TRIBHUWAN UNIVERSITY
INSTITUTE OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
Pulchowk Campus, Lalitpur

A
Report On

Earthquake Resistant Analysis and Design of Multistoreyed Residential Building

In the partial fulfillment of requirements for the Bachelor's
Degree in Civil Engineering
(Course Code: CE755)

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Submitted To
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August, 2017

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LETTER OF APPROVAL

This is to certify that this project work entitled "Earthquake Resistant Analysis and Design of Multistoreyed Residential Building" has been examined and it has been declared successful for the fulfillment of the academic requirements towards the completion of the Bachelor's Degree in Civil Engineering.

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Acknowledgement

The success of this project required a lot of guidance and assistance from many people and we are extremely fortunate to have got this all along the completion of our final year project work. Whatever we have done is only due to such guidance and assistance and we would not forget to thank them.

Firstly, we would like to thank Institute of Engineering for including the final year project as a part of our curriculum. Special thanks go to Department of Civil Engineering for initiating and facilitating this Building Project to further enhance our knowledge of structural analysis and design.

We respect and thank our Supervisor – Assistant Professor Sujan Tripathi for providing us all support and guidance during the working phase.

We are thankful to and fortunate enough to get constant encouragement, support and guidance from all teaching staffs namely Mahendra Raj Dhital, Dinesh Gupta, Pradip Koirala, Prof. Dr. Hikmat Raj Joshi, Dr. Bharat Mandal, Asso. Prof. Nabin Chandra Sharma and Department of Civil Engineering which helped us in successfully completing our project work.

Acknowledgement would be incomplete without mentioning our family members and friends who have been constant source of inspiration during the preparation of the project.

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ACRONYMS

SYMBOL	Meaning
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
T_C	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
H	Height of building
H	Height of underground water tank
I	Importance Factor (For Base Shear Calculation)
I_{XX},I_{YY}	Moment of Inertia (along x and y direction)
J	Neutral Axis Depth Factor
K	Coefficient of Constant or factor

k_1, k_2, k_3	Coefficient for wind pressure
K_A , K_P	Active and Passive Earth Pressure
L	Length of Member
L_{EF}	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
P_C	Percentage of Compression Reinforcement
P_T	Percentage of Tension Reinforcement
P_Z	Wind Pressure
Q, Q_U	Permissible and Ultimate bearing capacity of soil
Q_I	Design Lateral Force in i^{th} Level
SR, R_{MIN}	Slenderness Ratio,(minimum) for structural steel section
R	Response Reduction Factor
S_A/G	Average Response Acceleration Coefficient
S_V	Spacing of Each Bar
T_I	Torsional Moment due to Lateral Force in i-direction
T_A	Fundamental Natural Period of Vibrations
V_B	Basic wind speed
V_Z	Design wind speed
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, Fe415	Grade of Steel

Salient Features

a. Name of the Project: Seismic Analysis and Design of Multi-Storeyed RCC Building
b. Location:
    a. Region: Central Development Region
    b. Zone: Bagmati
    c. District: Kathmandu
c. Type of Building: Residential Building
d. Structural System: Special Moment Resisting Frame
e. Soil Type: ii
f. Seismic zone: V
g. No of Storey: Basement + 10 floors + Staircase Cover
h. Dimension of building:
    a. Maximum length: 21.463m
    b. Maximum Breadth: 24.130m
i. Type of Staircase: Open Well
j. Type of foundation: Raft Foundation
k. Floor Height:
    a. Basement: 2.997m
    b. Typical: 3.2004
    c. Staircase cover: 2.8956m
l. Infill wall: Brick Masonry
    a. Main wall: 0.2286m
    b. Partition wall: 0.1143m
m. Design criteria: As per IS code
n. Size of structural elements:
    a. Beam: 300*500mm
    b. Column: 540mm*540mm in basement and 1st floor
       500mm*500mm from 2nd floor to top floor
    c. Slab thickness: 150mm
    d. Depth of footing: 0.508m
o. No of columns:
    a. Basement: 42
    b. Typical: 42
    c. Staircase cover: 8
p. Number of lifts available: 2

ABSTRACT

The main aim of the project is to structurally analyze and design a seismic resistant multistoreyed building. A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic sanitation and ventilation and daylight standards. The design of the building is dependent upon the minimum requirement prescribed for each of the above functions.

As per the recent following of the Gorkha Earthquake that occurred in 25th April, 2015, the construction of multistoreyed building has been of major concern. So, proper selection of the building site is required. The analysis and design of our building is based on increasing the seismic capacity through proper configuration of the structure as well as proper designing and ductile detailing of structural elements.

The project is commenced within the above-mentioned criteria. Also, the strength and serviceability criteria are fulfilled. The final output of the project is object in the form of detailed drawings.

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1. Introduction

1.1. Background

One of the basic needs of a human being is shelter. Shelter being defined as a place giving temporary protection from bad weather or, danger. Long time ago people lived in temporary shelters as in caves. Later they built temporary shelters made from trees and bushes. With the evolution of humans, they started to build permanent houses consisted of masonry structures i.e. mud, stones, timber, straw, dongs etc. but these houses were not stable enough. As time passed and new methods of constructed were introduced humans started to build more stable and stronger houses for shelter.

With the present context, just building houses is not enough. There is less space available for construction but the population is increasing day by day. Moreover, in Nepal's capital the land price has been hiked to a limit which cannot be afford to build residential houses for a small family. As the land available is less and the available land is overpriced the construction has to be carried out vertically instead of lateral expansion. This has mostly led to the constructions of high rise multistoreyed buildings in Kathmandu.

Also with the occurrence of the recent Gorkha Earthquake occurred in 25th April, 2015 at 11:56:26 NST, it has added an extra attention in the design of a structure. The violent shaking occurred with a magnitude of 7.8 Richter with its focal point located 8.2 km downward with Mercalli intensity of grade IX. The total damage was estimated to be $5 billion with total deaths to be 8,959 with 23,447 casualties. Hundreds of thousands of people were made homeless with entire villages flattened, across many districts of the country. Centuries-old buildings were destroyed at UNESCO World Heritage sites in the Kathmandu Valley. The earthquake has created awareness among the people about the seismic effect on the structure, its unique loading patterns, bearing capacity of the subsurface and other effects like wind, storey drift for the seismic design and analysis of multistoreyed buildings.

The building associated with out project lies in Kathmandu valley which is allocated as seismic zone "V" according to its seismic severity. In the context of Kathmandu, here the earthquake load dominates the wind load and governs the lateral design loading.

This project has been undertaken as a partial requirement for B.E. degree in Civil Engineering. This project contains structural analysis, design and detailing of residential building located in Kathmandu district. All the theoretical knowledge of analysis and design acquired on the course work are utilized with the practical application.

1.2. Theme of the Project Work

The theme of the project is to structurally analyze and design an earthquake resistant multistoreyed building. During the execution of the project, we have acquired knowledge and skill to emphasis on practical application besides the utilization of analytical methods and design approaches, exposure and application of various available codes of practices.

1.3. Objective

The specific objectives are:

i. Reviewing of the available architectural drawing.
ii. Modification of Architectural drawing on the basis of earthquake force reduction principle.
iii. Preliminary design of the structural elements.
iv. Detailed structural analysis of the building using SAP2000 v19.
v. Design of various structural components.
vi. Ductile detailing of structural members.
vii. Preparation of detailed structural drawings.
viii. Better acquaintance with the code provisions related to RCC design.
ix. Acquire knowledge on earthquake engineering.

1.4. Scope

This project work provides us the information about how to analyse and design the multistoreyed earthquake resistant building. It further deals with

1.4.1. Work Scope

- Study architectural drawing and fixing structural system of the building to carry all the live load, dead load and lateral load.
- Calculation of loads including lateral loads.
- Preliminary design of structural elements.
- Identification of loads and load cases.
- Calculation of shear force, bending moment to determine size of the building components.
- To be familiar with structural analysis software i.e. SAP2000 v19 for different load cases.
- Determination of fundamental time period by SAP2000 v19.
- Review of analysis output for design of different components.
- Design of beam, column, slab and foundation by limit state method by following different codes.
- Final detailing of individual members and preparations of drawing to be applicable in fields.

1.4.2 Field Scope

- In the present context, in a developing city like Kathmandu, there is land crisis due to increasing population so as an engineer it will be challenging for us to minimize it. This can be solved upto some extent by designing/constructing high rise multistoreyd building for commercial, residential purposes, etc.
- Also our country lies in an earthquake prone area which may lead to loss of life and property which can be counteracted by seismic design of building.

1.5. Literature Review

Every engineering design is the outcome of the past experiences and observations. It is necessary to justify the result of the analysis and design properly with reference to the preexisting standard results or the past experiences. Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its service life. Safe design of structures can be achieved by applying the proper knowledge of structural mechanics and past experiences. It is needed to provide authentic reference to the design made i.e. the design should follow the provision made in codes of practices. Use of codes also keeps the designer to the safe side in case the structure fails within its service life. For this design, certain references and criteria are taken from the literatures discussed below.

I. Nepal National Building Code (NBC:000- 1994):

Nepal National Building Code was prepared during 1993 as part of a bigger project to mitigate the effect of earthquakes on the building of Nepal. It deals primarily with matters relating to the strength of buildings. However, there are some chapters on site considerations and safety during construction and fire hazards. This code aims to bring uniformity to the building construction by providing some bye-laws and mandatory rules. But its development is relatively recent and it <u>still lacks many documents required to support it</u>. To compensate for this unavailability, the <u>code frequently refers to Indian Standard codes</u>. The four different levels of sophistication of design and construction that are being addressed in this National Building Code are as follows.

i. International state-of-art
ii. Professionally engineered structures
iii. Buildings of restricted size designed to simple rules-of-thumb
iv. Remote rural buildings where control is impractical.

This project belongs to the second part of NBC i.e. Professionally Engineered Structures. <u>As the National Building Code defines the use of international codes which meets the requirements stated in NBC, different Indian Standard codes are used for the design and analysis purpose.</u>

II. Indian Standard (IS) Codes of Practice:

For the analysis and design of the building references have been made to Indian Standard code since National Building Codes of Nepal do not provide sufficient information and refers frequently to the Indian standard codes. Indian Standard codes used in the analysis and design of this building are described below:

1. **IS:875- 1987 (Reaffirmed 2003)- <u>Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures</u>:**

A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and daylight standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of the building are being covered in this code by way of laying down minimum designed load which have to be assumed for dead loads, imposed load, snow load and other external loads, the structure is required to bear. Strict conformity to loading standard recommended in this code claims to ensure the safety of the buildings and thereby reduced the hazards to life and property caused by unsafe structures as well as eliminates the wastage caused by the assumption of unnecessary heavy loading. This code is divided into five different parts for five different kinds of loadings. The different parts of the code are:

Part 1: Dead Loads- Unit Weight of Building Materials and Stored Materials:

This part deals with the dead load to be assumed in the design of the building. These loads are given in the form of unit weight of materials. The unit weight of the materials that are likely to be stored in the building are also given in the code for the purpose of the load calculation due to stored materials. This code covers the unit weight or mass of the materials and parts and components in the building that apply to the determination of the dead load in the design of building. Table 1 of this code covers unit weight of the building materials and Table 2 of the code covers the unit weight of the building parts or the components.

Part 2: Imposed Loads

Imposed load is the load assumed to be produced by the intended use or occupancy of a building including the weight of moveable partitions, distributed, concentrated loads, loads due to impact and vibrations and dust loads (Excluding wind, seismic, snow, load due to temperature change, creep, shrinkage, differential settlements etc.) This part of the code deals with imposed load of the building produced by the intended occupancy or use. Minimum imposed load that should be taken into consideration for the purpose of structural safety of the buildings are given in the code but it do not cover the incidental to construction and special cases of vibration, such as moving machinery, heavy acceleration from cranes hoist etc.

Part 3: Wind Loads

This part deals with the wind load to be considered when desigining the building, structure and component thereof. This code gives the wind force and their effect (Static and Dynamic) that should be taken into account when designing buildings, structures and components thereof. In the code wind load estimation is done by taking into account the random variation of the wind speed with time.

Part 4: Snow Loads

This part of the code deals with snow loads on roofs of buildings. Roofs should be designed for the actual load due to snow or the imposed load specified in Part 2 whichever is more sever. Since location of the building is within Kathmandu Valley, there is no possibility of snowfall. Hence the snow load is not considered in the design.

Part 5: Special Loads and Load Combinations

This code loads and loads effects (Except the loads covered in Part 1 to 4 and seismic load) due to temperature changes, internally generated stress due to creep shrinkage, differential settlement etc. in the building and its components, soil and hydrostatic pressures, accidental loads etc. This part also covers the guidance for the load combinations.

2. **IS 1893 (Part 1): 2002 Criteria for Earthquake Resistant Design of Structures (General Provision and Building):**

This code deals with the assessment of seismic loads on various structures and earthquake resistant design of buildings. Its basic provisions are applicable to buildings; elevated structures; industrial and stack like structures; bridges; concrete masonry and earth dams; embankment and retaining structures and other structures. Temporary supporting structures like scaffoldings etc. need not be considered for the seismic loads. It is concerned with the methods of determining seismic loads and the effects of various irregularities in a building can have upon its seismic response. This standard does not deal with the construction features relating to earthquake resistant design in building and other structures.

3. **IS 13920: 1993 (Reaffirmed 2003) Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Force- Code of Practice:**

This standard covers the requirements for designing and detailing of monolithic reinforced concrete buildings so as to give them adequate toughness and ductility to resist sever earthquake shock without collapse. The provision for the reinforced concrete construction given in the code are specifically to the monolithic reinforced concrete construction. For precast and prestressed concrete members, its use is limited only if they can provide the same level of ductility as that of monolithic reinforced concrete construction during or after earthquake. The code includes the detailing rules for flexural members, column and frame member subjected to bending and axial loads and shear walls.

4. **IS 456: 2000 (Reaffirmed 2005) Plain and Reinforced Concrete – Code of Practice:**

This Indian Standard code of practice deals with the general structural use of plain and reinforced concrete based on Limit State Design Method. According to the code, plain concrete structures referred to those structures where reinforcement if provided is ignored for determination of the strength of the structure. This code does not cover special requirements for the structures like bridges, chimneys, hydraulic structures, earthquake resistance buildings etc. but allows the use of separate code for those structures in conjunction with this code.

5. **IS 4326: 1993 (Reaffirmed 2003) <u>Earthquake Resistant Design and Construction of Buildings – Code of Practice:</u>**

This standard deal with the selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction using rectangular masonry units, timber construction and buildings with prefabricated flooring or roofing elements.

6. **IS 5525: 1969 (Reaffirmed 1990) <u>Recommendations for Detailing of Reinforcement in Reinforced Concrete Works:</u>**

This standard deal with the general requirements of detailing of reinforcement in reinforced concrete structures with some suitable modifications whenever necessary. This code includes the common method of detailing of reinforcement based on good practice with deviations made in special cases to comply with IS 456.

7. **IS 1642: 1989 (Reaffirmed 1994) <u>Fire Safety of Buildings (General): Details of Construction – Code of Practice:</u>**

This standard lays down the essential requirements of fire safety of buildings with respect to details of construction.

8. **IS 2950 (Part I): 1981 (Reaffirmed 1998) <u>Code of practice for design and construction of Raft Foundations:</u>**

Raft foundation is a substructure supporting an arrangement of columns or walls in a row or rows and transmitting the loads to the soil by means of a continuous slab with or without depressions or openings. Such types of foundations are found useful where soil has low bearing capacity. This standard covers the design of raft foundation based on conventional method (for rigid foundation) and simplified methods (flexible foundation) for residential and industrial buildings, store-houses, silos, storage tanks, etc., which have mainly vertical and evenly distributed loads.

III. Indian Standard Special Publications (SP):

For the clarification and explanation for the clauses and equations mentioned in Indian Standard Codes, Bureau of Indian Standard has published some special publications including charts and tables for required values like material properties and explaining examples of designs. Following design aids will be used for the design of the structure:

1. **SP 16: <u>Design Aids for Reinforced Concrete to IS 456-1978:</u>**

This handbook explains the use of formulae mentioned in IS 456 and provides several design charts and interaction diagrams for flexure, deflection control criteria, axial compression, compression with bending and tension with bending for rectangular cross-sections (for circular section in case of compression member) which can greatly expedite the design process if done manually. This design aid is particularly useful for the preliminary design.

2. **SP 22: Explanatory Handbook on Codes for Earthquake Engineering (IS 1893: 1975 and IS 4326: 1976):**

The theoretical background behind many of the code provisions have been elaborated herein. Additionally, many worked out examples explaining the use of equations and charts in the code can also be found in this handbook.

3. **SP 24: Explanatory Handbook on Indian Standard Code of Practice for Plain and Reinforced Concrete IS 456: 1978**

SP 16 is meant to aid the calculation process, while SP 24 is meant to aid the conceptual understanding of the IS 456 code. It contains clause by clause explanation of the original code. The logic and justification behind the various equations and assumptions in the code are well explained here.

4. **SP 34: Handbook on Concrete Reinforcement and Detailing**:

The compilation of provisions and guidelines regarding reinforcement detailing scattered throughout IS codes 456, 4326, 5525 and 13920 can be found in this handbook. Searching for that information in the original codes can be very time consuming. This handbook presents all that information in a well-organized manner.

IV. Textbooks on RCC Design and Earthquake Engineering:

Many available books related to design of reinforced concrete structure and earthquake engineering written by distinguished authors such as Pillai and Menon, SN Sinha and AK Jain are based on the Indian Standard Codes of Practice and provides sufficient theoretical background with illustrative examples. So, for the analysis and design, references from such textbooks are very helpful. Books related to foundation engineering will also be valuable in the design of building foundation. Besides these, other books related to structural mechanics (Statics and Dynamics) will also be helpful for performing and verifying the analysis output from computer software.

Apart from these references there may require data related to the past earthquake, the earthquake zoning map and soil condition of the site. These data may be obtained from the government authorities and other concerning organizations.

The reports on the same project prepared by the students of previous batches were also an important reference to the project.

2. Methodology

Each building has its own purposes and importance. Basically, buildings were constructed based on client requirement, geographical condition of the site, safety, privacy, available facilities, etc. and designed as:

2.1. 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:

2.1.1. 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.

2.1.2. 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 gain less inertial force (caused during earthquake). The regular geometrical shape building is designed as an earthquake resistant structure based on IS1893 (part1):2002.

2.2. 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:

2.2.1. 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

2.2.2. Lateral load

Lateral load includes wind load and earthquake load. Wind load acts on roof truss 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):2002. The dominant load is taken into consideration for design.

2.2.3. Load Combination

Combination of different loads is based on IS 875 (part V):1987 Load combinations.

2.3. 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 approximately calculation of axial load and moments.

2.4. Idealization of structure

2.4.1. 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.

2.4.2. 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 acts on the beam.

2.4.3. 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 frame work is modeled in SAP for analysis. Loads are modeled into the structure in several load cases and load combination.

2.5. Modeling and Analysis of structure

Salient Features of SAP2000 v19

SAP2000 v.19 represents one of the most sophisticated and user-friendly release of SAP 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. Dynamic loading can be in the form of a base acceleration response spectrum, or varying loads and base accelerations.

The building is modeled as a 3Dbare frame. Results from analysis are used in design of beams and columns only (i.e. linear elements). SAP2000 doesn’t design shell 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 SAP2000. 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):2002 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.

2.6. Design and Detailing

2.6.1. Design Philosophy

2.6.1.1. 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

2.6.1.2. Working Stress Method of Design for Steel Truss Member

The design philosophy of working stress method of design is to use working loads at service state and design the members to perform at characteristic loads with minimum factor of safety in material strength. This approach makes the design conservative and deterministic and quite obsolete compared to more logical Limit State Method of Design.
Hence by using different philosophy, the design of beam, column, footing, staircase and other structural component are done.

2.7. Detailing Principle for Reinforced Concrete and Steel Structures

2.7.1 Ductile Detailing of Reinforced Concrete Structure

Ductile detailing of reinforced concrete structure is done based on IS 13920:2002 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 assure the capacity theory of STRONG COLUMN | WEAK BEAMS.
Detailing provisions of IS 13920:2002 and IS 456:2000 are used extensively for these members to comply with the relevant codes of practice.

2.7.2. Ordinary Detailing of Reinforced Concrete Structure

SP 34 detailing handbook for IS 456 is used extensively for reinforcement detailing of area elements (SLABS & STAIRCASE). Defining the slabs to function as rigid floor diaphragm limits the necessity of special reinforcement provision for slabs eliminating the possibility of out-of-plane bending. Hence same follows for staircase slabs and detailing is done with the help of SP34.

Detailing of Substructures (MAT FOUNDATION) is also done based on SP34 to comply with the design requirement of IS 456:2000.

Reinforcement Detail drawings for typical representative elements are shown in detail in chapter 7 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.

2.7.3 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):2002, Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces- Code of Practice IS 13920:2002, Handbook on Concrete Reinforcement and Detailing SP-34. 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.

2.8. Drawings

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

1. Architectural Plan of Typical floors, Elevation and Cross Section of the building.
2. 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.

