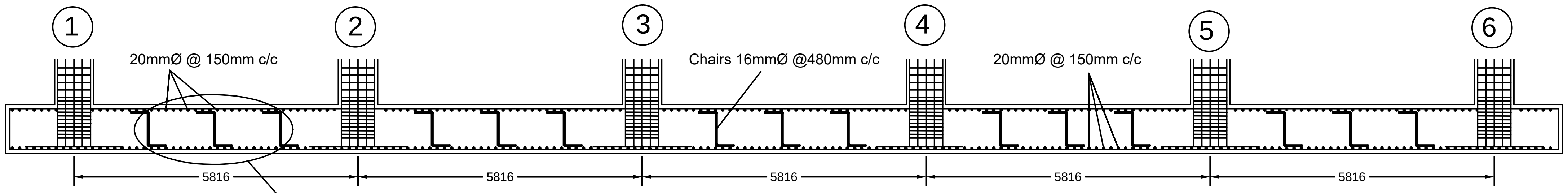


BOTTOM REINFORCEMENT BARS

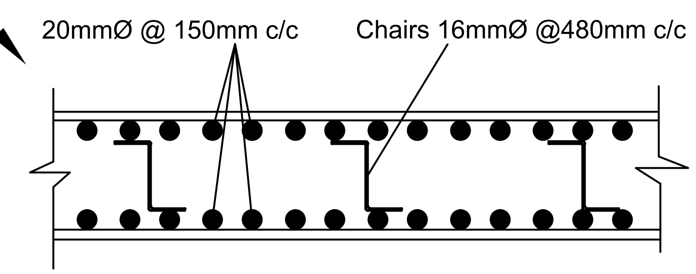
	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF MAT FOUNDATION	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 15



SECTION AT Y-Y

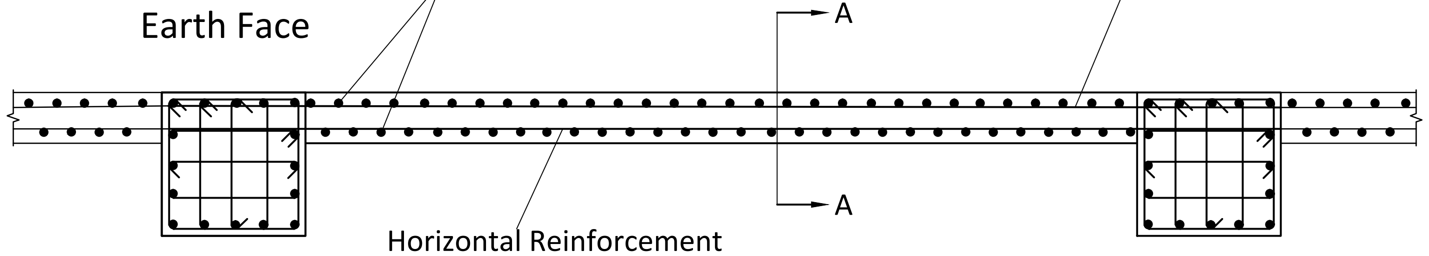


SECTION AT X-X

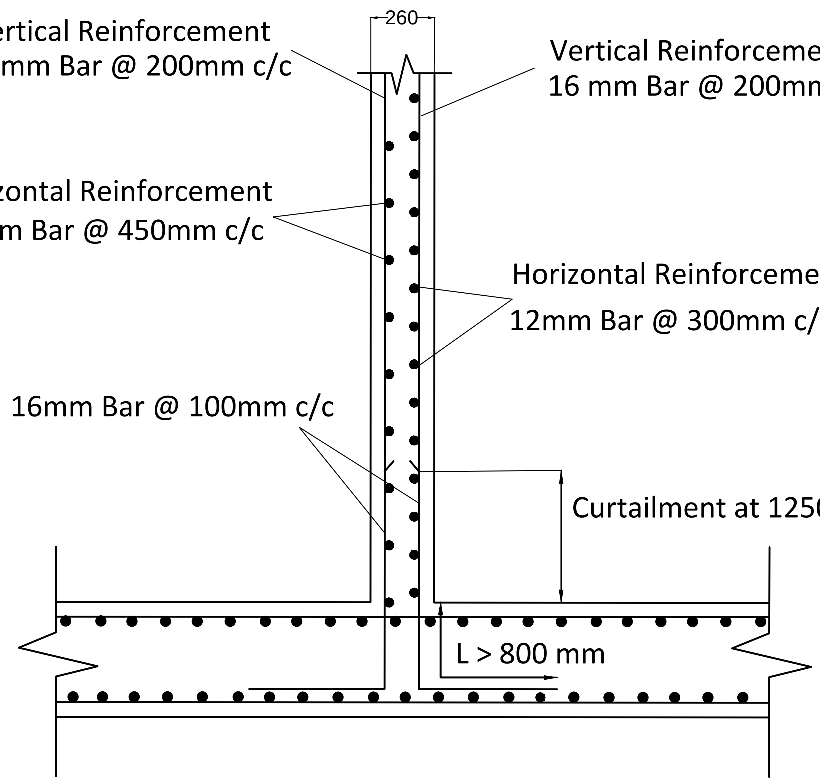


REINFORCEMENT DETAIL OF MAT FOUNDATION

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF MAT FOUNDATION	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 16