2.9. 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 five chapters; summary of each chapter is mentioned below:

Chapter 1: Introduction to Project Work

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

Chapter 2: Methodology

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

Chapter 3: 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 and justification of number of beams and columns, frames, their orientation/ arrangement.

Chapter 4: 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 5: 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 SAP2000 analysis and the tabular presentation of storey drift calculation and check of columns for sway and no-sway case. Critical responses are also tabulated.

Chapter 6: 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 use of codes pertinent to earthquake resistant design of building structures. Manual design of structural elements is done from the analysis results of SAP2000 using IS 456:2000 and compared with the design given by SAP2000. However, consideration for earthquake resistant design is incorporated in manual design with reference to IS 1893 (part 1):2002 with ductile detailing rules governed by IS 13920:2002.

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 13920:2002 respectively.

Chapter 7: Drawings

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

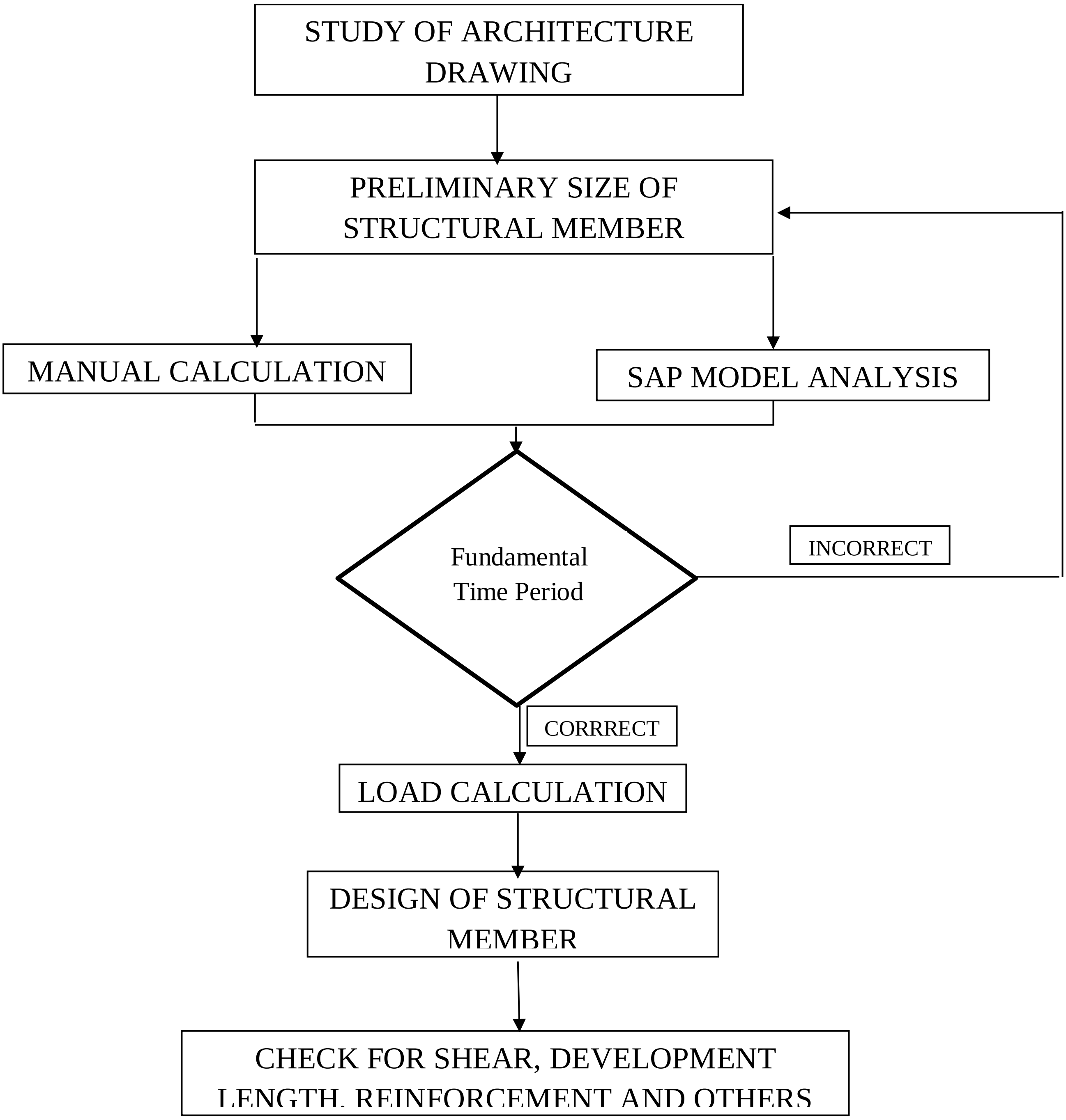
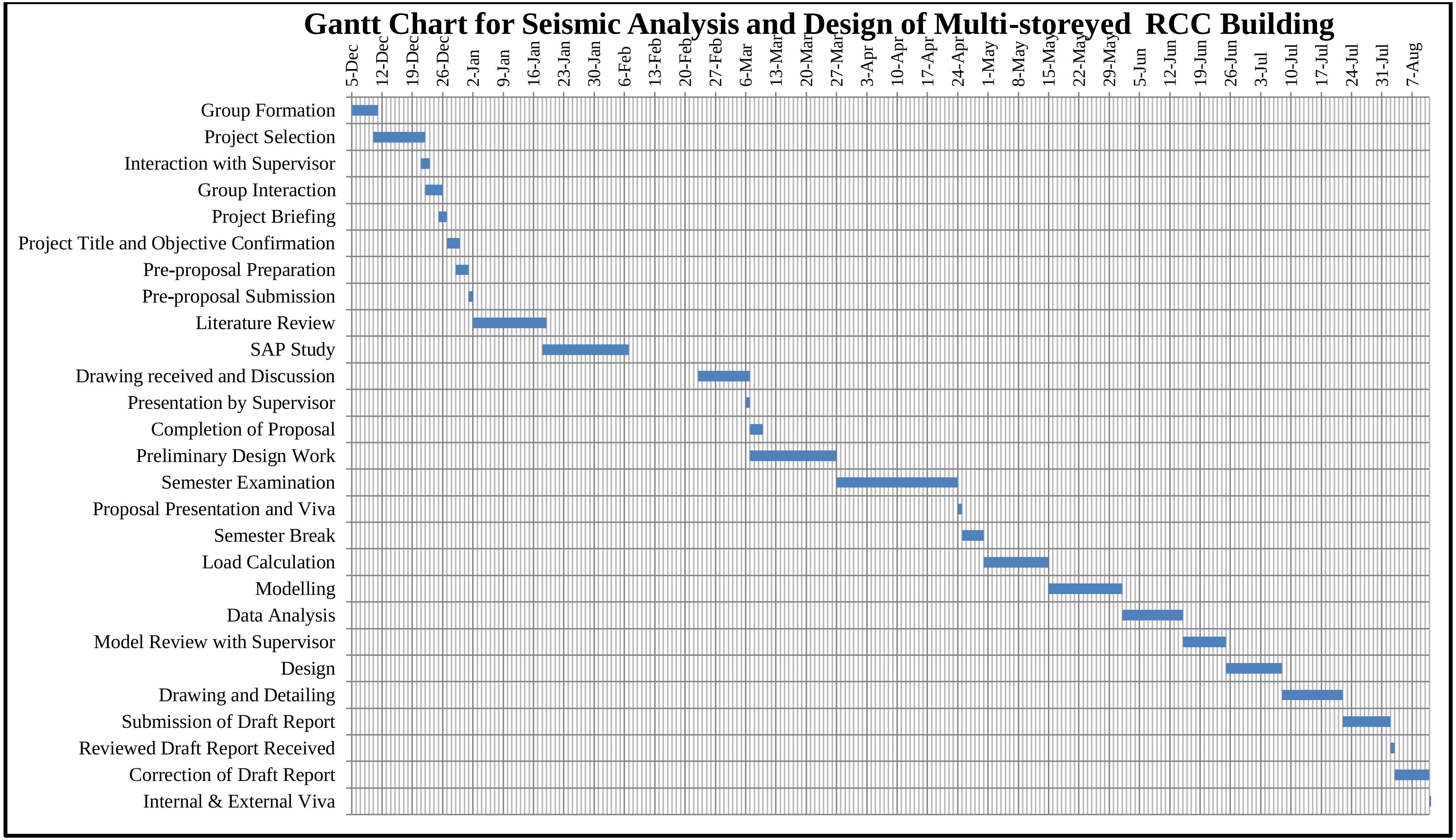


Fig.: Flowchart showing Method of design

2.10.Work Schedule

We planned out time for this project as:

Description	Start Date	Duration	End Date
Group Formation	5-Dec-16	6	10-Dec-16
Project Selection	10-Dec-16	12	21-Dec-16
Interaction with Supervisor	21-Dec-16	2	22-Dec-16
Group Interaction	22-Dec-16	4	25-Dec-16
Project Briefing	25-Dec-16	2	26-Dec-16
Project Title and Objective Confirmation	27-Dec-16	3	29-Dec-16
Pre-proposal Preparation	29-Dec-16	3	31-Dec-16
Pre-proposal Submission	1-Jan-17	1	1-Jan-17
Literature Review	2-Jan-17	17	18-Jan-17
SAP Study	18-Jan-17	20	6-Feb-17
Drawing received and Discussion	23-Feb-17	12	6-Mar-17
Presentation by Supervisor	6-Mar-17	1	6-Mar-17
Completion of Proposal	7-Mar-17	3	9-Mar-17
Preliminary Design Work	7-Mar-17	20	26-Mar-17
Semester Examination	27-Mar-17	28	23-Apr-17
Proposal Presentation and Viva	24-Apr-17	1	24-Apr-17
Semester Break	25-Apr-17	5	29-Apr-17
Load Calculation	30-Apr-17	15	14-May-17
Modelling	15-May-17	17	31-May-17
Data Analysis	1-Jun-17	14	14-Jun-17
Model Review with Supervisor	15-Jun-17	10	24-Jun-17
Design	25-Jun-17	13	7-Jul-17
Drawing and Detailing	8-Jul-17	14	21-Jul-17
Submission of Draft Report	22-Jul-17	11	1-Aug-17
Reviewed Draft Report Received	2-Aug-17	1	2-Aug-17
Correction of Draft Report	3-Aug-17	8	10-Aug-17
Internal & External Viva	11-Aug-17	1	11-Aug-17


Gantt Chart for Seismic Analysis and Design of Multi-storeyed RCC Building
5-Dec
12-Dec
19-Dec
26-Dec
2-Jan
9-Jan
16-Jan
23-Jan
30-Jan
6-Feb
13-Feb
20-Feb
27-Feb
6-Mar
13-Mar
20-Mar
27-Mar
3-Apr
10-Apr
17-Apr
24-Apr
1-May
8-May
15-May
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun
3-Jul
10-Jul
17-Jul
24-Jul
31-Jul
7-Aug
Group Formation
Project Selection
Interaction with Supervisor
Group Interaction
Project Briefing
Project Title and Objective Confirmation
Pre-proposal Preparation
Pre-proposal Submission
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SAP Study
Drawing received and Discussion
Presentation by Supervisor
Completion of Proposal
Preliminary Design Work
Semester Examination
Proposal Presentation and Viva
Semester Break
Load Calculation
Modelling
Data Analysis
Model Review with Supervisor
Design
Drawing and Detailing
Submission of Draft Report
Reviewed Draft Report Received
Correction of Draft Report
Internal & External Viva

3. Functional and Structural Planning of Building

3.1. 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.

3.1.1 Planning of Space and Facilities

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

For vertical mobility, open well staircase is provided. A prefabricated fire-escape was provided at the end of the building to facilitate evacuation in times of emergency.

Prefabricated Capsule type elevators were provided in the left part of the building. In terms of space management for elevator, slabs with openings were provided as shown in the building plan diagram.

Washroom for ladies and gents are provided centrally in each floor at four different location of the building. The washroom is specially provided for master bedroom. The washrooms are centrally located in the building to facilitate for the population distributed all over the floor area.

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.

3.1.2Architectural 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 commercial spaces is done with masonry wall.

A total of 42 numbers of columns are provided. The overall dimension of the building is 70’5” by 79’2” 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.

3.1.3 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.

3.2 Structural Planning

3.2.1 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):2002.

The following types of irregularities mentioned in Table 4 & 5 of IS 1893 (part 1):2002 should be avoided as far as practicable during functional planning.

Plan Irregularities	Vertical Irregularities
1. Torsion Irregularity	1. A) Stiffness Irregularity –Soft Storey
2. Re-entrant corners	B) Stiffness Irregularity-Extreme Soft storey
3. Diaphragm Discontinuity	2. Mass irregularity
4. Out of plane Offsets	3. Vertical Geometric Irregularity
5. Non-parallel Systems	4. In-plane discontinuity in vertical elements resisting lateral force
	5. Discontinuity in Capacity- Weak Storey

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 SAP 2000.

3.2.2 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 42 in number in each storey. Columns are of sizes 540*540 mm square and 500*500 mm square in cross section. The floor to floor height of the building is 10’6” for typical with basement of 9’10” and staircase cover of 9’6”.

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) :2002 by avoiding irregularities in plan. 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 SAP2000 with the structural plan and elevation. The area element occupying the floor space is also modeled in the program. The image generated from SAP2000 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.

4. Load Assessment and Preliminary Design

4.1 Preliminary Design

The preliminary sizing of structural elements was carried out based on deflection control criteria 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).
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.	Cement Concrete for RCC	25kN/m^3	Beams, Columns, Slabs.
2.	Common Burnt Clay Bricks	20kN/m^3	Infill & Partition Walls
3.	Screed on floor 25mm	20kN/m^3	All flooring spaces
4.	Finishing in step 30 mm	20kN/m^3	All flooring spaces
5.	Floor finishing	1.5 kN/m^2	Load on Slab

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

S.N.	Live Loads on Specified Spaces	Intensity of Load	Member Loaded
1.	All rooms and kitchens	2.0 kN/m^2	Live loads from building are acted on floor slabs, roof slabs and staircase slab.
2.	Toilet and bath rooms	2 kN/m^2	
3.	Corridors, passages, staircases including tire escapes and store Rooms	3 kN/m^2	

Preliminary Sizing of Slab
The depth of slab is obtained from deflection control criteria.
L/d = 32 for continuous two-way slab
Or, d = L/32 = 4114.8 / 32=128.58mm
Where, L = Longest Shorter span of all slabs=4114.8mm
Adopt d = 125mm and D=150 mm with clear cover of 25mm.

Load Intensity on Slab
Self-weight = 25 * 0.150 = 3.75 kN/m^2
Imposed live load = 2kN/m^2 (for rooms, kitchens, toilet and bathrooms)
= 3Kn/m^2 (for corridors, passages, staircases, store rooms)
Floor finish = 1.5 kN/m2
Total load intensity = 7.25 kN/m^2 (for rooms, kitchens, toilet and bathrooms)
= 8.25 KN/m^2 (for corridors, passages, staircases, store rooms)

Preliminary Sizing of Beam

Length of longest beam = 16’-6” = 5029.2mm

Deflection Control

For deflection control, as per IS456:2000, Clause 23.2.1,

$L/d \le \alpha\beta\gamma\delta\lambda$

Where,

L = length of beam = 5029.2 mm

d = Effective depth of the beam

α = 26 for continuous beams

β = 1 for spans below 10m

γ = 0.8 (assuming the tensile steel percentage as 1.2%)

δ = 1 for no compression steel

λ = 1 for no flanged beams

Substituting, we get

d = 242 mm

Adopt d=300 mm and D=325 mm with clear cover 25mm. Adopt b=230mm

Flexural loads on beam

The flexural load on the beam is calculated by uniformly distributing the loads from the effective slab area and walls throughout the beam. The beam is analyzed as a simply supported beam.

Self-weight of beam = 25×0.325×0.230=1.869 kN/m

Weight of wall, assuming 30% openings=20×0.23×3.2×0.7=10.304kN/m

Loads from Slabs

Effective Loading Area of Slabs on Beam=131.7959 ft^2=12.25 m^2

Distributed load = 12.25×6.05/5.0292 = 14.73 kN/m

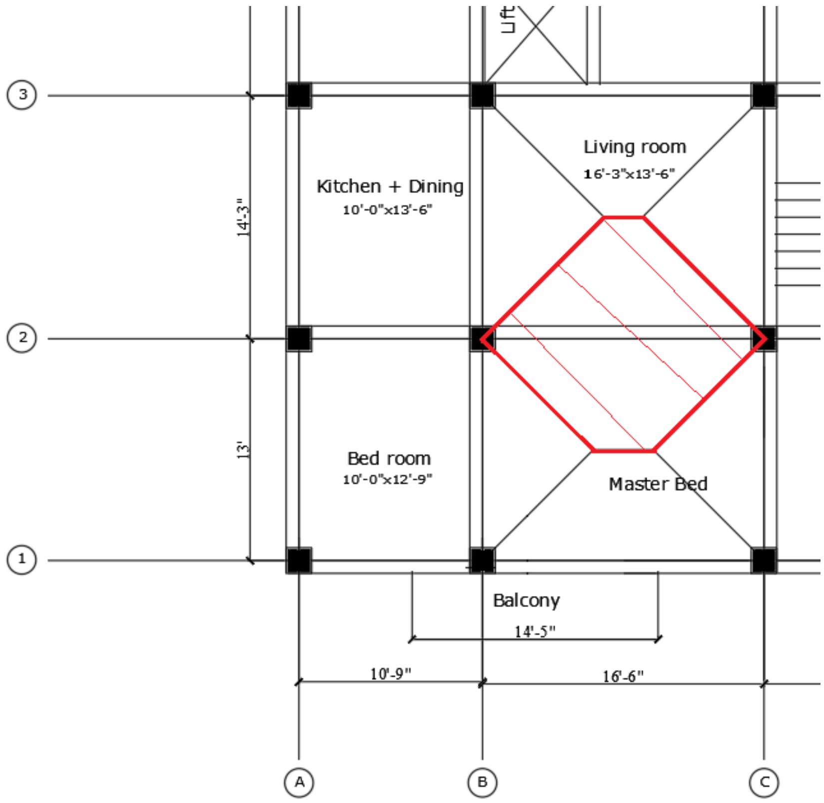
Total Distributed Load = 26.903kN/m

Design Mid-Span Moment= 1.5 $wL^2/8 = 1.5 \times 26.903 \times 5.0292^2/8$ = 127.58kNm

Q= $0.36 \times fck \times (X_{u,lim}/d)\,(1-0.416(X_{u,lim}/d))$ = 3.3478

$$d = \sqrt{\frac{Mu}{Qb}} = \sqrt{\frac{127.58 \times 10^6}{3.3478 \times 230}} = 407mm$$

Adopt b=300mm, D=500mm



Tributary area for beam 2BC

Preliminary Sizing of Columns

The column size is first assumed to be 500mm×500mm for dead load calculations.

Column 2B

Slab area = 185.6406 ft^2 = 17.26 m^2

Load of slab = 6.05 × 17.26 = 104.423kN

Load of Walls (Assuming 30% openings)

= 0.7×20×0.23×3.2× (7’1.5” + 8’3” + 6’6” + 5’4.5”) = 0.7×20×0.23×3.2 ×8.3058 = 85.58kN

Load of Beam = 25×0.3× (0.5-0.15) ×8.3058 = 21.80kN

Dead Load of Columns = 25×0.500×0.500×3.2=20kN

Dead load of basement column = 25×0.500×0.500×3.05=19.06

Total load = 11×104.42 + 11×21.8 + 10×85.58 +10×20 + 19.06= 2463.28kN

Factored Load = 1.5 × 2463.28 = 3694.92kN

Taking 2% steel, M25 Concrete and Fe500 Steel,

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

Or, 3694.92×1000 = 0.4 × 25 × (1-0.02) A + 0.67 × 500 × 0.02A

Or, A=223935mm^2

Taking a square column,

B=D=473.22mm

Column E3

Slab Area=204.3788ft^2=19.00m^2

Load of slab = 6.05 × 19.00 = 114.95kN×11

Load of Walls (Assuming 30% openings)

= 0.7×20×0.23×3.2× (8’3” + 7’10.5” + 5’4.5” + 7’1.5”)

= 0.7×20×0.23×3.2×8.7249

=89.90kN×10

Load of Beam = 25×0.3× (0.5-0.15) ×8.7249 = 22.90kN×11

Dead Load of Columns = 25×0.500×0.500×3.2=20kN×11

Dead load of basement column = 25×0.500×0.500×3.05=19.06kN×1

Load from Staircase cover

Slab = 25×6.05×64.9692ft^2=150.97kN×1

Walls = 20×0.23×3.2× (8’3” + 7’10.5”) =72.35kN×1

Beam = 25×0.3× (0.5-0.15) ×4.915 = 12.90kN×1

Total load = 11×114.95 + 10×89.90 + 11×22.90+11×20 +1×19.06 + 150.97 + 72.35+12.90 = 2890.63kN

Factored Load = 1.5 × 4335.945 = 4335.945kN

Taking 2% steel, M25 Concrete and Fe500 Steel,

Pu=0.4fck A_c + 0.67 fy A_s

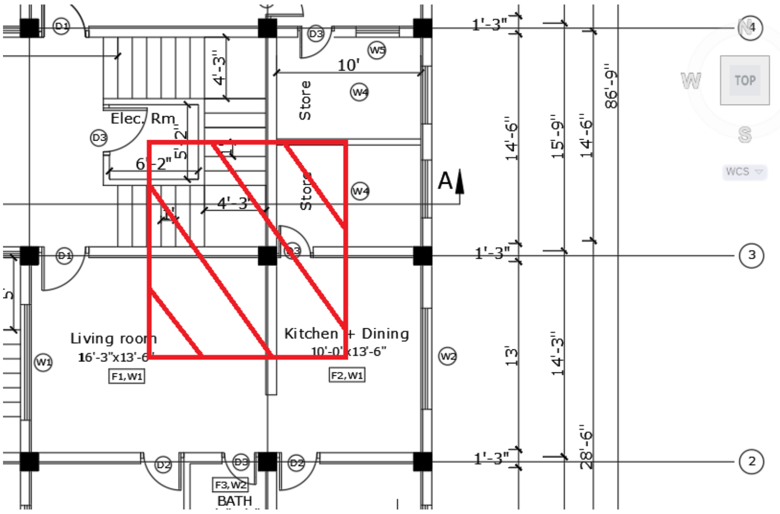
Or, 4335.945×1000 = 0.4 × 25 × (1-0.015) A + 0.67 × 500 × 0.015A

Or, A=262785mm^2

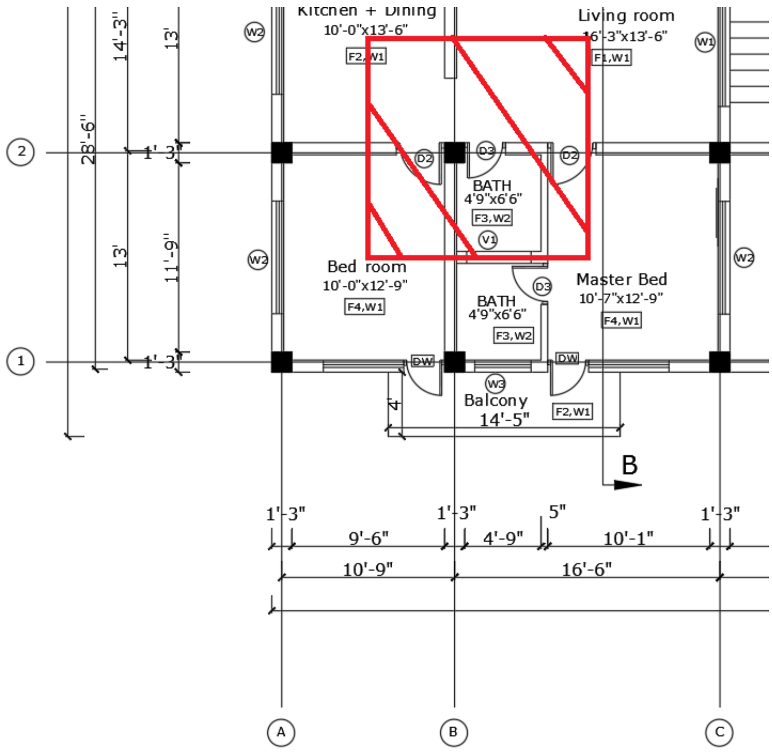
Taking a square column,

B=D=512.63mm^2

Adopt column size of 560mm×560mm



Tributary Area for Column E3



Tributary Area for Column B2

4.2. 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):2002. 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.

4.2.1 *Gravity Load Assessment on the Building*

The gravity loads on the building are derived from IS 875 (part I) dead loads and IS 875 (part II) imposed loads. The details of materials chosen for design of structural members and their unit weight, total loads on each structural member are tabulated below:

S.No.	**Material Used**	**Unit Weight**	**Type of Member**
1.	Cement Concrete for RCC	25kN/m^3	Beams, Columns, Slabs.
2.	Common Burnt Clay Bricks	20kN/m^3	Infill & Partition Walls
3.	Screed on floor 25mm	20kN/m^3	All flooring spaces
4.	Finishing in step 30 mm	20kN/m^3	All flooring spaces
5.	Floor finishing	1.5KN/m^2	Load on Slab

The details of imposed loads acting on the floors and roof of the building are also evaluated from the type of building (RESIDENTIAL BUILDING) and type of occupancy, the details of which are also tabulated below:

S.No.	Live Loads on Specified Spaces	Intensity of Load	Member Loaded
1.	All rooms and kitchens	2.0kN/m^2	Live loads from building are acted on floor slabs, roof slabs and staircase slab.
2.	Toilet and bath rooms	2kN/m^2	
3.	Corridors, passages, staircases including tire escapes and store Rooms	3kN/m^2	

Further, these loads are used to determine the seismic weight of the building based on IS 1893 (part 1):2002. For lateral load distribution in each storey, we use lumped mass approximation of structural elements in each floor, assumed to be lumped at respective floor levels.

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.

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

1. *Gravity Load Computation*

I. Terrace Level

a. Roof Slab

Self-Weight of Slab = 3.75 kN/m^2
25mm Screed = 0.50 kN/m^2
Floor finishing = 1.5 kN/m^2
Total Dead Load = 5.75 kN/m^2
Imposed Load =1.5kN/m^2 (Access Provided)
Imposed Load for corridor and passage = 3 KN/m^2

b. Beam

Dead load of main beam = 3.75kN/m

c. Column

Square Column = 7.84 kN/m

d. Wall

One Brick Thick Wall = 4.6kN/m^2

II. Intermediate Level

a. Floor Slab

Self-Weight of Slab = 3.75kN/m^2
25mm Screed = 0.5kN/m^2
Floor finishing = 1.5 kN/m^2
Total Dead Load =5.75 kN/m^2

Imposed Load

1.	All rooms and kitchens	2.0 kN/m^2
2.	Toilet and bath rooms	2 kN/m^2
3.	Corridors, passages, staircases including tire escapes and store Rooms	3 kN/m^2

b. Beam

Dead load of main beam = 3.75 kN/m

c. Column

Square Column = 7.84 kN/m

d. Wall

Brick Thick Wall = 4.6kN/m^2

Calculation of weight of building elements for determination of seismic weight for design with size of the elements modified after SAP2000 analysis conforming to storey drift.

1. **BEAM**

The dimension of main beam from preliminary design is 300mm x 500mm. 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 = 300mm x 500mm
Unit weight of concrete = 25 kN/m^3
For 'L' span of Beam weight of Beam = 0.3*0.5*L*25 kN

2. **COLUMN**

Column dimensions from preliminary design are 560mm x 560mm.
Height of a single column is taken from mid height of lower storey column to mid height of upper storey column. This height is 2.667m for Basement and 3.2004m for other storey level.
Height of Column = 3.2004m
Size of Column = 560mm x 560mm
Unit Weight of Concrete = 25kN/m^3
Weight of one column = 25.0911KN

4. **BRICK MASONRY WALL**

The calculation for brick masonry wall is the same as in the preliminarily designed building.

5. **LIFT MACHINE ROOM**

The lift machine room is located on the roof with the provision of RCC Slab cover to support the capsule lift by tension rope via pulley mechanism. The load of standard lift machine and the load from the lift are assumed to be concentrated at the support on the slab.
After assessment of all the loads, lumped mass for each floor is calculated and used in determining the base shear which in turn is distributed as lateral load to the building frames. The lumped mass calculation for the revised building after SAP2000 analysis is presented in the table below and this load is used in calculation of lateral load.

	Terrace(Cover)		10th Floor		Typical Floor (2 to 9)		1st Floor		Ground Floor	
	DL	LL	DL	LL	DL	LL	DL	LL	DL	LL
Wall	148.12	0.00	1284.78	0.00	2273.32	0.00	2273.32	0.00	1136.66	0.00
Column	72.39	0.00	492.44	0.00	840.11	0.00	910.00	0.00	918.30	0.00
Beam	180.01	0.00	1081.56	0.00	1081.56	0.00	1081.56	0.00	1081.56	0.00
Corridor & Store Room Slab	259.26	34.57	196.16	39.23	196.16	39.23	196.16	39.23	196.16	39.23
Remaining Slab	0.00	0.00	1124.04	149.87	1124.04	149.87	1124.04	149.87	1481.11	197.48
Floor Finish	51.85	0.00	528.08	0.00	528.08	0.00	528.08	0.00	670.91	0.00
Parapet Wall	0.00	0.00	583.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Tank	245.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staircase	0.00	0.00	144.90	39.90	144.90	39.90	144.90	39.90	144.90	39.90
Total	957.11	34.57	5435.23	229.00	6188.16	229.00	6258.06	229.00	5629.60	276.61
DL+LL	991.67		5664.23		6417.17		6487.06		5906.21	

4.2.2. Lateral Load Assessment

4.2.2. a. 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): 2002. 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):2002 to compute the base shear and the corresponding lateral forces; the detailed computation of which is shown in Annex 4. This calculation also incorporates calculation of additional shear due to torsional coupling of building when CM and CS do not coincide.

Theory of Base Shear Calculation

According to IS 1893 (Part I): 2002 Cl. No. 6.4.2, the design horizontal seismic coefficient Ah for a structure shall be determined by the following expression Ah=ZISa2Rg

Where,

Z = Zone factor given by IS 1893 (Part I): 2002 Table 2, Here for Zone V, Z = 0.36

I = Importance Factor, I = 1 for general purpose building

R = Response reduction factor given by IS 1893 (Part I): 2002 Table 7, R = 5.0

$\frac{Sa}{g}$ = Average response acceleration coefficient which depends on approximate fundamental natural period of vibration (Ta).

For Ta = 1.4 second soil type III (Soft Soil) $\frac{Sa}{g}$ = 0.97

∴ The value of design horizontal seismic coefficient is

$$Ah = \frac{Z}{2} * \frac{I}{R} * \frac{Sa}{g}$$

$$= \frac{0.36*1*0.97}{2*5}$$

$$= 0.03497$$

According to IS 1893 (Part I):2002 Cl. No. 7.5.3 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 = 70386.51 KN

$$V_B = 0.03497 * 70386.51 = 2461.416 \text{ kN}$$

According to IS 1893 (Part I): 2002 Cl. No. 7.7.1 the design base shear (V_B) computed above shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B * \frac{Wihi^2}{\sum_{i=1}^{n} Wihi^2}$$

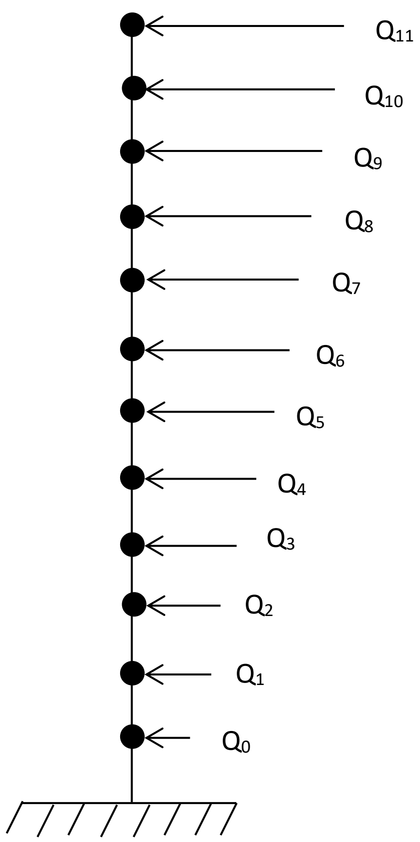
Where,

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 Q_i for i^{th}Storey from ground level.

Calculation of Base Shear:

Floor	Wi(KN)	Hi	Wi*Hi*Hi	Qi(KN)	Vi(KN)	Calculated		Permissible		Torsion Check	
						ex	ey	ex	ey	x-axis	y-axis
Terrace(Cover)	991.67	37.70	1409276.88	106.16	106.16	0.00	0.00	4.19	4.72	ok	ok
10	5664.23	34.80	6860403.48	516.80	622.96	0.06	0.24	4.19	4.72	ok	ok
9	6417.17	31.60	6408573.82	482.76	1105.72	0.06	0.24	4.19	4.72	ok	ok
8	6417.17	28.40	5176266.50	389.93	1495.65	0.06	0.24	4.19	4.72	ok	ok
7	6417.17	25.20	4075415.60	307.00	1802.66	0.06	0.24	4.19	4.72	ok	ok
6	6417.17	22.00	3106021.10	233.98	2036.63	0.06	0.24	4.19	4.72	ok	ok
5	6417.17	18.80	2268083.02	170.86	2207.49	0.06	0.24	4.19	4.72	ok	ok
4	6417.17	15.60	1561601.34	117.64	2325.13	0.06	0.24	4.19	4.72	ok	ok
3	6417.17	12.40	986576.07	74.32	2399.45	0.06	0.24	4.19	4.72	ok	ok
2	6417.17	9.20	543007.22	40.91	2440.35	0.06	0.24	4.19	4.72	ok	ok
1	6487.06	6.00	233409.71	17.58	2457.93	0.33	0.23	4.19	4.72	ok	ok
Basement	5906.21	2.80	46238.59	3.48	2461.42	0.00	0.32	4.19	4.72	ok	ok
Total	70386.51		32674873.34	2461.42							

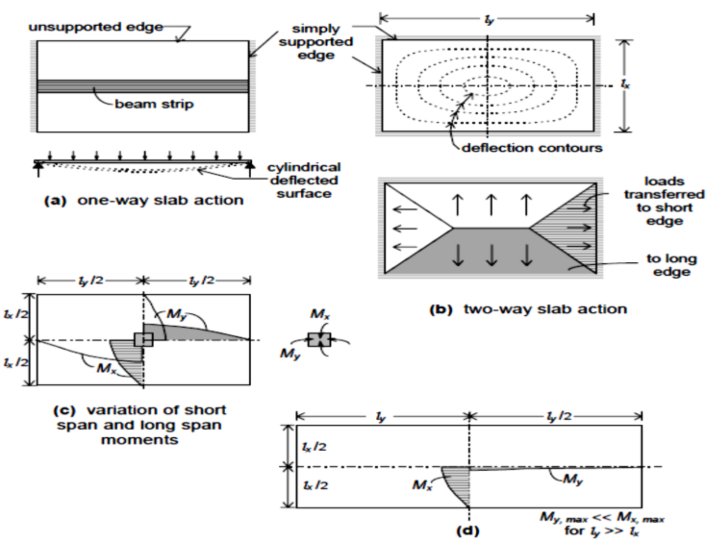
4.3 Idealization of load and load diagram

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.

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 uniform 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.



BEAMS

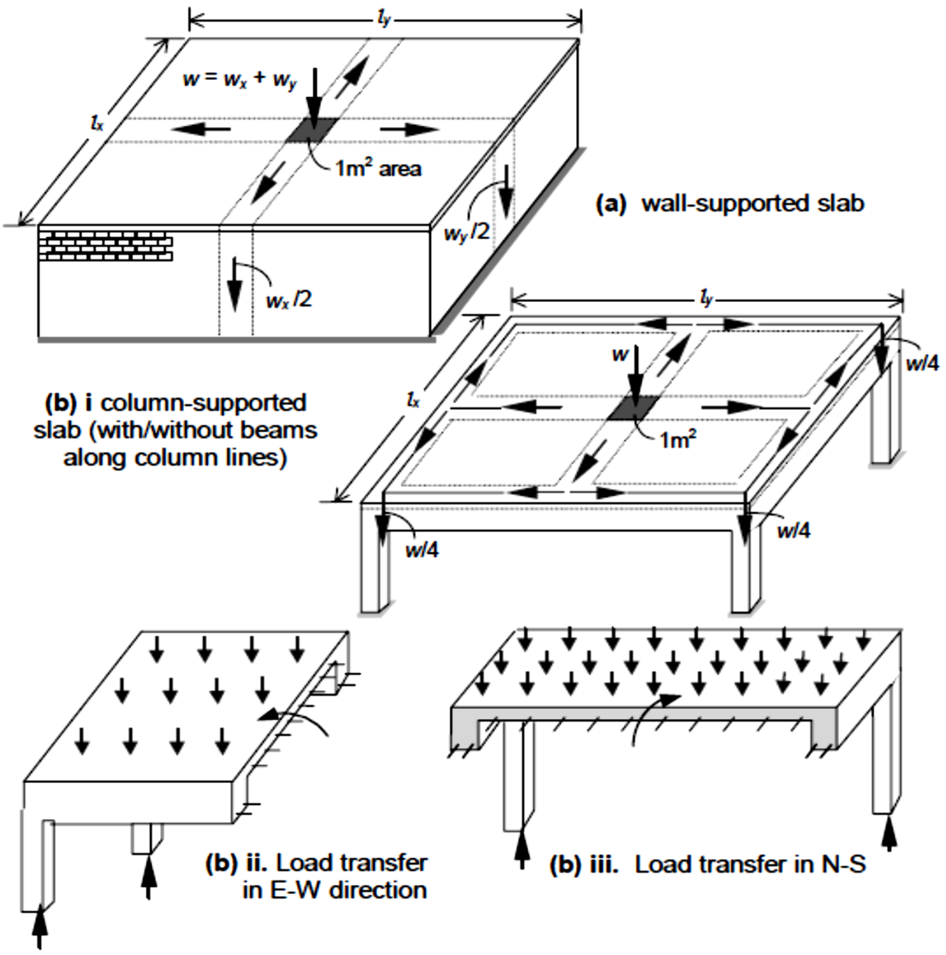
Idealization of self-weight of the RCC beam is done as uniformly distributed load acting along the centerline of the beam in the direction of gravity. Loads distributed from the slabs are however acting as distributed loads that may be uniform or varying as shown in the above figure in beams supporting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

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



5. Idealization and Analysis of Structure

5.1 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:

1. Idealization of Load
2. 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.

A. 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. The figure below explains the idealization of fixity of support for framed structure. This idealization is used in defining the fixed support of or 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.

B. 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 SAP2000 program for analysis.

C. 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.

D. 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.

E. Idealization of the Structural System

After idealizing individual elements, we idealize the structural system in its entirety to behave as your 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 SAP2000 for analysis. Loads are modeled into the structure in several load cases and load combinations defined in the next section.

The idealization of structure as 2D plane frame connected by links as shown in figure is used for lateral load analysis.

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.

5.2 Load Combination

Different load cases and load combination cases are considered to obtain most critical element stresses in the structure in the course of analysis. The wind load is not considered as a principal load case for the building as it is used only in design of Steel Roof Truss; Instead of 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 load consideration mentioned in IS 1893(Part 1):2002, the load combinations are divided into two parts:
1. Load Combinations for Limit State of Collapse
2. Load Combinations for Limit State of Serviceability.

Load Combinations for Limit State of Collapse

The basic load combinations for design considerations are:
i) 1.5(DL + %IL)
ii) 1.2(DL + %IL ± ELxa)
iii) 1.2(DL + %IL ± ELxb)
iv) 1.2(DL + %IL ± ELya)
v) 1.2(DL + %IL ± ELyb)
vi) 1.5(DL ± ELxa)
vii) 1.5(DL ± ELxb)
viii) 1.5(DL ± ELya)
ix) 1.5(DL ± ELyb)
x) 0.9(DL ± ELxa)
xi) 0.9(DL ± ELxb)
xii) 0.9(DL ± ELya)
xiii) 0.9(DL ± ELyb)
xiv)1.2(DL+%IL)

The above design combinations result in twenty-five load combinations. The maximum stresses from these combinations are used in design of elements.

Load Combination for Limit State of Serviceability

The basic load combinations for serviceability consideration are:
i) DL + IL
ii) DL ± ELxa
iii) DL ± ELxb
iv) DL ± ELya

v) DL ± ELyb
vi) DL + 0.8IL ± 0.8ELxa
vii) DL + 0.8IL ± 0.8ELxb
viii) DL + 0.8IL ± 0.8ELya
ix) DL + 0.8IL ± 0.8ELyb

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):2002. 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.

5.3 Analysis of Structure

The analysis of structure is carried out in a commercial computer software SAP2000 v19, 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. The subsequent tables show calculation of stability index of the columns for SWAY and NO SWAY case.
Sample output data from SAP2000 are also shown at the end of the chapter. These are only a representation of actual data extracted from SAP and used for design purposes.

5.3.1 Storey Drift Computation from SAP2000 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):2002. 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.