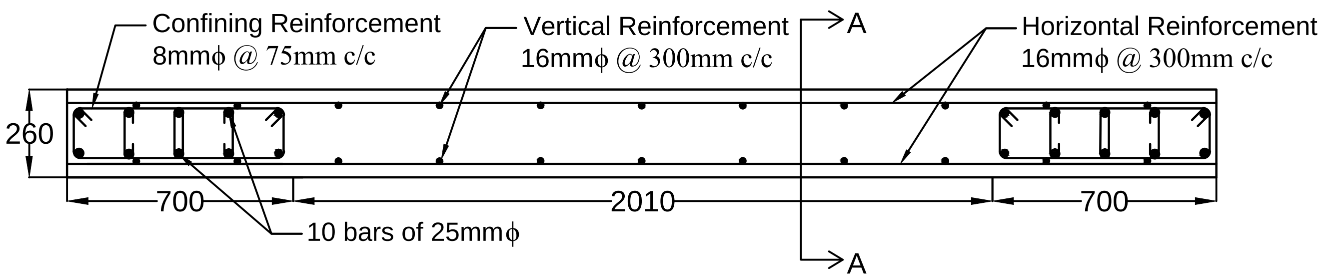


PLAN VIEW

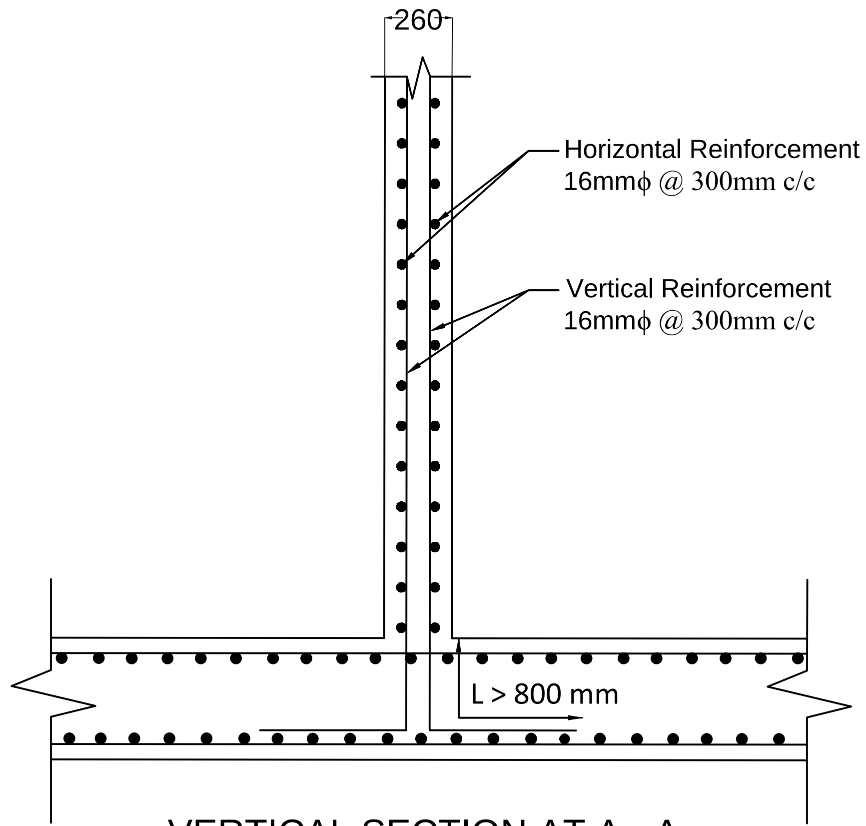


VERTICAL SECTION AT A-A

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF BASEMENT WALL	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 17



PLAN VIEW



VERTICAL SECTION AT A - A

	PROJECT TITLE	SHEET TITLE	GROUP MEMBERS		PROJECT SUPERVISOR	SCALE
TRIBHUVAN UNIVERSITY INSTITUTE OF ENGINEERING PULCHOWK CAMPUS DEPARTMENT OF CIVIL ENGINEERING	"STRUCTURAL ANALYSIS AND DESIGN OF COMMERCIAL BUILDING"	REINFORCEMENT DETAILING OF SHEAR WALL	RABIN LAMSAL SHREEJA RAJBAHAK SINAM ADHIKARI SNEHA NEOPANE SUSMITA TIMALSINA TIMILA MAHARJAN	075BCE110 075BCE157 075BCE162 075BCE164 075BCE182 075BCE187	ASST. PROF. THAMAN BAHADUR KHADKA CHECKED BY	FIT TO SCALE SHEET NO. 18

9. CONCLUSION

During our entire project different problems were encountered and solutions to these problems were found effectively. We were able to learn how to design and analyze a building using various codes and ETABS software. The project gave us a general idea regarding the earthquake resistant design, analysis with response spectrum method and ductility detailing that needs to be done in order to ensure safety to both structures and human life during an earthquake. It also helped us understand the mechanism of transfer of lateral earthquake load into vertical members and finally to the foundation. Due to the frequent earthquakes that strike Nepal every year, earthquake resistant design seems to be of utmost importance in infrastructure development.