Calculation of Center of Mass
Calculation for Column

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
For Typical Floor (above 2nd floor up to 10th floor) (500mm*500mm)															
A	1	A1	0	0	0.5	0.5	3.2004	25	20.0025	0	0	0.0052083	0.0052083	0	0
A	2	A2	0	3.9624	0.5	0.5	3.2004	25	20.0025	0	79.257906	0.0052083	0.0052083	0	0.0206375
A	3	A3	0	8.3058	0.5	0.5	3.2004	25	20.0025	0	166.13676	0.0052083	0.0052083	0	0.0432594
A	4	A4	0	13.1064	0.5	0.5	3.2004	25	20.0025	0	262.16077	0.0052083	0.0052083	0	0.0682625
A	5	A5	0	16.9926	0.5	0.5	3.2004	25	20.0025	0	339.89448	0.0052083	0.0052083	0	0.0885031
A	6	A6	0	20.3454	0.5	0.5	3.2004	25	20.0025	0	406.95886	0.0052083	0.0052083	0	0.1059656
A	7	A7	0	23.622	0.5	0.5	3.2004	25	20.0025	0	472.49906	0.0052083	0.0052083	0	0.1230313
B	1	B1	3.2766	0	0.5	0.5	3.2004	25	20.0025	65.540192	0	0.0052083	0.0052083	0.0170656	0
B	2	B2	3.2766	3.9624	0.5	0.5	3.2004	25	20.0025	65.540192	79.257906	0.0052083	0.0052083	0.0170656	0.0206375
B	3	B3	3.2766	8.3058	0.5	0.5	3.2004	25	20.0025	65.540192	166.13676	0.0052083	0.0052083	0.0170656	0.0432594
B	4	B4	3.2766	13.1064	0.5	0.5	3.2004	25	20.0025	65.540192	262.16077	0.0052083	0.0052083	0.0170656	0.0682625
B	5	B5	3.2766	16.9926	0.5	0.5	3.2004	25	20.0025	65.540192	339.89448	0.0052083	0.0052083	0.0170656	0.0885031
B	6	B6	3.2766	20.3454	0.5	0.5	3.2004	25	20.0025	65.540192	406.95886	0.0052083	0.0052083	0.0170656	0.1059656
B	7	B7	3.2766	23.622	0.5	0.5	3.2004	25	20.0025	65.540192	472.49906	0.0052083	0.0052083	0.0170656	0.1230313
C	1	C1	8.3058	0	0.5	0.5	3.2004	25	20.0025	166.13676	0	0.0052083	0.0052083	0.0432594	0
C	2	C2	8.3058	3.9624	0.5	0.5	3.2004	25	20.0025	166.13676	79.257906	0.0052083	0.0052083	0.0432594	0.0206375
C	3	C3	8.3058	8.3058	0.5	0.5	3.2004	25	20.0025	166.13676	166.13676	0.0052083	0.0052083	0.0432594	0.0432594
C	4	C4	8.3058	13.1064	0.5	0.5	3.2004	25	20.0025	166.13676	262.16077	0.0052083	0.0052083	0.0432594	0.0682625
C	5	C5	8.3058	16.9926	0.5	0.5	3.2004	25	20.0025	166.13676	339.89448	0.0052083	0.0052083	0.0432594	0.0885031
C	6	C6	8.3058	20.3454	0.5	0.5	3.2004	25	20.0025	166.13676	406.95886	0.0052083	0.0052083	0.0432594	0.1059656
C	7	C7	8.3058	23.622	0.5	0.5	3.2004	25	20.0025	166.13676	472.49906	0.0052083	0.0052083	0.0432594	0.1230313
D	1	D1	12.6492	0	0.5	0.5	3.2004	25	20.0025	253.01562	0	0.0052083	0.0052083	0.0658813	0
D	2	D2	12.6492	3.9624	0.5	0.5	3.2004	25	20.0025	253.01562	79.257906	0.0052083	0.0052083	0.0658813	0.0206375
D	3	D3	12.6492	8.3058	0.5	0.5	3.2004	25	20.0025	253.01562	166.13676	0.0052083	0.0052083	0.0658813	0.0432594
D	4	D4	12.6492	13.1064	0.5	0.5	3.2004	25	20.0025	253.01562	262.16077	0.0052083	0.0052083	0.0658813	0.0682625

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
D	5	D5	12.6492	16.9926	0.5	0.5	3.2004	25	20.0025	253.01562	339.89448	0.0052083	0.0052083	0.0658813	0.0885031
D	6	D6	12.6492	20.3454	0.5	0.5	3.2004	25	20.0025	253.01562	406.95886	0.0052083	0.0052083	0.0658813	0.1059656
D	7	D7	12.6492	23.622	0.5	0.5	3.2004	25	20.0025	253.01562	472.49906	0.0052083	0.0052083	0.0658813	0.1230313
E	1	E1	17.6784	0	0.5	0.5	3.2004	25	20.0025	353.6122	0	0.0052083	0.0052083	0.092075	0
E	2	E2	17.6784	3.9624	0.5	0.5	3.2004	25	20.0025	353.6122	79.257906	0.0052083	0.0052083	0.092075	0.0206375
E	3	E3	17.6784	8.3058	0.5	0.5	3.2004	25	20.0025	353.6122	166.13676	0.0052083	0.0052083	0.092075	0.0432594
E	4	E4	17.6784	13.1064	0.5	0.5	3.2004	25	20.0025	353.6122	262.16077	0.0052083	0.0052083	0.092075	0.0682625
E	5	E5	17.6784	16.9926	0.5	0.5	3.2004	25	20.0025	353.6122	339.89448	0.0052083	0.0052083	0.092075	0.0885031
E	6	E6	17.6784	20.3454	0.5	0.5	3.2004	25	20.0025	353.6122	406.95886	0.0052083	0.0052083	0.092075	0.1059656
E	7	E7	17.6784	23.622	0.5	0.5	3.2004	25	20.0025	353.6122	472.49906	0.0052083	0.0052083	0.092075	0.1230313
F	1	F1	20.955	0	0.5	0.5	3.2004	25	20.0025	419.15239	0	0.0052083	0.0052083	0.1091406	0
F	2	F2	20.955	3.9624	0.5	0.5	3.2004	25	20.0025	419.15239	79.257906	0.0052083	0.0052083	0.1091406	0.0206375
F	3	F3	20.955	8.3058	0.5	0.5	3.2004	25	20.0025	419.15239	166.13676	0.0052083	0.0052083	0.1091406	0.0432594
F	4	F4	20.955	13.1064	0.5	0.5	3.2004	25	20.0025	419.15239	262.16077	0.0052083	0.0052083	0.1091406	0.0682625
F	5	F5	20.955	16.9926	0.5	0.5	3.2004	25	20.0025	419.15239	339.89448	0.0052083	0.0052083	0.1091406	0.0885031
F	6	F6	20.955	20.3454	0.5	0.5	3.2004	25	20.0025	419.15239	406.95886	0.0052083	0.0052083	0.1091406	0.1059656
F	7	F7	20.955	23.622	0.5	0.5	3.2004	25	20.0025	419.15239	472.49906	0.0052083	0.0052083	0.1091406	0.1230313
Total									840.105	8802.2001	10361.447	0.21875	0.21875	2.2919531	2.6979563

1st floor (540mm*540mm)

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
A	1	A1	0	0	0.54	0.54	3.2004	25	23.33092	0	0	0.007086	0.007086	0	0
A	2	A2	0	3.9624	0.54	0.54	3.2004	25	23.33092	0	92.44642	0.007086	0.007086	0	0.028077
A	3	A3	0	8.3058	0.54	0.54	3.2004	25	23.33092	0	193.7819	0.007086	0.007086	0	0.058854
A	4	A4	0	13.1064	0.54	0.54	3.2004	25	23.33092	0	305.7843	0.007086	0.007086	0	0.09287
A	5	A5	0	16.9926	0.54	0.54	3.2004	25	23.33092	0	396.4529	0.007086	0.007086	0	0.120408
A	6	A6	0	20.3454	0.54	0.54	3.2004	25	23.33092	0	474.6768	0.007086	0.007086	0	0.144165
A	7	A7	0	23.622	0.54	0.54	3.2004	25	23.33092	0	551.1229	0.007086	0.007086	0	0.167383
B	1	B1	3.2766	0	0.54	0.54	3.2004	25	23.33092	76.44608	0	0.007086	0.007086	0.023218	0
B	2	B2	3.2766	3.9624	0.54	0.54	3.2004	25	23.33092	76.44608	92.44642	0.007086	0.007086	0.023218	0.028077
B	3	B3	3.2766	8.3058	0.54	0.54	3.2004	25	23.33092	76.44608	193.7819	0.007086	0.007086	0.023218	0.058854

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
B	4	B4	3.2766	13.1064	0.54	0.54	3.2004	25	23.33092	76.44608	305.7843	0.007086	0.007086	0.023218	0.09287
B	5	B5	3.2766	16.9926	0.54	0.54	3.2004	25	23.33092	76.44608	396.4529	0.007086	0.007086	0.023218	0.120408
B	6	B6	3.2766	20.3454	0.54	0.54	3.2004	25	23.33092	76.44608	474.6768	0.007086	0.007086	0.023218	0.144165
B	7	B7	3.2766	23.622	0.54	0.54	3.2004	25	23.33092	76.44608	551.1229	0.007086	0.007086	0.023218	0.167383
C	1	C1	8.3058	0	0.54	0.54	3.2004	25	23.33092	193.7819	0	0.007086	0.007086	0.058854	0
C	2	C2	8.3058	3.9624	0.54	0.54	3.2004	25	23.33092	193.7819	92.44642	0.007086	0.007086	0.058854	0.028077
C	3	C3	8.3058	8.3058	0.54	0.54	3.2004	25	23.33092	193.7819	193.7819	0.007086	0.007086	0.058854	0.058854
C	4	C4	8.3058	13.1064	0.54	0.54	3.2004	25	23.33092	193.7819	305.7843	0.007086	0.007086	0.058854	0.09287
C	5	C5	8.3058	16.9926	0.54	0.54	3.2004	25	23.33092	193.7819	396.4529	0.007086	0.007086	0.058854	0.120408
C	6	C6	8.3058	20.3454	0.54	0.54	3.2004	25	23.33092	193.7819	474.6768	0.007086	0.007086	0.058854	0.144165
C	7	C7	8.3058	23.622	0.54	0.54	3.2004	25	23.33092	193.7819	551.1229	0.007086	0.007086	0.058854	0.167383
D	1	D1	12.649	0	0.54	0.54	3.2004	25	23.33092	295.1174	0	0.007086	0.007086	0.089631	0
D	2	D2	12.649	3.9624	0.54	0.54	3.2004	25	23.33092	295.1174	92.44642	0.007086	0.007086	0.089631	0.028077
D	3	D3	12.649	8.3058	0.54	0.54	3.2004	25	23.33092	295.1174	193.7819	0.007086	0.007086	0.089631	0.058854
D	4	D4	12.649	13.1064	0.54	0.54	3.2004	25	23.33092	295.1174	305.7843	0.007086	0.007086	0.089631	0.09287
D	5	D5	12.649	16.9926	0.54	0.54	3.2004	25	23.33092	295.1174	396.4529	0.007086	0.007086	0.089631	0.120408
D	6	D6	12.649	20.3454	0.54	0.54	3.2004	25	23.33092	295.1174	474.6768	0.007086	0.007086	0.089631	0.144165
D	7	D7	12.649	23.622	0.54	0.54	3.2004	25	23.33092	295.1174	551.1229	0.007086	0.007086	0.089631	0.167383
E	1	E1	17.678	0	0.54	0.54	3.2004	25	23.33092	412.4533	0	0.007086	0.007086	0.125267	0
E	2	E2	17.678	3.9624	0.54	0.54	3.2004	25	23.33092	412.4533	92.44642	0.007086	0.007086	0.125267	0.028077
E	3	E3	17.678	8.3058	0.54	0.54	3.2004	25	23.33092	412.4533	193.7819	0.007086	0.007086	0.125267	0.058854
E	4	E4	17.678	13.1064	0.54	0.54	3.2004	25	23.33092	412.4533	305.7843	0.007086	0.007086	0.125267	0.09287
E	5	E5	17.678	16.9926	0.54	0.54	3.2004	25	23.33092	412.4533	396.4529	0.007086	0.007086	0.125267	0.120408
E	6	E6	17.678	20.3454	0.54	0.54	3.2004	25	23.33092	412.4533	474.6768	0.007086	0.007086	0.125267	0.144165
E	7	E7	17.678	23.622	0.54	0.54	3.2004	25	23.33092	412.4533	551.1229	0.007086	0.007086	0.125267	0.167383
F	1	F1	20.955	0	0.54	0.54	3.2004	25	23.33092	488.8993	0	0.007086	0.007086	0.148485	0
F	2	F2	20.955	3.9624	0.54	0.54	3.2004	25	23.33092	488.8993	92.44642	0.007086	0.007086	0.148485	0.028077
F	3	F3	20.955	8.3058	0.54	0.54	3.2004	25	23.33092	488.8993	193.7819	0.007086	0.007086	0.148485	0.058854
F	4	F4	20.955	13.1064	0.54	0.54	3.2004	25	23.33092	488.8993	305.7843	0.007086	0.007086	0.148485	0.09287
F	5	F5	20.955	16.9926	0.54	0.54	3.2004	25	23.33092	488.8993	396.4529	0.007086	0.007086	0.148485	0.120408
F	6	F6	20.955	20.3454	0.54	0.54	3.2004	25	23.33092	488.8993	474.6768	0.007086	0.007086	0.148485	0.144165
F	7	F7	20.955	23.622	0.54	0.54	3.2004	25	23.33092	488.8993	551.1229	0.007086	0.007086	0.148485	0.167383

Total	979.8985	10266.89	12085.59	0.297607	0.297607	3.118177	3.67054

Basement(540mm*540mm)															
Grid X	**Grid Y**	**Column ID**	**X**	**Y**	**B**	**D**	**H**	**Unit wt.**	**Weight**	**M*X**	**M*Y**	**Ixx**	**Iyy**	**Ixx*X**	**Iyy*Y**
A	1	A1	0	0	0.54	0.54	2.798	25	20.39742	0	0	0.007086	0.007086	0	0
A	2	A2	0	3.9624	0.54	0.54	2.798	25	20.39742	0	80.82274	0.007086	0.007086	0	0.028077
A	3	A3	0	8.3058	0.54	0.54	2.798	25	20.39742	0	169.4169	0.007086	0.007086	0	0.058854
A	4	A4	0	13.1064	0.54	0.54	2.798	25	20.39742	0	267.3367	0.007086	0.007086	0	0.09287
A	5	A5	0	16.9926	0.54	0.54	2.798	25	20.39742	0	346.6052	0.007086	0.007086	0	0.120408
A	6	A6	0	20.3454	0.54	0.54	2.798	25	20.39742	0	414.9937	0.007086	0.007086	0	0.144165
A	7	A7	0	23.622	0.54	0.54	2.798	25	20.39742	0	481.8279	0.007086	0.007086	0	0.167383
B	1	B1	3.2766	0	0.54	0.54	2.798	25	20.39742	66.83419	0	0.007086	0.007086	0.023218	0
B	2	B2	3.2766	3.9624	0.54	0.54	2.798	25	20.39742	66.83419	80.82274	0.007086	0.007086	0.023218	0.028077
B	3	B3	3.2766	8.3058	0.54	0.54	2.798	25	20.39742	66.83419	169.4169	0.007086	0.007086	0.023218	0.058854
B	4	B4	3.2766	13.1064	0.54	0.54	2.798	25	20.39742	66.83419	267.3367	0.007086	0.007086	0.023218	0.09287
B	5	B5	3.2766	16.9926	0.54	0.54	2.798	25	20.39742	66.83419	346.6052	0.007086	0.007086	0.023218	0.120408
B	6	B6	3.2766	20.3454	0.54	0.54	2.798	25	20.39742	66.83419	414.9937	0.007086	0.007086	0.023218	0.144165
B	7	B7	3.2766	23.622	0.54	0.54	2.798	25	20.39742	66.83419	481.8279	0.007086	0.007086	0.023218	0.167383
C	1	C1	8.3058	0	0.54	0.54	2.798	25	20.39742	169.4169	0	0.007086	0.007086	0.058854	0
C	2	C2	8.3058	3.9624	0.54	0.54	2.798	25	20.39742	169.4169	80.82274	0.007086	0.007086	0.058854	0.028077
C	3	C3	8.3058	8.3058	0.54	0.54	2.798	25	20.39742	169.4169	169.4169	0.007086	0.007086	0.058854	0.058854
C	4	C4	8.3058	13.1064	0.54	0.54	2.798	25	20.39742	169.4169	267.3367	0.007086	0.007086	0.058854	0.09287
C	5	C5	8.3058	16.9926	0.54	0.54	2.798	25	20.39742	169.4169	346.6052	0.007086	0.007086	0.058854	0.120408
C	6	C6	8.3058	20.3454	0.54	0.54	2.798	25	20.39742	169.4169	414.9937	0.007086	0.007086	0.058854	0.144165
C	7	C7	8.3058	23.622	0.54	0.54	2.798	25	20.39742	169.4169	481.8279	0.007086	0.007086	0.058854	0.167383
D	1	D1	12.649	0	0.54	0.54	2.798	25	20.39742	258.011	0	0.007086	0.007086	0.089631	0
D	2	D2	12.649	3.9624	0.54	0.54	2.798	25	20.39742	258.011	80.82274	0.007086	0.007086	0.089631	0.028077
D	3	D3	12.649	8.3058	0.54	0.54	2.798	25	20.39742	258.011	169.4169	0.007086	0.007086	0.089631	0.058854
D	4	D4	12.649	13.1064	0.54	0.54	2.798	25	20.39742	258.011	267.3367	0.007086	0.007086	0.089631	0.09287
D	5	D5	12.649	16.9926	0.54	0.54	2.798	25	20.39742	258.011	346.6052	0.007086	0.007086	0.089631	0.120408
D	6	D6	12.649	20.3454	0.54	0.54	2.798	25	20.39742	258.011	414.9937	0.007086	0.007086	0.089631	0.144165

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
D	7	D7	12.649	23.622	0.54	0.54	2.798	25	20.39742	258.011	481.8279	0.007086	0.007086	0.089631	0.167383
E	1	E1	17.678	0	0.54	0.54	2.798	25	20.39742	360.5937	0	0.007086	0.007086	0.125267	0
E	2	E2	17.678	3.9624	0.54	0.54	2.798	25	20.39742	360.5937	80.82274	0.007086	0.007086	0.125267	0.028077
E	3	E3	17.678	8.3058	0.54	0.54	2.798	25	20.39742	360.5937	169.4169	0.007086	0.007086	0.125267	0.058854
E	4	E4	17.678	13.1064	0.54	0.54	2.798	25	20.39742	360.5937	267.3367	0.007086	0.007086	0.125267	0.09287
E	5	E5	17.678	16.9926	0.54	0.54	2.798	25	20.39742	360.5937	346.6052	0.007086	0.007086	0.125267	0.120408
E	6	E6	17.678	20.3454	0.54	0.54	2.798	25	20.39742	360.5937	414.9937	0.007086	0.007086	0.125267	0.144165
E	7	E7	17.678	23.622	0.54	0.54	2.798	25	20.39742	360.5937	481.8279	0.007086	0.007086	0.125267	0.167383
F	1	F1	20.955	0	0.54	0.54	2.798	25	20.39742	427.4279	0	0.007086	0.007086	0.148485	0
F	2	F2	20.955	3.9624	0.54	0.54	2.798	25	20.39742	427.4279	80.82274	0.007086	0.007086	0.148485	0.028077
F	3	F3	20.955	8.3058	0.54	0.54	2.798	25	20.39742	427.4279	169.4169	0.007086	0.007086	0.148485	0.058854
F	4	F4	20.955	13.1064	0.54	0.54	2.798	25	20.39742	427.4279	267.3367	0.007086	0.007086	0.148485	0.09287
F	5	F5	20.955	16.9926	0.54	0.54	2.798	25	20.39742	427.4279	346.6052	0.007086	0.007086	0.148485	0.120408
F	6	F6	20.955	20.3454	0.54	0.54	2.798	25	20.39742	427.4279	414.9937	0.007086	0.007086	0.148485	0.144165
F	7	F7	20.955	23.622	0.54	0.54	2.798	25	20.39742	427.4279	481.8279	0.007086	0.007086	0.148485	0.167383
Total									856.6916	8975.987	10566.02	0.297607	0.297607	3.118177	3.67054

Cover(500mm*500mm)

Grid X	Grid Y	Column ID	X	Y	B	D	H	Unit wt.	Weight	M*X	M*Y	Ixx	Iyy	Ixx*X	Iyy*Y
B	3	B3	3.2766	8.3058	0.5	0.5	2.8956	25	18.0975	59.29827	150.3142	0.005208	0.005208	0.017066	0.043259
B	4	B4	3.2766	13.1064	0.5	0.5	2.8956	25	18.0975	59.29827	237.1931	0.005208	0.005208	0.017066	0.068263
C	3	C3	8.3058	8.3058	0.5	0.5	2.8956	25	18.0975	150.3142	150.3142	0.005208	0.005208	0.043259	0.043259
C	4	C4	8.3058	13.1064	0.5	0.5	2.8956	25	18.0975	150.3142	237.1931	0.005208	0.005208	0.043259	0.068263
D	3	D3	12.649	8.3058	0.5	0.5	2.8956	25	18.0975	228.9189	150.3142	0.005208	0.005208	0.065881	0.043259
D	4	D4	12.649	13.1064	0.5	0.5	2.8956	25	18.0975	228.9189	237.1931	0.005208	0.005208	0.065881	0.068263
E	3	E3	17.678	8.3058	0.5	0.5	2.8956	25	18.0975	319.9348	150.3142	0.005208	0.005208	0.092075	0.043259
E	4	E4	17.678	13.1064	0.5	0.5	2.8956	25	18.0975	319.9348	237.1931	0.005208	0.005208	0.092075	0.068263
Total									144.78	1516.932	1550.029	0.041667	0.041667	0.436563	0.446088