The purpose of this project, though fully academic oriented, we have made every effort to make it feasible for the real construction. Due attention was given to maintain the accuracy while analyzing the data and designing the structural elements in computer. Design and layout of other building services like electrical and sanitary appliances were not conducted in this project. Also, cost estimate is not included in the project. Nevertheless, the main objective of project was not overruled.

Finally, we hope that the group efforts and coordination for the project has recognized this project as a success and we anticipate to work in similar analyzing and designing career of earthquake resistant building in the future.

10. REFERENCES

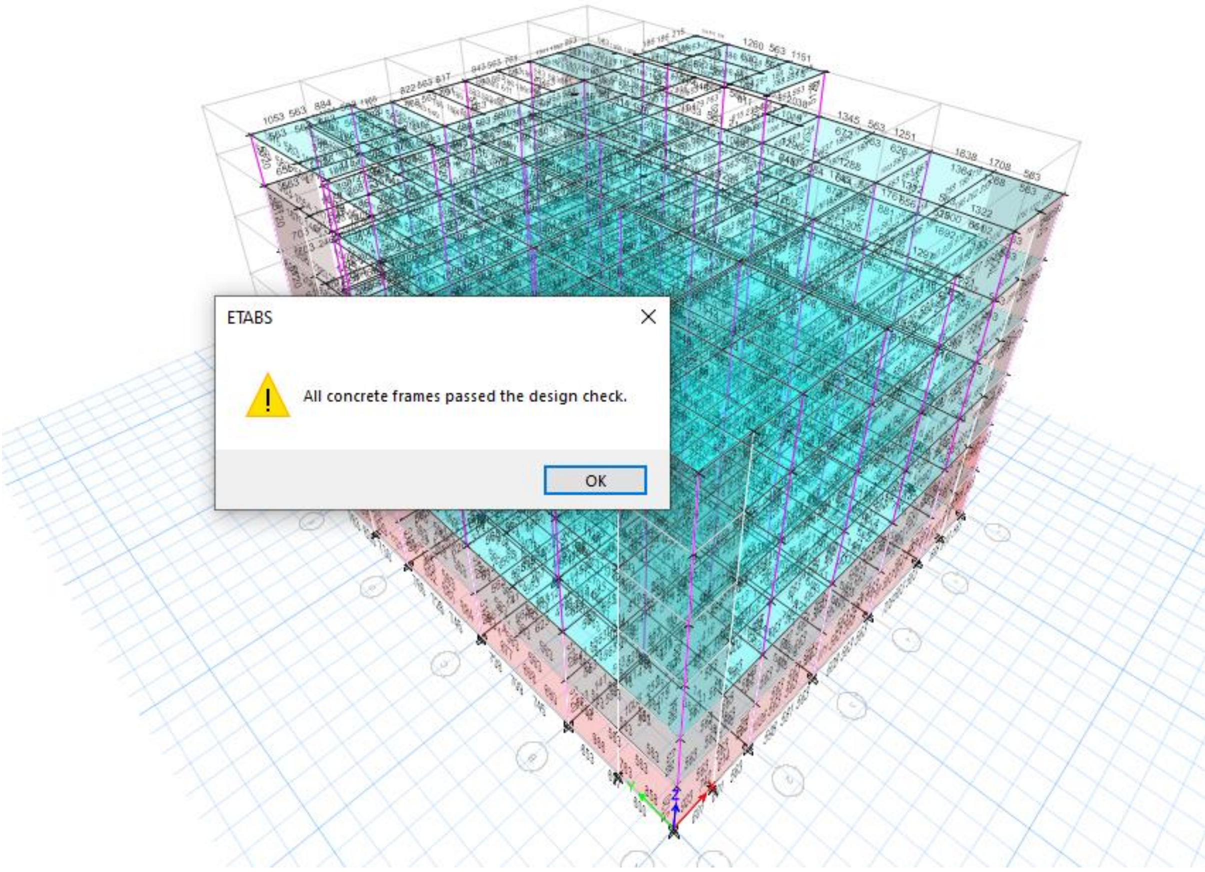
10.1. Design Handbook and Textbook

- Jain, A.K. (2007), Reinforced Concrete Structures Limit State Design- Sixth Edition, Nemchand Brothers and Sons' Publishers.
- Thapa, K.B., Design of Reinforced Concreter-First Edition, Rihand Engineering Consultancy Pvt. Ltd., Kathmandu-2016.
- Subramanian N. (2013), Design of Reinforced concrete structures- First Edition, Oxford University Press, New Delhi,
- Pillai, S.U. and Menon, D. (2009), Reinforced Concrete Design-Third Edition, Tata McGraw Hill Education Private Limited, New Delhi-2009.
- Clough, R.W. and Penzien, P., Dynamics of Structure-Second Edition, CBS Publisher and Distributors Pvt. Ltd., New Delhi-2015.

10.2. Code of Practice and Special Publications

- IS 456:2000, Indian Standard Plain and Reinforced Concrete- Code of Practice, Indian Standards Institution
- IS 1893(Part 1):2016, Indian Standard Criteria for Earthquake Resistant Design of Structure, Part 1- General Provisions and Buildings, Indian Standards Institution
- IS 13920:1993, Indian Standard Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces- Code of Practice, Indian Standards Institution
- SP 16: Design Aids for Reinforced Concrete to IS 456-1978
- SP 34 Hand Book on Concrete Reinforcement and Detailing
- IS 875(Part 1):1987, Indian Standard Code of Practice for Design Loads (Other than earthquake) for Buildings and Structures, Part 1- Dead Loads Indian Standards Institution
- IS 875(Part 2):1987, Indian Standard Code of Practice for Design Loads (Other than earthquake) for Buildings and Structures, Part 2- Imposed Loads, Indian Standards Institution

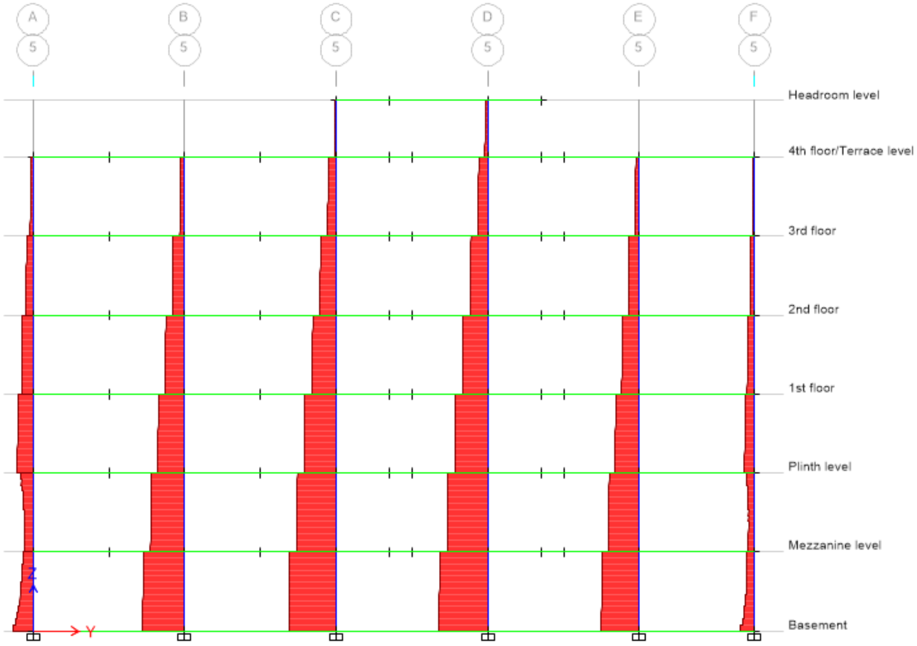
ANNEX



Members Check

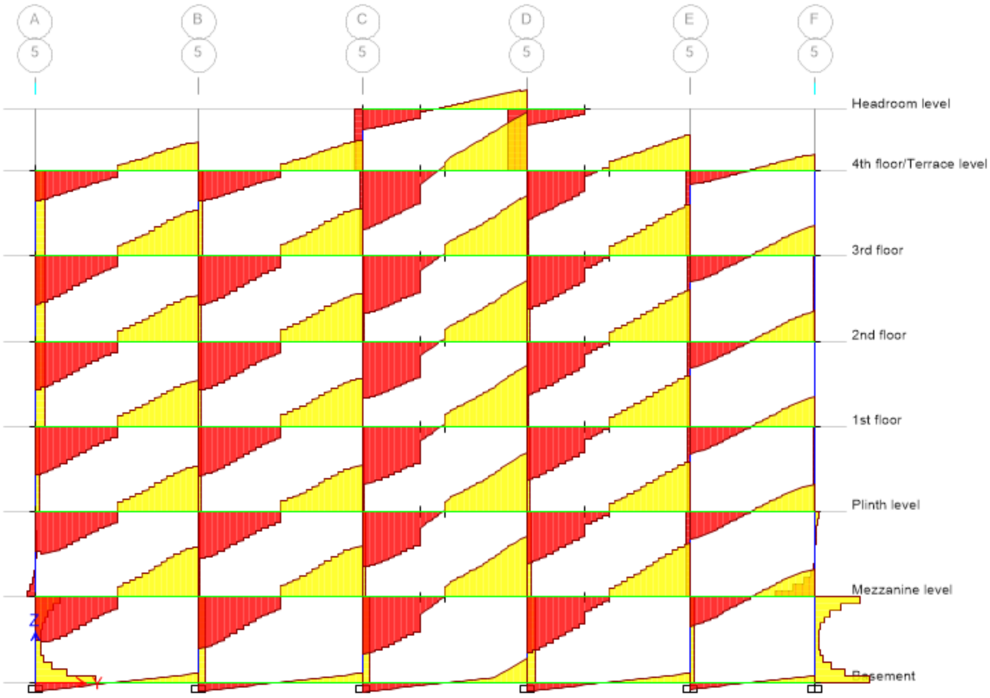
Axial Force Diagram

For 1.5(DL+LL)