Calculation for Beam

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
Typical Floor (1st to 10th floor)(300mm*500m)															
1	A	B	1AB	0	0	3.2766	1.6383	0	3.2766	0.5	0.3	25	12.28725	20.130202	0
2	A	B	2AB	3.9624	0	3.2766	1.6383	3.9624	3.2766	0.5	0.3	25	12.28725	20.130202	48.686999
3	A	B	3AB	8.3058	0	3.2766	1.6383	8.3058	3.2766	0.5	0.3	25	12.28725	20.130202	102.05544
4	A	B	4AB	13.106	0	3.2766	1.6383	13.106	3.2766	0.5	0.3	25	12.28725	20.130202	161.0367
5	A	B	5AB	16.993	0	3.2766	1.6383	16.993	3.2766	0.5	0.3	25	12.28725	20.130202	208.79724
6	A	B	6AB	20.345	0	3.2766	1.6383	20.345	3.2766	0.5	0.3	25	12.28725	20.130202	249.9841
7	A	B	7AB	23.622	0	3.2766	1.6383	23.622	3.2766	0.5	0.3	25	12.28725	20.130202	290.24942
1	B	C	1BC	0	3.2766	8.3058	5.7912	0	5.0292	0.5	0.3	25	18.8595	109.21914	0
2	B	C	2BC	3.9624	3.2766	8.3058	5.7912	3.9624	5.0292	0.5	0.3	25	18.8595	109.21914	74.728883
3	B	C	3BC	8.3058	3.2766	8.3058	5.7912	8.3058	5.0292	0.5	0.3	25	18.8595	109.21914	156.64324
4	B	C	4BC	13.106	3.2766	8.3058	5.7912	13.106	5.0292	0.5	0.3	25	18.8595	109.21914	247.17261
5	B	C	5BC	16.993	3.2766	8.3058	5.7912	16.993	5.0292	0.5	0.3	25	18.8595	109.21914	320.47948
6	B	C	6BC	20.345	3.2766	8.3058	5.7912	20.345	5.0292	0.5	0.3	25	18.8595	109.21914	383.69653
7	B	C	7BC	23.622	3.2766	8.3058	5.7912	23.622	5.0292	0.5	0.3	25	18.8595	109.21914	445.49911
1	C	D	1CD	0	8.3058	12.649	10.4774	0	4.3432	0.5	0.3	25	16.287	170.64541	0
2	C	D	2CD	3.9624	8.3058	12.649	10.4774	3.9624	4.3432	0.5	0.3	25	16.287	170.64541	64.535609
3	C	D	3CD	8.3058	8.3058	12.649	10.4774	8.3058	4.3432	0.5	0.3	25	16.287	170.64541	135.27656
4	C	D	4CD	13.106	8.3058	12.649	10.4774	13.106	4.3432	0.5	0.3	25	16.287	170.64541	213.45742
5	C	D	5CD	16.993	8.3058	12.649	10.4774	16.993	4.3432	0.5	0.3	25	16.287	170.64541	276.76499
6	C	D	6CD	20.345	8.3058	12.649	10.4774	20.345	4.3432	0.5	0.3	25	16.287	170.64541	331.35902
7	C	D	7CD	23.622	8.3058	12.649	10.4774	23.622	4.3432	0.5	0.3	25	16.287	170.64541	384.73151

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
1	D	E	1DE	0	12.649	17.678	15.1635	0	5.029	0.5	0.3	25	18.85875	285.96466	0
2	D	E	2DE	3.9624	12.649	17.678	15.1635	3.9624	5.029	0.5	0.3	25	18.85875	285.96466	74.725911
3	D	E	3DE	8.3058	12.649	17.678	15.1635	8.3058	5.029	0.5	0.3	25	18.85875	285.96466	156.63701
4	D	E	4DE	13.106	12.649	17.678	15.1635	13.106	5.029	0.5	0.3	25	18.85875	285.96466	247.16278
5	D	E	5DE	16.993	12.649	17.678	15.1635	16.993	5.029	0.5	0.3	25	18.85875	285.96466	320.46674
6	D	E	6DE	20.345	12.649	17.678	15.1635	20.345	5.029	0.5	0.3	25	18.85875	285.96466	383.68127
7	D	E	7DE	23.622	12.649	17.678	15.1635	23.622	5.029	0.5	0.3	25	18.85875	285.96466	445.48139
1	E	F	1EF	0	17.678	20.955	19.3165	0	3.277	0.5	0.3	25	12.28875	237.37564	0
2	E	F	2EF	3.9624	17.678	20.955	19.3165	3.9624	3.277	0.5	0.3	25	12.28875	237.37564	48.692943
3	E	F	3EF	8.3058	17.678	20.955	19.3165	8.3058	3.277	0.5	0.3	25	12.28875	237.37564	102.0679
4	E	F	4EF	13.106	17.678	20.955	19.3165	13.106	3.277	0.5	0.3	25	12.28875	237.37564	161.05636
5	E	F	5EF	16.993	17.678	20.955	19.3165	16.993	3.277	0.5	0.3	25	12.28875	237.37564	208.82273
6	E	F	6EF	20.345	17.678	20.955	19.3165	20.345	3.277	0.5	0.3	25	12.28875	237.37564	250.01462
7	E	F	7EF	23.622	17.678	20.955	19.3165	23.622	3.277	0.5	0.3	25	12.28875	237.37564	290.28485
A	1	2	A12	0	0	3.9624	0	1.9812	3.9624	0.5	0.3	25	14.859	0	29.438651
B	1	2	B12	3.2766	0	3.9624	3.2766	1.9812	3.9624	0.5	0.3	25	14.859	48.686999	29.438651
C	1	2	C12	8.3058	0	3.9624	8.3058	1.9812	3.9624	0.5	0.3	25	14.859	123.41588	29.438651
D	1	2	D12	12.649	0	3.9624	12.649	1.9812	3.9624	0.5	0.3	25	14.859	187.95149	29.438651
E	1	2	E12	17.678	0	3.9624	17.678	1.9812	3.9624	0.5	0.3	25	14.859	262.6774	29.438651
F	1	2	F12	20.955	0	3.9624	20.955	1.9812	3.9624	0.5	0.3	25	14.859	311.37035	29.438651
A	2	3	A23	0	3.9624	8.3058	0	6.1341	4.3434	0.5	0.3	25	16.28775	0	99.910687
B	2	3	B23	3.2766	3.9624	8.3058	3.2766	6.1341	4.3434	0.5	0.3	25	16.28775	53.368442	99.910687
C	2	3	C23	8.3058	3.9624	8.3058	8.3058	6.1341	4.3434	0.5	0.3	25	16.28775	135.28279	99.910687
D	2	3	D23	12.649	3.9624	8.3058	12.649	6.1341	4.3434	0.5	0.3	25	16.28775	206.02375	99.910687
E	2	3	E23	17.678	3.9624	8.3058	17.678	6.1341	4.3434	0.5	0.3	25	16.28775	287.93484	99.910687
F	2	3	F23	20.955	3.9624	8.3058	20.955	6.1341	4.3434	0.5	0.3	25	16.28775	341.3098	99.910687
A	3	4	A34	0	8.3058	13.106	0	10.706	4.8002	0.5	0.3	25	18.00075	0	192.71423

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
B	3	4	B34	3.2766	8.3058	13.106	3.2766	10.706	4.8002	0.5	0.3	25	18.00075	58.981257	192.71423
C	3	4	C34	8.3058	8.3058	13.106	8.3058	10.706	4.8002	0.5	0.3	25	18.00075	149.51063	192.71423
D	3	4	D34	12.649	8.3058	13.106	12.649	10.706	4.8002	0.5	0.3	25	18.00075	227.69149	192.71423
E	3	4	E34	17.678	8.3058	13.106	17.678	10.706	4.8002	0.5	0.3	25	18.00075	318.21726	192.71423
F	3	4	F34	20.955	8.3058	13.106	20.955	10.706	4.8002	0.5	0.3	25	18.00075	377.20572	192.71423
A	4	5	A45	0	13.106	16.993	0	15.05	3.887	0.5	0.3	25	14.57625	0	219.36527
B	4	5	B45	3.2766	13.106	16.993	3.2766	15.05	3.887	0.5	0.3	25	14.57625	47.760541	219.36527
C	4	5	C45	8.3058	13.106	16.993	8.3058	15.05	3.887	0.5	0.3	25	14.57625	121.06742	219.36527
D	4	5	D45	12.649	13.106	16.993	12.649	15.05	3.887	0.5	0.3	25	14.57625	184.37499	219.36527
E	4	5	E45	17.678	13.106	16.993	17.678	15.05	3.887	0.5	0.3	25	14.57625	257.67895	219.36527
F	4	5	F45	20.955	13.106	16.993	20.955	15.05	3.887	0.5	0.3	25	14.57625	305.44532	219.36527
A	5	6	A56	0	16.993	20.345	0	18.669	3.352	0.5	0.3	25	12.57	0	234.66933
B	5	6	B56	3.2766	16.993	20.345	3.2766	18.669	3.352	0.5	0.3	25	12.57	41.186862	234.66933
C	5	6	C56	8.3058	16.993	20.345	8.3058	18.669	3.352	0.5	0.3	25	12.57	104.40391	234.66933
D	5	6	D56	12.649	16.993	20.345	12.649	18.669	3.352	0.5	0.3	25	12.57	158.99793	234.66933
E	5	6	E56	17.678	16.993	20.345	17.678	18.669	3.352	0.5	0.3	25	12.57	222.21246	234.66933
F	5	6	F56	20.955	16.993	20.345	20.955	18.669	3.352	0.5	0.3	25	12.57	263.40435	234.66933
A	6	7	A67	0	20.345	23.622	0	21.984	3.277	0.5	0.3	25	12.28875	0	270.14974
B	6	7	B67	3.2766	20.345	23.622	3.2766	21.984	3.277	0.5	0.3	25	12.28875	40.265318	270.14974
C	6	7	C67	8.3058	20.345	23.622	8.3058	21.984	3.277	0.5	0.3	25	12.28875	102.0679	270.14974
D	6	7	D67	12.649	20.345	23.622	12.649	21.984	3.277	0.5	0.3	25	12.28875	155.4404	270.14974
E	6	7	E67	17.678	20.345	23.622	17.678	21.984	3.277	0.5	0.3	25	12.28875	217.24052	270.14974
F	6	7	F67	20.955	20.345	23.622	20.955	21.984	3.277	0.5	0.3	25	12.28875	257.51076	270.14974
Total													1081.564	11332.031	13061.737

Basement Floor (300mm*500m)															
Main Grid	**Start Grid**	**End Grid**	**Wall ID**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit wt.**	**Mass**	**M*X**	**M*Y**
1	A	B	1AB	0	0	3.2766	1.6383	0	3.2766	0.5	0.3	25	12.2873	20.1302	0
2	A	B	2AB	3.962	0	3.2766	1.6383	3.962	3.2766	0.5	0.3	25	12.2873	20.1302	48.687
3	A	B	3AB	8.306	0	3.2766	1.6383	8.306	3.2766	0.5	0.3	25	12.2873	20.1302	102.0554
4	A	B	4AB	13.11	0	3.2766	1.6383	13.11	3.2766	0.5	0.3	25	12.2873	20.1302	161.0367
5	A	B	5AB	16.99	0	3.2766	1.6383	16.99	3.2766	0.5	0.3	25	12.2873	20.1302	208.7972
6	A	B	6AB	20.35	0	3.2766	1.6383	20.35	3.2766	0.5	0.3	25	12.2873	20.1302	249.9841
7	A	B	7AB	23.62	0	3.2766	1.6383	23.62	3.2766	0.5	0.3	25	12.2873	20.1302	290.2494
1	B	C	1BC	0	3.2766	8.3058	5.7912	0	5.0292	0.5	0.3	25	18.8595	109.2191	0
2	B	C	2BC	3.962	3.2766	8.3058	5.7912	3.962	5.0292	0.5	0.3	25	18.8595	109.2191	74.72888
3	B	C	3BC	8.306	3.2766	8.3058	5.7912	8.306	5.0292	0.5	0.3	25	18.8595	109.2191	156.6432
4	B	C	4BC	13.11	3.2766	8.3058	5.7912	13.11	5.0292	0.5	0.3	25	18.8595	109.2191	247.1726
5	B	C	5BC	16.99	3.2766	8.3058	5.7912	16.99	5.0292	0.5	0.3	25	18.8595	109.2191	320.4795
6	B	C	6BC	20.35	3.2766	8.3058	5.7912	20.35	5.0292	0.5	0.3	25	18.8595	109.2191	383.6965
7	B	C	7BC	23.62	3.2766	8.3058	5.7912	23.62	5.0292	0.5	0.3	25	18.8595	109.2191	445.4991
1	C	D	1CD	0	8.3058	12.649	10.477	0	4.3432	0.5	0.3	25	16.287	170.6454	0
2	C	D	2CD	3.962	8.3058	12.649	10.477	3.962	4.3432	0.5	0.3	25	16.287	170.6454	64.53561
3	C	D	3CD	8.306	8.3058	12.649	10.477	8.306	4.3432	0.5	0.3	25	16.287	170.6454	135.2766
4	C	D	4CD	13.11	8.3058	12.649	10.477	13.11	4.3432	0.5	0.3	25	16.287	170.6454	213.4574
5	C	D	5CD	16.99	8.3058	12.649	10.477	16.99	4.3432	0.5	0.3	25	16.287	170.6454	276.765
6	C	D	6CD	20.35	8.3058	12.649	10.477	20.35	4.3432	0.5	0.3	25	16.287	170.6454	331.359
7	C	D	7CD	23.62	8.3058	12.649	10.477	23.62	4.3432	0.5	0.3	25	16.287	170.6454	384.7315
1	D	E	1DE	0	12.649	17.678	15.164	0	5.029	0.5	0.3	25	18.8588	285.9647	0
2	D	E	2DE	3.962	12.649	17.678	15.164	3.962	5.029	0.5	0.3	25	18.8588	285.9647	74.72591
3	D	E	3DE	8.306	12.649	17.678	15.164	8.306	5.029	0.5	0.3	25	18.8588	285.9647	156.637

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
4	D	E	4DE	13.11	12.649	17.678	15.164	13.11	5.029	0.5	0.3	25	18.8588	285.9647	247.1628
5	D	E	5DE	16.99	12.649	17.678	15.164	16.99	5.029	0.5	0.3	25	18.8588	285.9647	320.4667
6	D	E	6DE	20.35	12.649	17.678	15.164	20.35	5.029	0.5	0.3	25	18.8588	285.9647	383.6813
7	D	E	7DE	23.62	12.649	17.678	15.164	23.62	5.029	0.5	0.3	25	18.8588	285.9647	445.4814
1	E	F	1EF	0	17.678	20.955	19.317	0	3.277	0.5	0.3	25	12.2888	237.3756	0
2	E	F	2EF	3.962	17.678	20.955	19.317	3.962	3.277	0.5	0.3	25	12.2888	237.3756	48.69294
3	E	F	3EF	8.306	17.678	20.955	19.317	8.306	3.277	0.5	0.3	25	12.2888	237.3756	102.0679
4	E	F	4EF	13.11	17.678	20.955	19.317	13.11	3.277	0.5	0.3	25	12.2888	237.3756	161.0564
5	E	F	5EF	16.99	17.678	20.955	19.317	16.99	3.277	0.5	0.3	25	12.2888	237.3756	208.8227
6	E	F	6EF	20.35	17.678	20.955	19.317	20.35	3.277	0.5	0.3	25	12.2888	237.3756	250.0146
7	E	F	7EF	23.62	17.678	20.955	19.317	23.62	3.277	0.5	0.3	25	12.2888	237.3756	290.2849
A	1	2	A12	0	0	3.9624	0	1.981	3.9624	0.5	0.3	25	14.859	0	29.43865
B	1	2	B12	3.277	0	3.9624	3.2766	1.981	3.9624	0.5	0.3	25	14.859	48.687	29.43865
C	1	2	C12	8.306	0	3.9624	8.3058	1.981	3.9624	0.5	0.3	25	14.859	123.4159	29.43865
D	1	2	D12	12.65	0	3.9624	12.649	1.981	3.9624	0.5	0.3	25	14.859	187.9515	29.43865
E	1	2	E12	17.68	0	3.9624	17.678	1.981	3.9624	0.5	0.3	25	14.859	262.6774	29.43865
F	1	2	F12	20.96	0	3.9624	20.955	1.981	3.9624	0.5	0.3	25	14.859	311.3703	29.43865
A	2	3	A23	0	3.9624	8.3058	0	6.134	4.3434	0.5	0.3	25	16.2878	0	99.91069
B	2	3	B23	3.277	3.9624	8.3058	3.2766	6.134	4.3434	0.5	0.3	25	16.2878	53.36844	99.91069
C	2	3	C23	8.306	3.9624	8.3058	8.3058	6.134	4.3434	0.5	0.3	25	16.2878	135.2828	99.91069
D	2	3	D23	12.65	3.9624	8.3058	12.649	6.134	4.3434	0.5	0.3	25	16.2878	206.0237	99.91069
E	2	3	E23	17.68	3.9624	8.3058	17.678	6.134	4.3434	0.5	0.3	25	16.2878	287.9348	99.91069
F	2	3	F23	20.96	3.9624	8.3058	20.955	6.134	4.3434	0.5	0.3	25	16.2878	341.3098	99.91069
A	3	4	A34	0	8.3058	13.106	0	10.71	4.8002	0.5	0.3	25	18.0008	0	192.7142
B	3	4	B34	3.277	8.3058	13.106	3.2766	10.71	4.8002	0.5	0.3	25	18.0008	58.98126	192.7142
C	3	4	C34	8.306	8.3058	13.106	8.3058	10.71	4.8002	0.5	0.3	25	18.0008	149.5106	192.7142
D	3	4	D34	12.65	8.3058	13.106	12.649	10.71	4.8002	0.5	0.3	25	18.0008	227.6915	192.7142

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
E	3	4	E34	17.68	8.3058	13.106	17.678	10.71	4.8002	0.5	0.3	25	18.0008	318.2173	192.7142
F	3	4	F34	20.96	8.3058	13.106	20.955	10.71	4.8002	0.5	0.3	25	18.0008	377.2057	192.7142
A	4	5	A45	0	13.106	16.993	0	15.05	3.887	0.5	0.3	25	14.5763	0	219.3653
B	4	5	B45	3.277	13.106	16.993	3.2766	15.05	3.887	0.5	0.3	25	14.5763	47.76054	219.3653
C	4	5	C45	8.306	13.106	16.993	8.3058	15.05	3.887	0.5	0.3	25	14.5763	121.0674	219.3653
D	4	5	D45	12.65	13.106	16.993	12.649	15.05	3.887	0.5	0.3	25	14.5763	184.375	219.3653
E	4	5	E45	17.68	13.106	16.993	17.678	15.05	3.887	0.5	0.3	25	14.5763	257.6789	219.3653
F	4	5	F45	20.96	13.106	16.993	20.955	15.05	3.887	0.5	0.3	25	14.5763	305.4453	219.3653
A	5	6	A56	0	16.993	20.345	0	18.67	3.352	0.5	0.3	25	12.57	0	234.6693
B	5	6	B56	3.277	16.993	20.345	3.2766	18.67	3.352	0.5	0.3	25	12.57	41.18686	234.6693
C	5	6	C56	8.306	16.993	20.345	8.3058	18.67	3.352	0.5	0.3	25	12.57	104.4039	234.6693
D	5	6	D56	12.65	16.993	20.345	12.649	18.67	3.352	0.5	0.3	25	12.57	158.9979	234.6693
E	5	6	E56	17.68	16.993	20.345	17.678	18.67	3.352	0.5	0.3	25	12.57	222.2125	234.6693
F	5	6	F56	20.96	16.993	20.345	20.955	18.67	3.352	0.5	0.3	25	12.57	263.4044	234.6693
A	6	7	A67	0	20.345	23.622	0	21.98	3.277	0.5	0.3	25	12.2888	0	270.1497
B	6	7	B67	3.277	20.345	23.622	3.2766	21.98	3.277	0.5	0.3	25	12.2888	40.26532	270.1497
C	6	7	C67	8.306	20.345	23.622	8.3058	21.98	3.277	0.5	0.3	25	12.2888	102.0679	270.1497
D	6	7	D67	12.65	20.345	23.622	12.649	21.98	3.277	0.5	0.3	25	12.2888	155.4404	270.1497
E	6	7	E67	17.68	20.345	23.622	17.678	21.98	3.277	0.5	0.3	25	12.2888	217.2405	270.1497
F	6	7	F67	20.96	20.345	23.622	20.955	21.98	3.277	0.5	0.3	25	12.2888	257.5108	270.1497
Total													1081.56	11332.03	13061.74