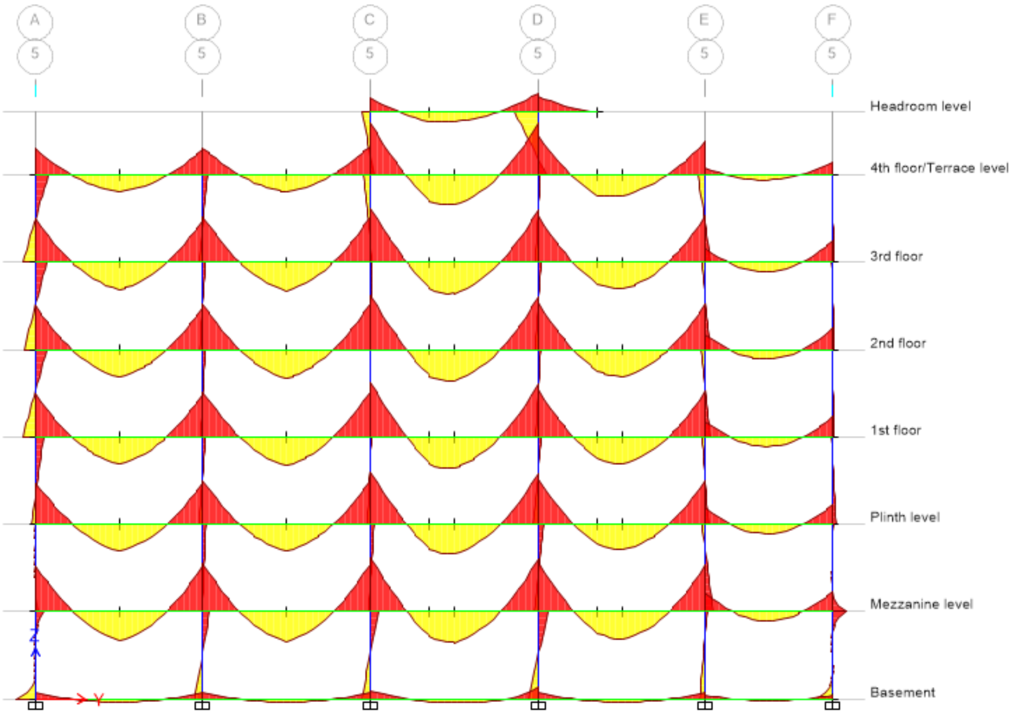
Shear Force Diagram

For 1.5(DL+LL)



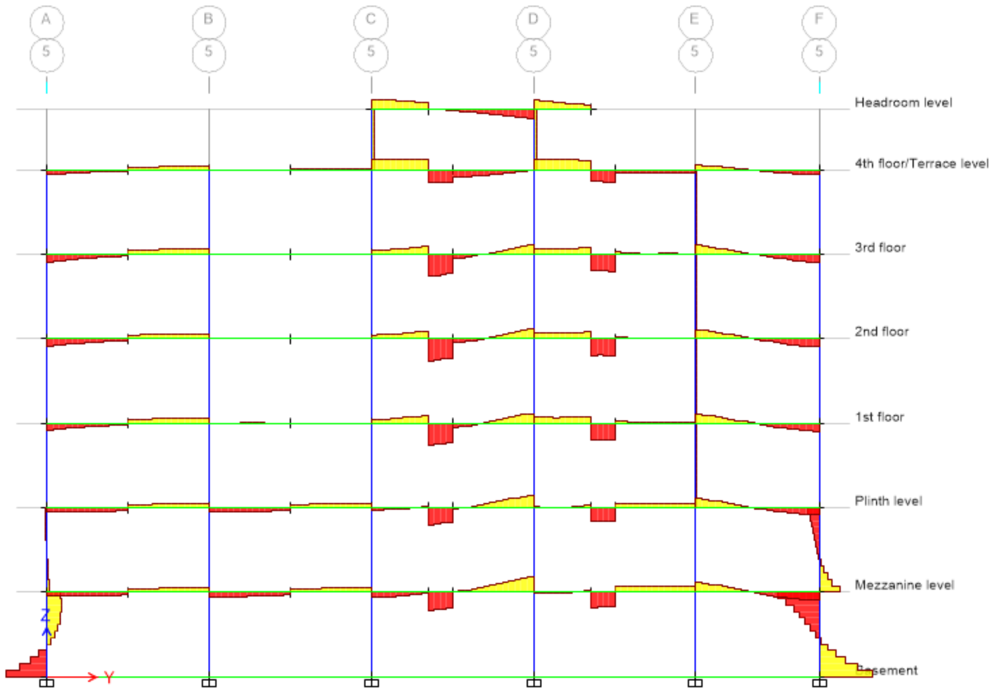
Bending Moment Diagram

For 1.5(DL+LL)