Cover(300mm*500mm)															
Main Grid	**Start Grid**	**End Grid**	**Wall ID**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit wt.**	**Mass**	**M*X**	**M*Y**
3	B	C	3BC	8.306	3.2766	8.3058	5.7912	8.306	5.0292	0.5	0.3	25	18.8595	109.2191	156.6432
4	B	C	4BC	13.11	3.2766	8.3058	5.7912	13.11	5.0292	0.5	0.3	25	18.8595	109.2191	247.1726
3	C	D	3CD	8.306	8.3058	12.649	10.477	8.306	4.3432	0.5	0.3	25	16.287	170.6454	135.2766
4	C	D	4CD	13.11	8.3058	12.649	10.477	13.11	4.3432	0.5	0.3	25	16.287	170.6454	213.4574
3	D	E	3DE	8.306	12.649	17.678	15.164	8.306	5.029	0.5	0.3	25	18.8588	285.9647	156.637
4	D	E	4DE	13.11	12.649	17.678	15.164	13.11	5.029	0.5	0.3	25	18.8588	285.9647	247.1628
B	3	4	B34	3.277	8.3058	13.106	3.2766	10.71	4.8002	0.5	0.3	25	18.0008	58.98126	192.7142
C	3	4	C34	8.306	8.3058	13.106	8.3058	10.71	4.8002	0.5	0.3	25	18.0008	149.5106	192.7142
D	3	4	D34	12.65	8.3058	13.106	12.649	10.71	4.8002	0.5	0.3	25	18.0008	227.6915	192.7142
E	3	4	E34	17.68	8.3058	13.106	17.678	10.71	4.8002	0.5	0.3	25	18.0008	318.2173	192.7142
Total													180.014	1886.059	1927.207

Calculation for Slab

Along Y		Along X		Slab ID	Along Y		Along X		L	B	X	Y	Thickness	Unit Wt.	Mass	Mx	My	A
Start Grid	End Grid	Start Grid	End Grid		SO	EO	SO	EO										
Typical Floor (1st to 10th floor)(150mm)																		
1	2	A	B	12AB	0	3.9624	0	3.2766	3.2766	3.9624	1.6383	1.9812	0.15	25	48.687	79.76391	96.45868	12.9832
1	2	B	C	12BC	0	3.9624	3.9624	8.3058	4.3434	3.9624	6.1341	1.9812	0.15	25	64.53858	395.8861	127.8638	17.21029
1	2	D	E	12DE	0	3.9624	12.6492	17.6784	5.0292	3.9624	15.1638	1.9812	0.15	25	74.72888	1133.174	148.0529	19.9277
1	2	E	F	12EF	0	3.9624	17.6784	20.955	3.2766	3.9624	19.3167	1.9812	0.15	25	48.687	940.4722	96.45868	12.9832
2	3	A	B	23AB	3.9626	8.3058	0	3.2766	3.2766	4.3432	1.6383	6.1342	0.15	25	53.36598	87.42949	327.3576	14.23093
2	3	B	C	23BC	3.9626	8.3058	3.9624	8.3058	4.3434	4.3432	6.1341	6.1342	0.15	25	70.74096	433.9321	433.9392	18.86425
2	3	D	E	23DE	3.9626	8.3058	12.6492	17.6784	5.0292	4.3432	15.1638	6.1342	0.15	25	81.91058	1242.076	502.4559	21.84282
2	3	E	F	23EF	3.9626	8.3058	17.6784	20.955	3.2766	4.3432	19.3167	6.1342	0.15	25	53.36598	1030.855	327.3576	14.23093
3	4	A	B	34AB	8.3058	13.1064	0	3.2766	3.2766	4.8006	1.6383	10.7061	0.15	25	58.98617	96.63705	631.5119	15.72965
3	4	C	D	34CD	8.3058	13.1064	8.3058	12.6492	4.3434	4.8006	10.4775	10.7061	0.15	25	78.19097	819.2459	837.1204	20.85093
3	4	E	F	34EF	8.3058	13.1064	17.6784	20.955	3.2766	4.8006	19.3167	10.7061	0.15	25	58.98617	1139.418	631.5119	15.72965
4	5	A	B	45AB	13.1064	16.9926	0	3.2766	3.2766	3.8862	1.6383	15.0495	0.15	25	47.75071	78.22999	718.6243	12.73352
4	5	B	C	45BC	13.1064	16.9926	3.9624	8.3058	4.3434	3.8862	6.1341	15.0495	0.15	25	63.29745	388.2729	952.595	16.87932
4	5	D	E	45DE	13.1064	16.9926	12.6492	17.6784	5.0292	3.8862	15.1638	15.0495	0.15	25	73.29179	1111.382	1103.005	19.54448
4	5	E	F	45EF	13.1064	16.9926	17.6784	20.955	3.2766	3.8862	19.3167	15.0495	0.15	25	47.75071	922.3862	718.6243	12.73352
5	6	A	B	56AB	16.9926	20.3454	0	3.2766	3.2766	3.3528	1.6383	18.669	0.15	25	41.19669	67.49254	769.101	10.98578
5	6	B	C	56BC	16.9926	20.3454	3.9624	8.3058	4.3434	3.3528	6.1341	18.669	0.15	25	54.60957	334.9806	1019.506	14.56255
5	6	D	E	56DE	16.9926	20.3454	12.6492	17.6784	5.0292	3.3528	15.1638	18.669	0.15	25	63.23213	958.8394	1180.481	16.8619
5	6	E	F	56EF	16.9926	20.3454	17.6784	20.955	3.2766	3.3528	19.3167	18.669	0.15	25	41.19669	795.7841	769.101	10.98578
6	7	A	B	67AB	20.3454	23.622	0	3.2766	3.2766	3.2766	1.6383	21.9837	0.15	25	40.2604	65.95862	885.0726	10.73611
6	7	B	C	67BC	20.3454	23.622	3.9624	8.3058	4.3434	3.2766	6.1341	21.9837	0.15	25	53.36844	327.3674	1173.236	14.23158
6	7	D	E	67DE	20.3454	23.622	12.6492	17.6784	5.0292	3.2766	15.1638	21.9837	0.15	25	61.79504	937.0476	1358.484	16.47868
6	7	E	F	67EF	20.3454	23.622	17.6784	20.955	3.2766	3.2766	19.3167	21.9837	0.15	25	40.2604	777.6981	885.0726	10.73611
Total															1320.198	14164.33	15692.99	352.0529

Basement Floor(150mm)																		
Along Y		**Along X**		**Slab**	**Along Y**		**Along X**											
Start Grid	**End Grid**	**Start Grid**	**End Grid**	**ID**	**SO**	**EO**	**SO**	**EO**	**L**	**B**	**X**	**Y**	**Thickness**	**Unit Wt.**	**Mass**	**Mx**	**My**	**Area**
1	2	A	B	12AB	0	3.9624	0	3.2766	3.2766	3.9624	1.6383	1.9812	0.15	25	48.686999	79.763911	96.458683	12.9832
1	2	B	C	12BC	0	3.9624	3.2766	8.3058	5.0292	3.9624	5.7912	1.9812	0.15	25	74.728883	432.76991	148.05286	19.927702
1	2	C	D	12CD	0	3.9624	8.3058	12.6492	4.3434	3.9624	10.4775	1.9812	0.15	25	64.538581	676.20298	127.86384	17.210288
1	2	D	E	12DE	0	3.9624	12.6192	17.6784	5.0592	3.9624	15.1488	1.9812	0.15	25	75.174653	1138.8058	148.93602	20.046574
1	2	E	F	12EF	0	3.9624	17.6784	20.955	3.2766	3.9624	19.3167	1.9812	0.15	25	48.686999	940.47216	96.458683	12.9832
2	3	A	B	23AB	3.9626	8.3058	0	3.2766	3.2766	4.3432	1.6383	6.1342	0.15	25	53.365984	87.429492	327.35762	14.230929
2	3	B	C	23BC	3.9626	8.3058	3.2766	8.3058	5.0292	4.3432	5.7912	6.1342	0.15	25	81.91058	474.36055	502.45588	21.842821
2	3	C	D	23CD	3.9626	8.3058	8.3058	12.6492	4.3434	4.3432	10.4775	6.1342	0.15	25	70.740956	741.18836	433.93917	18.864255
2	3	D	E	23DE	3.9626	8.3058	12.6192	17.6784	5.0592	4.3432	15.1488	6.1342	0.15	25	82.39919	1248.2489	505.45311	21.973117
2	3	E	F	23EF	3.9626	8.3058	17.6784	20.955	3.2766	4.3432	19.3167	6.1342	0.15	25	53.365984	1030.8547	327.35762	14.230929
3	4	A	B	34AB	8.3058	13.1064	0	3.2766	3.2766	4.8006	1.6383	10.7061	0.15	25	58.986172	96.637046	631.51186	15.729646
3	4	C	D	34CD	8.3058	13.1064	8.3058	12.6492	4.3434	4.8006	10.4775	10.7061	0.15	25	78.190973	819.24592	837.12037	20.850926
3	4	E	F	34EF	8.3058	13.1064	17.6784	20.955	3.2766	4.8006	19.3167	10.7061	0.15	25	58.986172	1139.4182	631.51186	15.729646
4	5	A	B	45AB	13.1064	16.9926	0	3.2766	3.2766	3.8862	1.6383	15.0495	0.15	25	47.750711	78.22999	718.62432	12.733523
4	5	B	C	45BC	13.1064	16.9926	3.2766	8.3058	5.0292	3.8862	5.7912	15.0495	0.15	25	73.291789	424.44741	1103.0048	19.544477
4	5	C	D	45CD	13.1064	16.9926	8.3058	12.6492	4.3434	3.8862	10.4775	15.0495	0.15	25	63.297454	663.19907	952.59503	16.879321
4	5	D	E	45DE	13.1064	16.9926	12.6192	17.6784	5.0592	3.8862	15.1488	15.0495	0.15	25	73.728986	1116.9057	1109.5844	19.661063
4	5	E	F	45EF	13.1064	16.9926	17.6784	20.955	3.2766	3.8862	19.3167	15.0495	0.15	25	47.750711	922.38616	718.62432	12.733523
5	6	A	B	56AB	16.9926	20.3454	0	3.2766	3.2766	3.3528	1.6383	18.669	0.15	25	41.196692	67.49254	769.10104	10.985784
5	6	B	C	56BC	16.9926	20.3454	3.2766	8.3058	5.0292	3.3528	5.7912	18.669	0.15	25	63.232132	366.18992	1180.4807	16.861902
5	6	C	D	56CD	16.9926	20.3454	8.3058	12.6492	4.3434	3.3528	10.4775	18.669	0.15	25	54.609568	572.17175	1019.506	14.562552
5	6	D	E	56DE	16.9926	20.3454	12.6192	17.6784	5.0592	3.3528	15.1488	18.669	0.15	25	63.609322	963.60489	1187.5224	16.962486
5	6	E	F	56EF	16.9926	20.3454	17.6784	20.955	3.2766	3.3528	19.3167	18.669	0.15	25	41.196692	795.78414	769.10104	10.985784
6	7	A	B	67AB	20.3454	23.622	0	3.2766	3.2766	3.2766	1.6383	21.9837	0.15	25	40.260403	65.958619	885.07263	10.736108
6	7	B	C	67BC	20.3454	23.622	3.2766	8.3058	5.0292	3.2766	5.7912	21.9837	0.15	25	61.795038	357.86742	1358.4836	16.478677
6	7	C	D	67CD	20.3454	23.622	8.3058	12.6492	4.3434	3.2766	10.4775	21.9837	0.15	25	53.368442	559.16785	1173.2358	14.231584
6	7	D	E	67DE	20.3454	23.622	12.6192	17.6784	5.0592	3.2766	15.1488	21.9837	0.15	25	62.163655	941.70478	1366.5871	16.576975
6	7	E	F	67EF	20.3454	23.622	17.6784	20.955	3.2766	3.2766	19.3167	21.9837	0.15	25	40.260403	777.69813	885.07263	10.736108
Total															1677.2741	17578.206	20011.073	447.2731

Cover(150mm)																		
Along	**Y**	**Along**	**X**	**Slab**	**Along**	**Y**	**Along**	**X**						**Unit**				
Start Grid	**End Grid**	**Start Grid**	**End Grid**	**ID**	**SO**	**EO**	**SO**	**EO**	**L**	**B**	**X**	**Y**	**TH.**	**Wt.**	**Mass**	**Mx**	**My**	**Area**
3	4	B	C	34BC	8.3058	13.1064	3.2766	8.3058	5.0292	4.8006	5.7912	10.7061	0.15	25	90.536916	524.31739	969.29727	24.143178
3	4	C	D	34CD	8.3058	13.1064	8.3058	12.6492	4.3434	4.8006	10.4775	10.7061	0.15	25	78.190973	819.24592	837.12037	20.850926
3	4	D	E	34DE	8.3058	13.1064	12.6492	17.6784	5.0292	4.8006	15.1638	10.7061	0.15	25	90.536916	1372.8837	969.29727	24.143178
Total															259.2648	2716.447	2775.7149	69.137281

Calculation for Wall

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
Typical Floor(1st to 10th floor)															
1	A	B	1AB	0	0	3.2766	1.6383	0	3.2766	2.7004	0.23	20	28.490981	46.676774	0
2	A	B	2AB	3.9624	0	3.2766	1.6383	3.9624	3.2766	2.7004	0.23	20	28.490981	46.676774	112.89266
3	A	B	3AB	8.3058	0	3.2766	1.6383	8.3058	3.2766	2.7004	0.23	20	28.490981	46.676774	236.64039
4	A	B	4AB	13.106	0	3.2766	1.6383	13.1064	3.2766	2.7004	0.23	20	28.490981	46.676774	373.41419
5	A	B	5AB	16.993	0	3.2766	1.6383	16.9926	3.2766	2.7004	0.23	20	28.490981	46.676774	484.13584
6	A	B	6AB	20.345	0	3.2766	1.6383	20.3454	3.2766	2.7004	0.23	20	28.490981	46.676774	579.6604
7	A	B	7AB	23.622	0	3.2766	1.6383	23.622	3.2766	2.7004	0.23	20	28.490981	46.676774	673.01395
1	B	C	1BC	0	3.2766	8.3058	5.7912	0	5.0292	2.7004	0.23	20	43.730342	253.25116	0
2	B	C	2BC	3.9624	3.2766	8.3058	5.7912	3.9624	5.0292	2.7004	0.23	20	43.730342	253.25116	173.27711
3	B	C	3BC	8.3058	3.2766	8.3058	5.7912	8.3058	5.0292	2.7004	0.23	20	43.730342	253.25116	363.21548
4	B	C	4BC	13.106	3.2766	8.3058	5.7912	13.1064	5.0292	2.7004	0.23	20	43.730342	253.25116	573.14736
5	B	C	5BC	16.993	3.2766	8.3058	5.7912	16.9926	5.0292	2.7004	0.23	20	43.730342	253.25116	743.09222
6	B	C	6BC	20.345	3.2766	8.3058	5.7912	20.3454	5.0292	2.7004	0.23	20	43.730342	253.25116	889.71131
7	B	C	7BC	23.622	3.2766	8.3058	5.7912	23.622	5.0292	2.7004	0.23	20	43.730342	253.25116	1032.9981
3	C	D	3CD	8.3058	8.3058	12.6492	10.4775	8.3058	4.3434	2.7004	0.23	20	37.767114	395.70494	313.68609
4	C	D	4CD	13.106	8.3058	12.6492	10.4775	13.1064	4.3434	2.7004	0.23	20	37.767114	395.70494	494.9909
5	C	D	5CD	16.993	8.3058	12.6492	10.4775	16.9926	4.3434	2.7004	0.23	20	37.767114	395.70494	641.76146
1	D	E	1DE	0	12.649	17.6784	15.1638	0	5.0292	2.7004	0.23	20	43.730342	663.11817	0
2	D	E	2DE	3.9624	12.649	17.6784	15.1638	3.9624	5.0292	2.7004	0.23	20	43.730342	663.11817	173.27711
3	D	E	3DE	8.3058	12.649	17.6784	15.1638	8.3058	5.0292	2.7004	0.23	20	43.730342	663.11817	363.21548
4	D	E	4DE	13.106	12.649	17.6784	15.1638	13.1064	5.0292	2.7004	0.23	20	43.730342	663.11817	573.14736
5	D	E	5DE	16.993	12.649	17.6784	15.1638	16.9926	5.0292	2.7004	0.23	20	43.730342	663.11817	743.09222
6	D	E	6DE	20.345	12.649	17.6784	15.1638	20.3454	5.0292	2.7004	0.23	20	43.730342	663.11817	889.71131

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
7	D	E	7DE	23.622	12.649	17.6784	15.1638	23.622	5.0292	2.7004	0.23	20	43.730342	663.11817	1032.9981
1	E	F	1EF	0	17.678	20.955	19.3167	0	3.2766	2.7004	0.23	20	28.490981	550.35173	0
2	E	F	2EF	3.9624	17.678	20.955	19.3167	3.9624	3.2766	2.7004	0.23	20	28.490981	550.35173	112.89266
3	E	F	3EF	8.3058	17.678	20.955	19.3167	8.3058	3.2766	2.7004	0.23	20	28.490981	550.35173	236.64039
4	E	F	4EF	13.106	17.678	20.955	19.3167	13.1064	3.2766	2.7004	0.23	20	28.490981	550.35173	373.41419
5	E	F	5EF	16.993	17.678	20.955	19.3167	16.9926	3.2766	2.7004	0.23	20	28.490981	550.35173	484.13584
6	E	F	6EF	20.345	17.678	20.955	19.3167	20.3454	3.2766	2.7004	0.23	20	28.490981	550.35173	579.6604
7	E	F	7EF	23.622	17.678	20.955	19.3167	23.622	3.2766	2.7004	0.23	20	28.490981	550.35173	673.01395
A	1	2	A12	0	0	3.9624	0	1.9812	3.9624	2.7004	0.23	20	34.454209	0	68.260679
B	1	2	B12	3.2766	0	3.9624	3.2766	1.9812	3.9624	2.7004	0.23	20	34.454209	112.89266	68.260679
C	1	2	C12	8.3058	0	3.9624	8.3058	1.9812	3.9624	2.7004	0.23	20	34.454209	286.16977	68.260679
D	1	2	D12	12.649	0	3.9624	12.6492	1.9812	3.9624	2.7004	0.23	20	34.454209	435.81818	68.260679
E	1	2	E12	17.678	0	3.9624	17.6784	1.9812	3.9624	2.7004	0.23	20	34.454209	609.09529	68.260679
F	1	2	F12	20.955	0	3.9624	20.955	1.9812	3.9624	2.7004	0.23	20	34.454209	721.98795	68.260679
A	2	3	A23	0	3.9624	8.3058	0	6.1341	4.3434	2.7004	0.23	20	37.767114	0	231.66725
B	2	3	B23	3.2766	3.9624	8.3058	3.2766	6.1341	4.3434	2.7004	0.23	20	37.767114	123.74773	231.66725
C	2	3	C23	8.3058	3.9624	8.3058	8.3058	6.1341	4.3434	2.7004	0.23	20	37.767114	313.68609	231.66725
D	2	3	D23	12.649	3.9624	8.3058	12.6492	6.1341	4.3434	2.7004	0.23	20	37.767114	477.72378	231.66725
E	2	3	E23	17.678	3.9624	8.3058	17.6784	6.1341	4.3434	2.7004	0.23	20	37.767114	667.66215	231.66725
F	2	3	F23	20.955	3.9624	8.3058	20.955	6.1341	4.3434	2.7004	0.23	20	37.767114	791.40987	231.66725
A	3	4	A34	0	8.3058	13.1064	0	10.7061	4.8006	2.7004	0.23	20	41.7426	0	446.90045
B	3	4	B34	3.2766	8.3058	13.1064	3.2766	10.7061	4.8006	2.7004	0.23	20	41.7426	136.7738	446.90045
E	3	4	E34	17.678	8.3058	13.1064	17.6784	10.7061	4.8006	2.7004	0.23	20	41.7426	737.94237	446.90045
F	3	4	F34	20.955	8.3058	13.1064	20.955	10.7061	4.8006	2.7004	0.23	20	41.7426	874.71617	446.90045
A	4	5	A45	0	13.106	16.9926	0	15.0495	3.8862	2.7004	0.23	20	33.791628	0	508.54711
B	4	5	B45	3.2766	13.106	16.9926	3.2766	15.0495	3.8862	2.7004	0.23	20	33.791628	110.72165	508.54711
C	4	5	C45	8.3058	13.106	16.9926	8.3058	15.0495	3.8862	2.7004	0.23	20	33.791628	280.66651	508.54711

Main Grid	Start Grid	End Grid	Wall ID	MO	SO	EO	X	Y	Length	Height	Width	Unit wt.	Mass	M*X	M*Y
D	4	5	D45	12.649	13.106	16.9926	12.6492	15.0495	3.8862	2.7004	0.23	20	33.791628	427.43706	508.54711
E	4	5	E45	17.678	13.106	16.9926	17.6784	15.0495	3.8862	2.7004	0.23	20	33.791628	597.38192	508.54711
F	4	5	F45	20.955	13.106	16.9926	20.955	15.0495	3.8862	2.7004	0.23	20	33.791628	708.10357	508.54711
A	5	6	A56	0	16.993	20.3454	0	18.669	3.3528	2.7004	0.23	20	29.153562	0	544.26784
B	5	6	B56	3.2766	16.993	20.3454	3.2766	18.669	3.3528	2.7004	0.23	20	29.153562	95.52456	544.26784
C	5	6	C56	8.3058	16.993	20.3454	8.3058	18.669	3.3528	2.7004	0.23	20	29.153562	242.14365	544.26784
D	5	6	D56	12.649	16.993	20.3454	12.6492	18.669	3.3528	2.7004	0.23	20	29.153562	368.76923	544.26784
E	5	6	E56	17.678	16.993	20.3454	17.6784	18.669	3.3528	2.7004	0.23	20	29.153562	515.38832	544.26784
F	5	6	F56	20.955	16.993	20.3454	20.955	18.669	3.3528	2.7004	0.23	20	29.153562	610.91288	544.26784
A	6	7	A67	0	20.345	23.622	0	21.9837	3.2766	2.7004	0.23	20	28.490981	0	626.33717
B	6	7	B67	3.2766	20.345	23.622	3.2766	21.9837	3.2766	2.7004	0.23	20	28.490981	93.353547	626.33717
C	6	7	C67	8.3058	20.345	23.622	8.3058	21.9837	3.2766	2.7004	0.23	20	28.490981	236.64039	626.33717
D	6	7	D67	12.649	20.345	23.622	12.6492	21.9837	3.2766	2.7004	0.23	20	28.490981	360.38811	626.33717
E	6	7	E67	17.678	20.345	23.622	17.6784	21.9837	3.2766	2.7004	0.23	20	28.490981	503.67495	626.33717
F	6	7	F67	20.955	20.345	23.622	20.955	21.9837	3.2766	2.7004	0.23	20	28.490981	597.0285	626.33717
Total													2273.3152	23818.66	27582.919

Basement															
Main Grid	**Start Grid**	**End Grid**	**Wall ID**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit wt.**	**Mass**	**M*X**	**M*Y**
1	A	B	1AB	0	0	3.2766	1.6383	0	3.2766	2.373	0.2	25	38.87686	63.69196	0
1	B	C	1BC	0	3.277	8.3058	5.7912	0	5.0292	2.373	0.2	25	59.67146	345.5693	0
1	C	D	1CD	0	8.306	12.6492	10.4775	0	4.3434	2.373	0.2	25	51.53444	539.9521	0
1	D	E	1DE	0	12.65	17.6784	15.1638	0	5.0292	2.373	0.2	25	59.67146	904.8461	0
1	E	F	1EF	0	17.68	20.955	19.3167	0	3.2766	2.373	0.2	25	38.87686	750.9726	0
7	A	B	7AB	23.62	0	3.2766	1.6383	23.622	3.2766	2.373	0.2	25	38.87686	63.69196	918.3492
7	B	C	7BC	23.62	3.277	8.3058	5.7912	23.622	5.0292	2.373	0.2	25	59.67146	345.5693	1409.559
7	C	D	7CD	23.62	8.306	12.6492	10.4775	23.622	4.3434	2.373	0.2	25	51.53444	539.9521	1217.347
7	D	E	7DE	23.62	12.65	17.6784	15.1638	23.622	5.0292	2.373	0.2	25	59.67146	904.8461	1409.559
7	E	F	7EF	23.62	17.68	20.955	19.3167	23.622	3.2766	2.373	0.2	25	38.87686	750.9726	918.3492
A	1	2	A12	0	0	3.9624	0	1.9812	3.9624	2.373	0.2	25	47.01388	0	93.14389
A	2	3	A23	0	3.962	8.3058	0	6.1341	4.3434	2.373	0.2	25	51.53444	0	316.1174
A	3	4	A34	0	8.306	13.1064	0	10.706	4.8006	2.373	0.2	25	56.95912	0	609.81
A	4	5	A45	0	13.11	16.9926	0	15.05	3.8862	2.373	0.2	25	46.10976	0	693.9289
A	5	6	A56	0	16.99	20.3454	0	18.669	3.3528	2.373	0.2	25	39.78097	0	742.671
A	6	7	A67	0	20.35	23.622	0	21.984	3.2766	2.373	0.2	25	38.87686	0	854.6572
F	1	2	F12	20.96	0	3.9624	20.955	1.9812	3.9624	2.373	0.2	25	47.01388	985.1758	93.14389
F	2	3	F23	20.96	3.962	8.3058	20.955	6.1341	4.3434	2.373	0.2	25	51.53444	1079.904	316.1174
F	3	4	F34	20.96	8.306	13.1064	20.955	10.706	4.8006	2.373	0.2	25	56.95912	1193.578	609.81
F	4	5	F45	20.96	13.11	16.9926	20.955	15.05	3.8862	2.373	0.2	25	46.10976	966.2301	693.9289
F	5	6	F56	20.96	16.99	20.3454	20.955	18.669	3.3528	2.373	0.2	25	39.78097	833.6103	742.671
F	6	7	F67	20.96	20.35	23.622	20.955	21.984	3.2766	2.373	0.2	25	38.87686	814.6646	854.6572
Total													1057.812	11083.23	12493.82

Cover															
Main Grid	**Start Grid**	**End Grid**	**Wall ID**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit wt.**	**Mass**	**M*X**	**M*Y**
3	B	C	3BC	8.306	3.277	8.3058	5.7912	8.3058	5.0292	2.3956	0.23	20	38.7944	224.6662	322.2186
3	C	D	3CD	8.306	8.306	12.6492	10.4775	8.3058	4.3434	2.3956	0.23	20	33.50426	351.0409	278.2797
3	D	E	3DE	8.306	12.65	17.6784	15.1638	8.3058	5.0292	2.3956	0.23	20	38.7944	588.2706	322.2186
4	B	C	4BC	13.11	3.277	8.3058	5.7912	13.106	5.0292	2.3956	0.23	20	38.7944	224.6662	508.455
4	C	D	4CD	13.11	8.306	12.6492	10.4775	13.106	4.3434	2.3956	0.23	20	33.50426	351.0409	439.1202
4	D	E	4DE	13.11	12.65	17.6784	15.1638	13.106	5.0292	2.3956	0.23	20	38.7944	588.2706	508.455
B	3	4	B34	3.277	8.306	13.1064	3.2766	10.706	4.8006	2.3956	0.23	20	37.03102	121.3358	396.4578
E	3	4	E34	17.68	8.306	13.1064	17.6784	10.706	4.8006	2.3956	0.23	20	37.03102	654.6492	396.4578
Total													296.2482	3103.94	3171.663

Parapet Wall (10th Floor)															
Main Grid	**Start Grid**	**End Grid**	**Wall ID**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit wt.**	**Mass**	**M*X**	**M*Y**
1	A	B	1AB	0	0	3.2766	1.6383	0	3.2766	1	0.23	20	15.07236	24.69305	0
1	B	C	1BC	0	3.277	8.3058	5.7912	0	5.0292	1	0.23	20	23.13432	133.9755	0
1	D	E	1DE	0	12.65	17.6784	15.1638	0	5.0292	1	0.23	20	23.13432	350.8042	0
1	E	F	1EF	0	17.68	20.955	19.3167	0	3.2766	1	0.23	20	15.07236	291.1483	0
3	C	D	3CD	8.306	8.306	12.6492	10.4775	8.3058	4.3434	1	0.23	20	19.97964	209.3367	165.9469
4	C	D	4CD	13.11	8.306	12.6492	10.4775	13.106	4.3434	1	0.23	20	19.97964	209.3367	261.8612
7	A	B	7AB	23.62	0	3.2766	1.6383	23.622	3.2766	1	0.23	20	15.07236	24.69305	356.0393
7	B	C	7BC	23.62	3.277	8.3058	5.7912	23.622	5.0292	1	0.23	20	23.13432	133.9755	546.4789
7	D	E	7DE	23.62	12.65	17.6784	15.1638	23.622	5.0292	1	0.23	20	23.13432	350.8042	546.4789
7	E	F	7EF	23.62	17.68	20.955	19.3167	23.622	3.2766	1	0.23	20	15.07236	291.1483	356.0393
A	1	2	A12	0	0	3.9624	0	1.9812	3.9624	1	0.23	20	18.22704	0	36.11141
A	2	3	A23	0	3.962	8.3058	0	8.1153	4.3434	1	0.23	20	19.97964	0	162.1408
A	3	4	A34	0	8.306	13.1064	0	14.859	4.8006	1	0.23	20	22.08276	0	328.1277
A	4	5	A45	0	13.11	16.9926	0	21.603	3.8862	1	0.23	20	17.87652	0	386.1811
A	5	6	A56	0	16.99	20.3454	0	27.165	3.3528	1	0.23	20	15.42288	0	418.9672
A	6	7	A67	0	20.35	23.622	0	32.156	3.2766	1	0.23	20	15.07236	0	484.6728
C	1	2	C12	8.306	0	3.9624	8.3058	1.9812	3.9624	1	0.23	20	18.22704	151.3901	36.11141
C	2	3	C23	8.306	3.962	8.3058	8.3058	8.1153	4.3434	1	0.23	20	19.97964	165.9469	162.1408
C	4	5	C45	8.306	13.11	16.9926	8.3058	21.603	3.8862	1	0.23	20	17.87652	148.4788	386.1811
C	5	6	C56	8.306	16.99	20.3454	8.3058	27.165	3.3528	1	0.23	20	15.42288	128.0994	418.9672
C	6	7	C67	8.306	20.35	23.622	8.3058	32.156	3.2766	1	0.23	20	15.07236	125.188	484.6728
D	1	2	D12	12.65	0	3.9624	12.6492	1.9812	3.9624	1	0.23	20	18.22704	230.5575	36.11141
D	2	3	D23	12.65	3.962	8.3058	12.6492	8.1153	4.3434	1	0.23	20	19.97964	252.7265	162.1408
D	4	5	D45	12.65	13.11	16.9926	12.6492	21.603	3.8862	1	0.23	20	17.87652	226.1237	386.1811
Main	**Start**	**End**	**Wall**	**MO**	**SO**	**EO**	**X**	**Y**	**Length**	**Height**	**Width**	**Unit**	**Mass**	**M*X**	**M*Y**

Grid	Grid	Grid	ID									wt.			
D	5	6	D56	12.65	16.99	20.3454	12.6492	27.165	3.3528	1	0.23	20	15.42288	195.0871	418.9672
D	6	7	D67	12.65	20.35	23.622	12.6492	32.156	3.2766	1	0.23	20	15.07236	190.6533	484.6728
F	1	2	F12	20.96	0	3.9624	20.955	1.9812	3.9624	1	0.23	20	18.22704	381.9476	36.11141
F	2	3	F23	20.96	3.962	8.3058	20.955	8.1153	4.3434	1	0.23	20	19.97964	418.6734	162.1408
F	3	4	F34	20.96	8.306	13.1064	20.955	14.859	4.8006	1	0.23	20	22.08276	462.7442	328.1277
F	4	5	F45	20.96	13.11	16.9926	20.955	21.603	3.8862	1	0.23	20	17.87652	374.6025	386.1811
F	5	6	F56	20.96	16.99	20.3454	20.955	27.165	3.3528	1	0.23	20	15.42288	323.1865	418.9672
F	6	7	F67	20.96	20.35	23.622	20.955	32.156	3.2766	1	0.23	20	15.07236	315.8413	484.6728
Total													583.2653	6111.162	8841.393

Typical Floor (2nd to 10th floor)

	Mass(kN)	Mx(kNm)	My(kNm)
Colum n	840.105	8802.2	10361.45
Beam	1081.564	11332.03	13061.74
Slab	1320.198	14164.33	15692.99
Wall	2273.315	23818.66	27582.92
Total	5515.182	58117.22	66699.09

Center of Mass		
Along X-axis	10.53768	m
Along Y-axis	12.09372	m

Center of Rigidity		
Along X-axis	10.4775	m
Along Y-axis	12.33351	m

Basement

	Mass(kN)	Mx(kNm)	My(kNm)
Colum n	856.6916	8975.987	10566.02
Beam	1081.564	11332.03	13061.74
Slab	1677.274	17578.21	20011.07
Wall	1057.812	11083.23	12493.82
Total	4673.342	48969.45	56132.65

Center of Mass		
Along X-axis	10.47847	m
Along Y-axis	12.01124	m

Center of Rigidity		
Along X-axis	10.4775	m
Along Y-axis	12.33351	m

1st Floor

	Mass(KN)	Mx(KNm)	My(KNm)
Column	979.8985	10266.89	12085.59
Beam	1081.564	11332.03	13061.74
Slab	1320.198	15692.99	15692.99
Wall	2273.315	23818.66	27582.92
Total	5654.976	61110.57	68423.24

Center of Mass		
Along X-axis	10.80651	m
Along Y-axis	12.09965	m

Center of Rigidity		
Along X-axis	10.4775	m
Along Y-axis	12.33351	m

Staircase Cover

	Mass (kN)	Mx (kNm)	My (kNm)
Column	144.78	1516.932	1550.029
Beam	180.0135	1886.059	1927.207
Slab	259.2648	2716.447	2775.715
Wall	296.2482	3103.94	3171.663
Total	880.3065	9223.379	9424.613

Center of Mass		
Along X-axis	10.47746	m
Along Y-axis	10.70606	m

Center of Rigidity		
Along X-axis	10.4775	m
Along Y-axis	10.7061	m

Eccentricity Calculation

Element	Along X-axis	Along Y-axis
Typical floor (2nd to 10th floor)	0.060179219	0.239789832
1st Floor	0.329013114	0.233862113
Basement	0.000966114	0.322269666
Staircase Cover	0	0

Calculation of Center of Stiffness

Basement

h=	2.798	m
b=	0.54	m
d=	0.54	m
E=	25000000	kN/m²
I=	0.007086	m^4
K=	97044.72	kN/m

S.N.	Grid	K	x	y	kx	ky
1	A1	97044.721	0.000	0.000	0.000	0.000
2	B1	97044.721	3.277	0.000	317976.724	0.000
3	C1	97044.721	8.306	0.000	806034.021	0.000
4	D1	97044.721	12.649	0.000	1227538.050	0.000
5	E1	97044.721	17.678	0.000	1715595.348	0.000
6	F1	97044.721	20.955	0.000	2033572.071	0.000
7	A2	97044.721	0.000	3.962	0.000	384529.992
8	B2	97044.721	3.277	3.962	317976.724	384529.992
9	C2	97044.721	8.306	3.962	806034.021	384529.992
10	D2	97044.721	12.649	3.962	1227538.050	384529.992
11	E2	97044.721	17.678	3.962	1715595.348	384529.992
12	F2	97044.721	20.955	3.962	2033572.071	384529.992
13	A3	97044.721	0.000	8.306	0.000	806034.021
14	B3	97044.721	3.277	8.306	317976.724	806034.021
15	C3	97044.721	8.306	8.306	806034.021	806034.021
16	D3	97044.721	12.649	8.306	1227538.050	806034.021
17	E3	97044.721	17.678	8.306	1715595.348	806034.021
18	F3	97044.721	20.955	8.306	2033572.071	806034.021
19	A4	97044.721	0.000	13.106	0.000	1271906.896
20	B4	97044.721	3.277	13.106	317976.724	1271906.896
21	C4	97044.721	8.306	13.106	806034.021	1271906.896
22	D4	97044.721	12.649	13.106	1227538.050	1271906.896
23	E4	97044.721	17.678	13.106	1715595.348	1271906.896
24	F4	97044.721	20.955	13.106	2033572.071	1271906.896
25	A5	97044.721	0.000	16.993	0.000	1649042.080
26	B5	97044.721	3.277	16.993	317976.724	1649042.080
27	C5	97044.721	8.306	16.993	806034.021	1649042.080
28	D5	97044.721	12.649	16.993	1227538.050	1649042.080
29	E5	97044.721	17.678	16.993	1715595.348	1649042.080
30	F5	97044.721	20.955	16.993	2033572.071	1649042.080
31	A6	97044.721	0.000	20.345	0.000	1974413.611
32	B6	97044.721	3.277	20.345	317976.724	1974413.611
33	C6	97044.721	8.306	20.345	806034.021	1974413.611

S.N.	Grid	K	x	y	kx	ky
34	D6	97044.721	12.649	20.345	1227538.050	1974413.611
35	E6	97044.721	17.678	20.345	1715595.348	1974413.611
36	F6	97044.721	20.955	20.345	2033572.071	1974413.611
37	A7	97044.721	0.000	23.622	0.000	2292390.335
38	B7	97044.721	3.277	23.622	317976.724	2292390.335
39	C7	97044.721	8.306	23.622	806034.021	2292390.335
40	D7	97044.721	12.649	23.622	1227538.050	2292390.335
41	E7	97044.721	17.678	23.622	1715595.348	2292390.335
42	F7	97044.721	20.955	23.622	2033572.071	2292390.335
	Sum	4075878.298			42705013.501	50269901.607
	Center of Stiffness				10.477	12.334

1st Floor

h=	3.2004	m
b=	0.54	m
d=	0.54	m
E=	25000000	kN/m²
I=	0.007086	m^4
K=	64848.85	kN/m

S.N.	Grid	K	x	y	kx	ky
1	A1	64848.848	0.000	0.000	0.000	0.000
2	B1	64848.848	3.277	0.000	212483.727	0.000
3	C1	64848.848	8.306	0.000	538621.541	0.000
4	D1	64848.848	12.649	0.000	820286.017	0.000
5	E1	64848.848	17.678	0.000	1146423.831	0.000
6	F1	64848.848	20.955	0.000	1358907.558	0.000
7	A2	64848.848	0.000	3.962	0.000	256957.065
8	B2	64848.848	3.277	3.962	212483.727	256957.065
9	C2	64848.848	8.306	3.962	538621.541	256957.065
10	D2	64848.848	12.649	3.962	820286.017	256957.065
11	E2	64848.848	17.678	3.962	1146423.831	256957.065
12	F2	64848.848	20.955	3.962	1358907.558	256957.065
13	A3	64848.848	0.000	8.306	0.000	538621.541
14	B3	64848.848	3.277	8.306	212483.727	538621.541
15	C3	64848.848	8.306	8.306	538621.541	538621.541
16	D3	64848.848	12.649	8.306	820286.017	538621.541
17	E3	64848.848	17.678	8.306	1146423.831	538621.541
18	F3	64848.848	20.955	8.306	1358907.558	538621.541
19	A4	64848.848	0.000	13.106	0.000	849934.909
20	B4	64848.848	3.277	13.106	212483.727	849934.909
21	C4	64848.848	8.306	13.106	538621.541	849934.909
22	D4	64848.848	12.649	13.106	820286.017	849934.909
23	E4	64848.848	17.678	13.106	1146423.831	849934.909
24	F4	64848.848	20.955	13.106	1358907.558	849934.909
25	A5	64848.848	0.000	16.993	0.000	1101950.492
26	B5	64848.848	3.277	16.993	212483.727	1101950.492
27	C5	64848.848	8.306	16.993	538621.541	1101950.492
28	D5	64848.848	12.649	16.993	820286.017	1101950.492
29	E5	64848.848	17.678	16.993	1146423.831	1101950.492
30	F5	64848.848	20.955	16.993	1358907.558	1101950.492
31	A6	64848.848	0.000	20.345	0.000	1319375.701
32	B6	64848.848	3.277	20.345	212483.727	1319375.701
33	C6	64848.848	8.306	20.345	538621.541	1319375.701
34	D6	64848.848	12.649	20.345	820286.017	1319375.701
35	E6	64848.848	17.678	20.345	1146423.831	1319375.701

S.N.	Grid	K	x	y	kx	ky
36	F6	64848.848	20.955	20.345	1358907.558	1319375.701
37	A7	64848.848	0.000	23.622	0.000	1531859.429
38	B7	64848.848	3.277	23.622	212483.727	1531859.429
39	C7	64848.848	8.306	23.622	538621.541	1531859.429
40	D7	64848.848	12.649	23.622	820286.017	1531859.429
41	E7	64848.848	17.678	23.622	1146423.831	1531859.429
42	F7	64848.848	20.955	23.622	1358907.558	1531859.429
	Sum	2723651.599			28537058.712	33592194.827
	Center of Stiffness				10.477	12.334

Typical Floor

h=	3.2004	m
b=	0.5	m
d=	0.5	m
E=	25000000	kN/m^2
I=	0.005208	m^4
K=	47665.84	kN/m