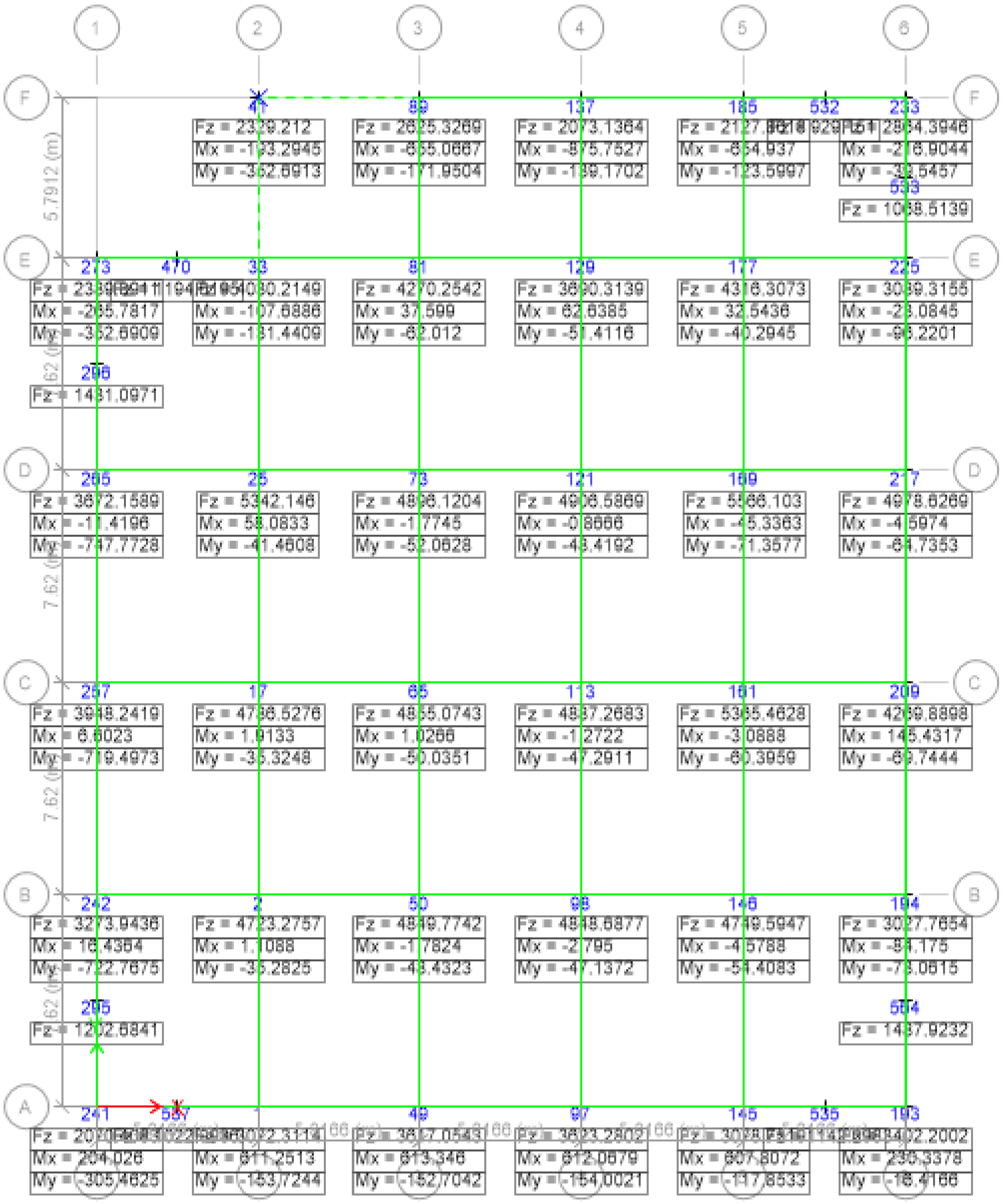
Torsion Diagram

For 1.5(DL+LL)

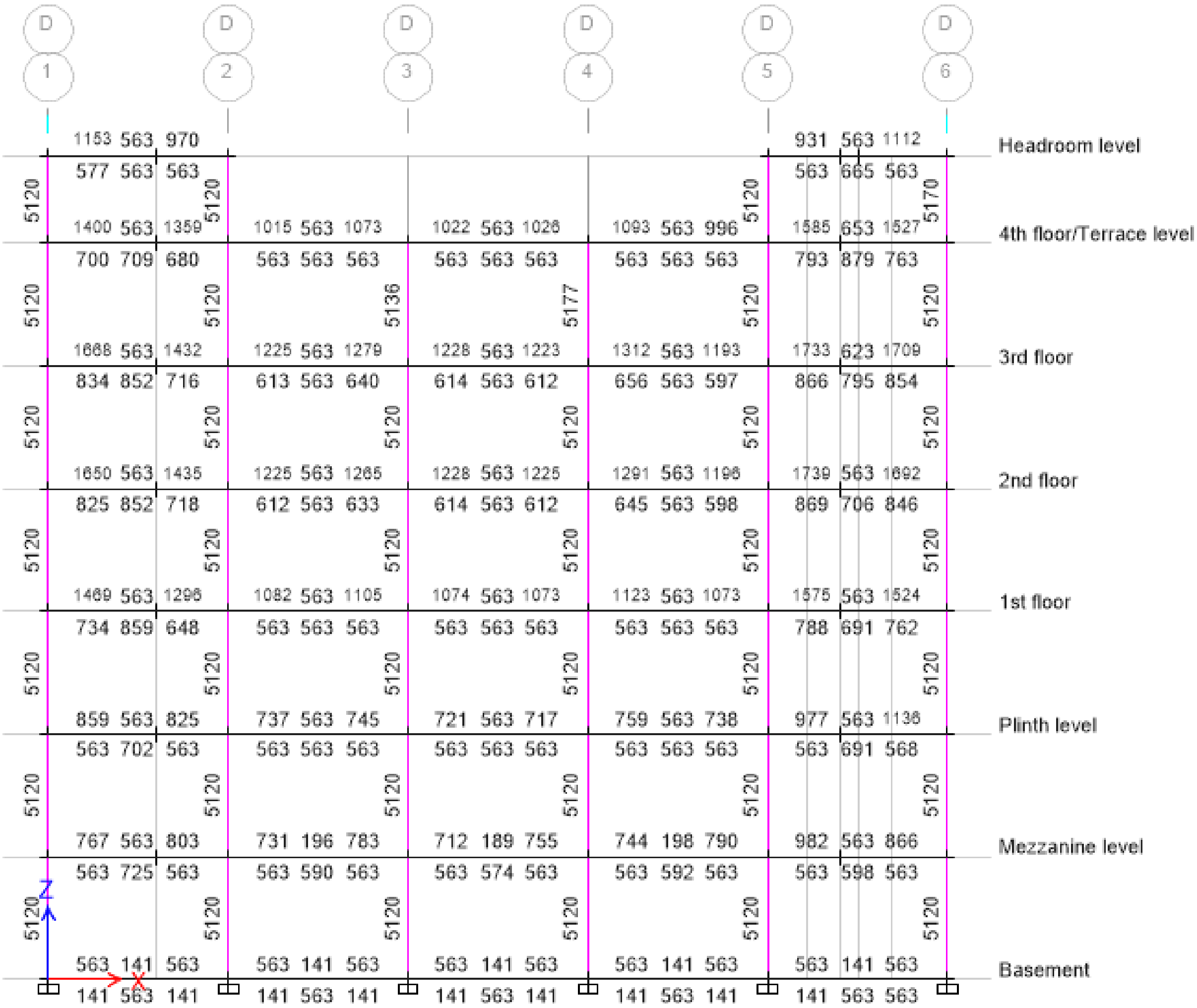


Restraint Reaction

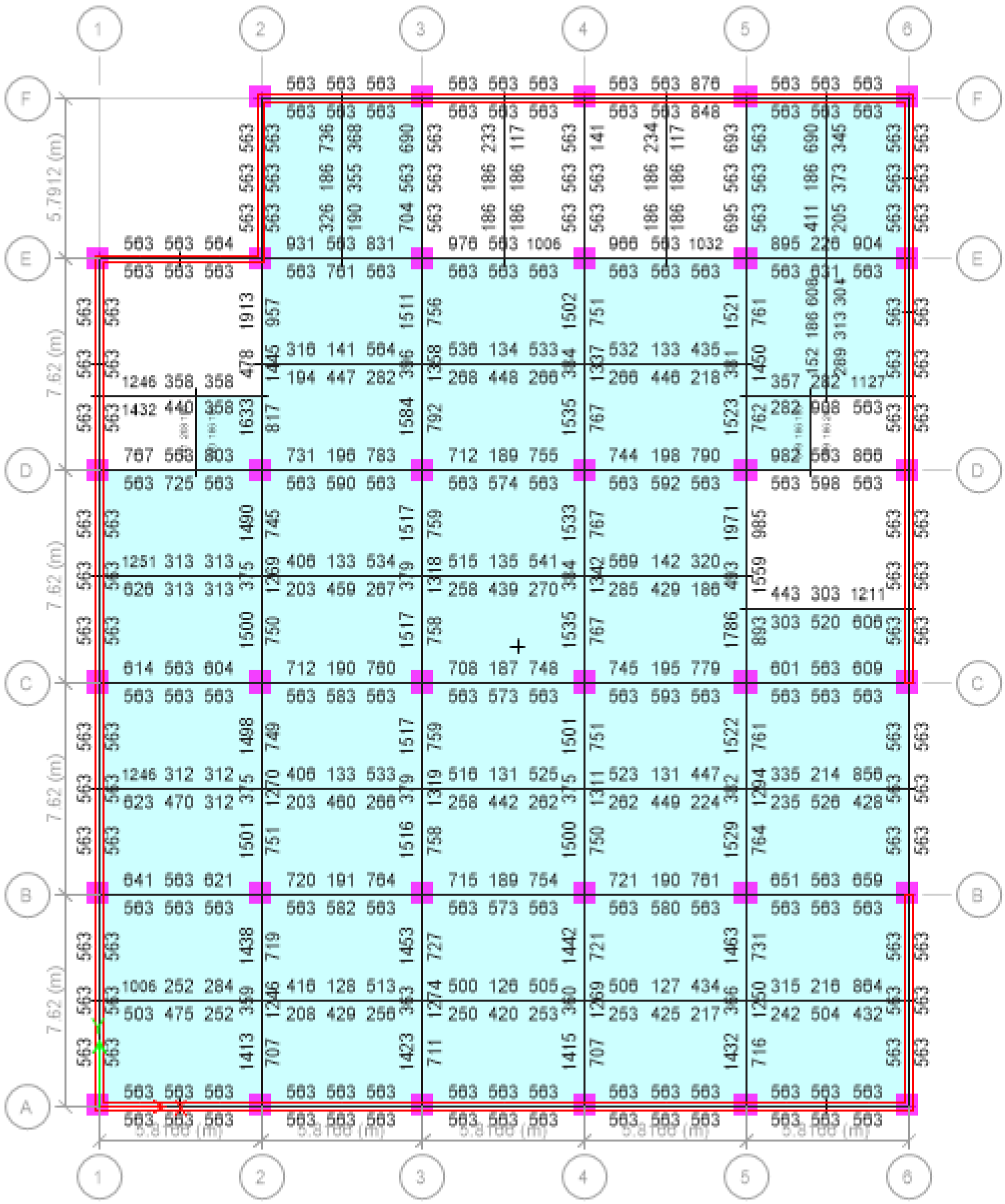
For 1.5(DL+LL)



Longitudinal Reinforcement: Elevation

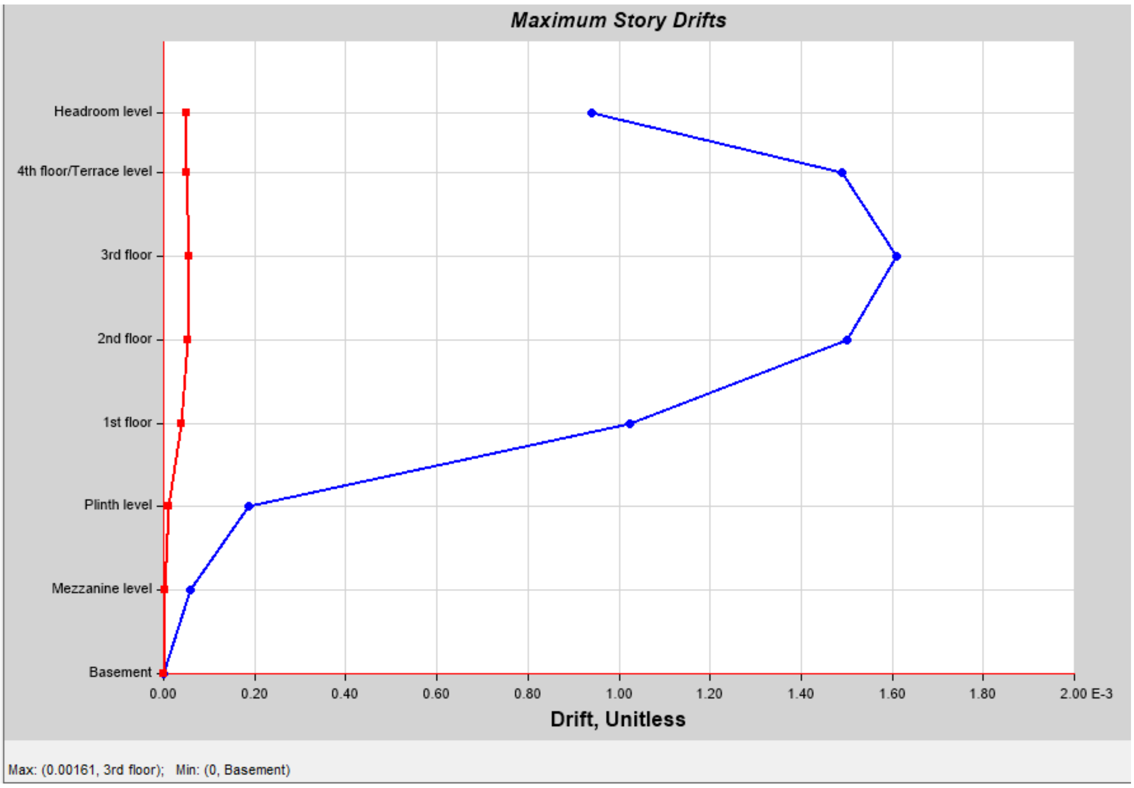


Longitudinal Reinforcement: Plan



Maximum Storey Drift

In X- Direction



In Y- Direction