S.N.	Grid	K	x	y	kx	ky
1	A1	47665.839	0.000	0.000	0.000	0.000
2	B1	47665.839	3.277	0.000	156181.883	0.000
3	C1	47665.839	8.306	0.000	395902.912	0.000
4	D1	47665.839	12.649	0.000	602934.710	0.000
5	E1	47665.839	17.678	0.000	842655.739	0.000
6	F1	47665.839	20.955	0.000	998837.622	0.000
7	A2	47665.839	0.000	3.962	0.000	188871.114
8	B2	47665.839	3.277	3.962	156181.883	188871.114
9	C2	47665.839	8.306	3.962	395902.912	188871.114
10	D2	47665.839	12.649	3.962	602934.710	188871.114
11	E2	47665.839	17.678	3.962	842655.739	188871.114
12	F2	47665.839	20.955	3.962	998837.622	188871.114
13	A3	47665.839	0.000	8.306	0.000	395902.912
14	B3	47665.839	3.277	8.306	156181.883	395902.912
15	C3	47665.839	8.306	8.306	395902.912	395902.912
16	D3	47665.839	12.649	8.306	602934.710	395902.912
17	E3	47665.839	17.678	8.306	842655.739	395902.912
18	F3	47665.839	20.955	8.306	998837.622	395902.912
19	A4	47665.839	0.000	13.106	0.000	624727.531
20	B4	47665.839	3.277	13.106	156181.883	624727.531
21	C4	47665.839	8.306	13.106	395902.912	624727.531
22	D4	47665.839	12.649	13.106	602934.710	624727.531
23	E4	47665.839	17.678	13.106	842655.739	624727.531
24	F4	47665.839	20.955	13.106	998837.622	624727.531
25	A5	47665.839	0.000	16.993	0.000	809966.508
26	B5	47665.839	3.277	16.993	156181.883	809966.508
27	C5	47665.839	8.306	16.993	395902.912	809966.508
28	D5	47665.839	12.649	16.993	602934.710	809966.508
29	E5	47665.839	17.678	16.993	842655.739	809966.508
30	F5	47665.839	20.955	16.993	998837.622	809966.508
31	A6	47665.839	0.000	20.345	0.000	969780.528
32	B6	47665.839	3.277	20.345	156181.883	969780.528
33	C6	47665.839	8.306	20.345	395902.912	969780.528
34	D6	47665.839	12.649	20.345	602934.710	969780.528
35	E6	47665.839	17.678	20.345	842655.739	969780.528

S.N.	Grid	K	x	y	kx	ky
36	F6	47665.839	20.955	20.345	998837.622	969780.528
37	A7	47665.839	0.000	23.622	0.000	1125962.410
38	B7	47665.839	3.277	23.622	156181.883	1125962.410
39	C7	47665.839	8.306	23.622	395902.912	1125962.410
40	D7	47665.839	12.649	23.622	602934.710	1125962.410
41	E7	47665.839	17.678	23.622	842655.739	1125962.410
42	F7	47665.839	20.955	23.622	998837.622	1125962.410
	Sum	2001965.234			20975590.064	24691266.019
	Center of Stiffness				10.477	12.334

Staircase Cover

h=	2.896	m
b=	0.5	m
d=	0.5	m
E=	25000000	kN/m²
I=	0.005208	m^4
K=	64331.6	kN/m

S.N.	Grid	K	x	y	kx	ky
1	B3	64331.600	3.277	8.306	210788.914	534325.387
2	C3	64331.600	8.306	8.306	534325.387	534325.387
3	D3	64331.600	12.649	8.306	813743.250	534325.387
4	E3	64331.600	17.678	8.306	1137279.722	534325.387
5	B4	64331.600	3.277	13.106	210788.914	843155.656
6	C4	64331.600	8.306	13.106	534325.387	843155.656
7	D4	64331.600	12.649	13.106	813743.250	843155.656
8	E4	64331.600	17.678	13.106	1137279.722	843155.656

	Sum	514652.801			5392274.546	5509924.172
	Center of Stiffness				10.477	10.706

	Terrace(Cover)		10th Floor		Typical Floor(2 to 9)		1st Floor		Ground Floor	
	DL	LL	DL	LL	DL	LL	DL	LL	DL	LL
Wall	148.12	0.00	1284.78	0.00	2273.32	0.00	2273.32	0.00	1136.66	0.00
Column	72.39	0.00	492.44	0.00	840.11	0.00	910.00	0.00	918.30	0.00
Beam	180.01	0.00	1081.56	0.00	1081.56	0.00	1081.56	0.00	1081.56	0.00
Corridor & Store Room Slab	259.26	34.57	196.16	39.23	196.16	39.23	196.16	39.23	196.16	39.23
Remaining Slab	0.00	0.00	1124.04	149.87	1124.04	149.87	1124.04	149.87	1481.11	197.48
Floor Finish	51.85	0.00	528.08	0.00	528.08	0.00	528.08	0.00	670.91	0.00
Parapet Wall	0.00	0.00	583.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Tank	245.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staircase	0.00	0.00	144.90	39.90	144.90	39.90	144.90	39.90	144.90	39.90
Total	957.11	34.57	5435.23	229.00	6188.16	229.00	6258.06	229.00	5629.60	276.61
DL+LL	991.67		5664.23		6417.17		6487.06		5906.21	

Theory of Base Shear Calculation

According to IS 1893 (Part I): 2002 Cl. No. 6.4.2 the design horizontal seismic coefficient Ah for a structure shall be determined by the following expression Ah=ZISa2Rg

Where,

Z = Zone factor given by IS 1893 (Part I): 2002 Table 2, Here for Zone V, Z = 0.36

I = Importance Factor, I = 1 for general purpose building

R = Response reduction factor given by IS 1893 (Part I): 2002 Table 7, R = 5.0

$\frac{\mathrm{Sa}}{g}$ = Average response acceleration coefficient which depends on approximate fundamental natural period of vibration (Ta).

For Ta = 1.4 second soil type III (Soft Soil) $\frac{\mathrm{Sa}}{g}$ = 0.97

∴ The value of design horizontal seismic coefficient is

$$\mathrm{Ah} = \frac{Z}{2} * \frac{I}{R} * \frac{Sa}{g}$$

$$= \frac{0.36*1*0.97}{2*5}$$

$$= 0.03497$$

According to IS 1893 (Part I):2002 Cl. No. 7.5.3 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 = 70386.51 KN

$$V_B = 0.03497 * 70386.51 = 2461.416 \text{ kN}$$

Floor	Wi(KN)	Hi	Wi*Hi*Hi	Qi(KN)	Vi(KN)	Calculated		Permissible		Torsion Check	
						ex	ey	ex	ey	x-axis	y-axis
Terrace(Cover)	991.67	37.70	1409276.88	106.16	106.16	0.00	0.00	4.19	4.72	ok	ok
10	5664.23	34.80	6860403.48	516.80	622.96	0.06	0.24	4.19	4.72	ok	ok
9	6417.17	31.60	6408573.82	482.76	1105.72	0.06	0.24	4.19	4.72	ok	ok
8	6417.17	28.40	5176266.50	389.93	1495.65	0.06	0.24	4.19	4.72	ok	ok
7	6417.17	25.20	4075415.60	307.00	1802.66	0.06	0.24	4.19	4.72	ok	ok
6	6417.17	22.00	3106021.10	233.98	2036.63	0.06	0.24	4.19	4.72	ok	ok
5	6417.17	18.80	2268083.02	170.86	2207.49	0.06	0.24	4.19	4.72	ok	ok
4	6417.17	15.60	1561601.34	117.64	2325.13	0.06	0.24	4.19	4.72	ok	ok
3	6417.17	12.40	986576.07	74.32	2399.45	0.06	0.24	4.19	4.72	ok	ok
2	6417.17	9.20	543007.22	40.91	2440.35	0.06	0.24	4.19	4.72	ok	ok
1	6487.06	6.00	233409.71	17.58	2457.93	0.33	0.23	4.19	4.72	ok	ok
Basement	5906.21	2.80	46238.59	3.48	2461.42	0.00	0.32	4.19	4.72	ok	ok
Total	70386.51		32674873.34	2461.42							

Calculation of Storey Drift

When earthquake in action along X-direction

Along X-direction							
column line	floor level	floor height (m)	node ID	Absolute Displacement (m)	Relative Displacement (m)	Permissible (m)	Remark
	11(Terrace)	2.8956	85	0.0455	0.001	0.0115824	ok
	10	3.2004	524	0.0445	0.0019	0.0128016	ok
	9	3.2004	482	0.0426	0.0028	0.0128016	ok
	8	3.2004	440	0.0398	0.0036	0.0128016	ok
	7	3.2004	398	0.0362	0.0043	0.0128016	ok
	6	3.2004	356	0.0319	0.0048	0.0128016	ok
	5	3.2004	314	0.0271	0.005	0.0128016	ok
	4	3.2004	272	0.0221	0.0053	0.0128016	ok
	3	3.2004	230	0.0168	0.0053	0.0128016	ok
	2	3.2004	188	0.0115	0.0052	0.0128016	ok
	1	3.2004	146	0.0063	0.0043	0.0128016	ok
	Ground	2.798	20	0.002	0.002	0.011192	ok
	Basement	0	62	0	0	0	ok

When earthquake in action along Y-direction

Along Y-direction							
column line	floor level	floor height (m)	node ID	Absolute Displacement (m)	Relative Displacement (m)	Permissible (m)	Remark
	11(Terrace)	2.8956	89	0.0436	0.0008	0.0115824	ok
	10	3.2004	521	0.0428	0.0016	0.0128016	ok
	9	3.2004	479	0.0412	0.0026	0.0128016	ok
	8	3.2004	437	0.0386	0.0033	0.0128016	ok
	7	3.2004	395	0.0353	0.0041	0.0128016	ok
	6	3.2004	353	0.0312	0.0045	0.0128016	ok
	5	3.2004	331	0.0267	0.0049	0.0128016	ok
	4	3.2004	269	0.0218	0.0052	0.0128016	ok
	3	3.2004	227	0.0166	0.0052	0.0128016	ok
	2	3.2004	185	0.0114	0.0051	0.0128016	ok
	1	3.2004	143	0.0063	0.0043	0.0128016	ok
	Ground	2.798	17	0.002	0.002	0.011192	ok
	Basement	0	59	0	0	0	ok

6. Design and Detailing

6.1 Design of Slab:

Slab are plate elements forming floors and roof of a building and carrying distributed load primarily by flexure. A slab may be supported by beams or wall and may be used as the flange of a T or L beam. Moreover, a slab may be simply supported or continuous over one or more supports and classified accordingly.

(a) One-way slab spanning in one direction – Length is more than twice the breadth.
(b) Two-way slab spanning on both direction
(c) Circular slabs
(d) Flat slabs (Resting directly on column)
(e) Grid floor and Ribbed slab

Slab are designed using same theories of beam i.e. theories of bending and shear. Following are the method that can be used for analysis of slab:

(a) Elastic analysis (Idealization on strip as Beam)
(b) Semi empirical coefficients (As given in Code)
(c) Yield line theory

Reinforcement provided is least in slab among three structural members: slab, beam and column. A slab can be distinguished from a beam as follows:

(a) Minimum span of slab should not be less than four times the overall depth and slab are much thinner than beam.
(b) Slab are analyzed and designed as having unit width i.e. 1 m
(c) Compressional reinforcement is used only in exceptional case
(d) Shear stress is very low in slab hence shear reinforcement is not provided. If needed, depth is increased rather than providing shear reinforcement.

The slab selected to show detailed design is a corridor slab with maximum live load intensity (i.e. 3 kN/m^2) and longest short span. Details of the slab and supporting beams are given below:

Depth of the beam = 500 mm

Width of the beam = 300 mm

Assumed overall depth of slab = 150 mm

Clear dimensions of the selected Slab panel: L_x = 4043.5 mm, L_y = 4500.7 mm

Loadings:

Dead Load (i.e. Self-weight of RCC) is taken as 25 kN/m^3 **(IS 875 Part 1)**

Live (or Imposed) Load that act on the slab is taken as per **IS 875 Part 2 Table 1**

Type of the Building: <u>Residential building</u>

<u>Dwelling houses</u>: These shall include any building or part occupied by members of single/ multi-family units with independent cooking facilities. These shall also include apartment houses (flats).

Live load:

All rooms and kitchen = 2 kN/m^2

Toilet and Bathrooms = 2 kN/m^2

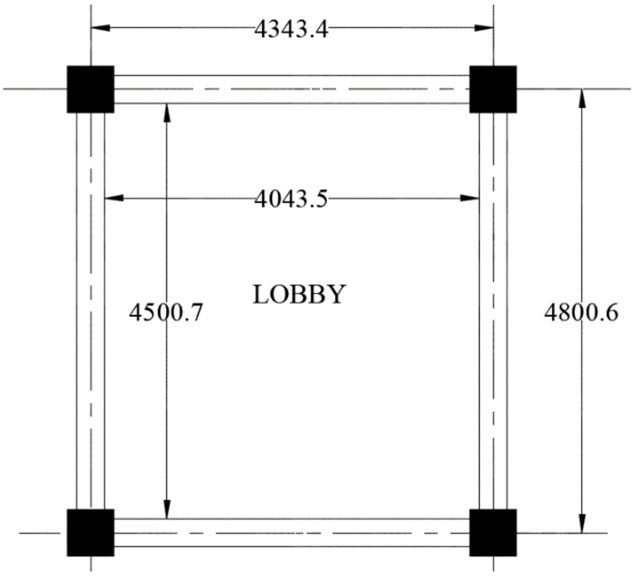
<u>Corridors, passages, staircase including fire escape and store rooms = 3 kN/m^2</u>

Balconies = 3 kN/m^2

Floor Finish = 1.5 kN/m^2

Self- Weight of the Slab = γ_{RCC}×b×D×1 = 25×1×0.15×1 = 3.75 kN/m

Step 1: Depth or Thickness Calculation



The thickness of slab is assumed from deflection control criteria for further design.

Provisions of beam mentioned in IS 456: 2000 Cl. 23.2 for beam apply to slab also. **(IS 456: 2000 Cl. 24.1)**

$\frac{Span}{d}$ = 26 (For continuous slab with span > 3.5 m)

Therefore, d = $\frac{Span}{26} = \frac{4043.5}{26}$ = 155.51mm

Also, For Earthquake resistant design D ≥ 125 mm (For rigid diaphragm action)

Let us assume overall Depth (D) = 150 mm, this will be verified for the deflection control criteria at the end.

Provided nominal cover 15 mm **(Table 16 IS 456:2000)**

Therefore, d = 150 – 15 – 8/2 = 131 mm

Step 2: Calculation of effective Span

Effective span of the slab is taken as maximum of C/C distance of the slab or clear span + effective depth of the slab for x- and y- direction separately.

C/C distance of slab in short span = 4.343 m

C/C distance in longer span = 4.800 m

In shorter span; Clear Span + Effective Thickness = 4.0435 + 0.131 = 4.1745m

In longer Span; Clear Span + Effective Thickness = 4.5007 + 0.131 = 4.6317m

So, take, l_x = 4.343 m and l_y = 4.800 m

Step 3: Calculation of Design moment

Total load intensity (w) = 3 + 1.5 + 3.75 = 8.25 kN/m^2

Total Factored load (w_f) = 1.5 × 8.25 = 12.375 kN/m^2

The slab is rigidly supported (monolithic casting of concrete) by beam on four sides.

The moment coefficients are taken from **Table 26 (IS 456:2000).**

It is the interior panel so case 1 is taken.

We have, $\frac{l_y}{l_x} = \frac{4.800}{4.343} = 1.105 < 2$ Hence, the slab is a two-way slab.

From table, we have

For $\frac{l_y}{l_x} = 1.10$, $\alpha^-_x = 0.037$; $\alpha^+_x = 0.028$ and $\alpha^-_y = 0.032$; $\alpha^+_y = 0.024$

And for $\frac{l_y}{l_x} = 1.20$, $\alpha^-_x = 0.043$; $\alpha^+_x = 0.032$ and $\alpha^-_y = 0.032$; $\alpha^+_y = 0.024$

By interpolating; $\alpha^-_x = 0.0373$; $\alpha^+_x = 0.0282$ and $\alpha^-_y = 0.032$; $\alpha^+_y = 0.024$

Now, along shorter span;

Maximum Negative Moment (M_x^-) = $\alpha_x^- \times w_f \times l_x^2 = 0.0373 \times 12.375 \times 4.343^2 = 8.706$ kN-m

Maximum Positive Moment (M_x^+) = $\alpha_x^+ \times w_f \times l_x^2 = 0.0282 \times 12.375 \times 4.343^2 = 6.582$ kN-m

Along longer Span;

Maximum Negative Moment (M_y^-) = $\alpha_y^- \times w_f \times l_x^2 = 0.032 \times 12.375 \times 4.343^2 = 7.469$ kN-m

Maximum Positive Moment (M_y^+) = $\alpha_y^+ \times w_f \times l_x^2 = 0.024 \times 12.375 \times 4.343^2 = 5.602$ kN-m

Step 4: Design of main reinforcement

a. Reinforcement in x-direction

d = 135 mm

From clause 38.1 of IS 456:2000, foe Fe500; $\frac{X_{u,max}}{d}$ = 0.46

$x_{u,max}$ = 0.46×135 = 62.1 mm

We have from **ANNEX 'G' (IS 456:2000):**

$M_{u,lim} = 0.36\times\frac{X_{u,max}}{d}\times\left(1 - 0.42 \times \frac{X_{u,max}}{d}\right) \times bd^2 \times f_{ck}$

Here, Grade of concrete (f_{ck}) = 25 N/mm^2

Therefore, $M_{u,lim}$ = 3.340×bd^2 = 3.340×1000×150^2 = 75.150 kN—m

Here, $M_{u,max.} < M_{u,lim}$, hence it is under reinforced section.

Again, from **ANNEX 'G':**

$M_u = 0.87\times f_y\times A_{st}\times d\times(1 - \frac{A_{st}}{bd} \times \frac{f_y}{f_{ck}})$ ————(1)

For x-direction, M_x = 8.706 kN—m

Substituting and solving equation (1)

A_{st} = 6598.34 mm^2 and 151.658 mm^2

Take $A_{st}^{Required}$ = 151.658 mm^2

The mild steel reinforcement in either direction in slabs shall not be less than 0.15% of the total cross sectional. However, this value can be reduced to 0.12% when high strength deform bars are used. **(IS 456:2000 Cl. 26.5.2.1)**

So, $A_{st}^{min.}$ = 0.12%×131×1000 = 157.2 mm^2 > $A_{st}^{Required}$

Use 8 mm Ø bars then,

Spacing with $A_{st}^{Min.} = \frac{\pi\times4^2}{180}\times1000$ = 279.253 mm < 300 mm

The horizontal maximum distance between parallel main reinforcement bar shall not be more than three times the effective depth or 300 mm whichever is smaller **(IS 456:2000 Cl. 26.3.3).**

Hence, provide spacing @ 250 mm C/C.

Therefore, $A_{st.}^{Provided} = \frac{\pi\times4^2}{250}\times1000$ = 201.062 mm^2

b. Reinforcement in y-direction:

Since the moment M_x^{-} = 8.706 kN—m is maximum among all the moments and minimum reinforcement is provided for the maximum moment, we provide minimum reinforcement in y-direction i.e. provide 8 mm Ø @ 250 mm C/C.

Check for Shear:

We have, $V_{ux} = \frac{w_u l_x}{3}$ = 17.915 kN and $V_{uy} = \frac{w l_x}{4}(2 - \frac{l_x}{l_y})$ = 12.022 kN

$\tau_v = V_u/bd$ = (17.915×1000) / (1000×135) = 0.133 N/mm^2

Percentage of steel $P_t = (A_{st,\ provided}/bD) \times 100$ = 0.134 %

From **Table 19 IS 456:2000** for P_t = 0.134% and M25 Concrete;

τ_c = 0.290 N/mm^2 (for ≤ 0.15%)

Again, from **Clause 40.2.1.1 of IS 456** for slab thickness = 150 mm; k = 1.30

Therefore, Permissible shear stress (τ'_c) = k× τ_c = 1.30×0.290 = 0.377 N/mm^2

Also from **Table 20 of IS 456**; $\tau_{c,\ max}$ = 3.1 N/mm^2 (for M25) i.e. $\tau_v < \tau_c' < \tau_{c,max}$, hence shear reinforcement is not required.

Check for Deflection Criteria

$\frac{l}{d} = \frac{4043.5}{131}$ = 30.637

$\alpha = 26$ (For Continious Slab; **IS456:2000 Cl. 23.2.1**)

$\beta = 1$ ($\beta = \frac{Span}{10}$ For span > 10m, 1 Otherwise)

$f_s = 0.58 \times f_y \times (A_{st}^{required}/A_{st}^{Provided})$ = 0.58×500 × (151.658/201.062) = 218.743

Hence for f_s = 218.773 and $\%A_{st}^{Provided}$ = 0.134% From **Fig. 4 IS456:2000;** $\gamma = 1.6$

$\delta = 1$ (From **Fig. 5 IS456:2000)**

$\lambda = 1$ (From **Fig. 6 IS456:2000)**

$\alpha\beta\gamma\delta\lambda$ = 26×1×1.6×1×1 = 41.6

Hence, $\frac{l}{d} \leq \alpha\beta\gamma\delta\lambda$ hence the design is safe in deflection control criterion. **OK**

Check for Development Length

The development length (L_d) is given by **(IS 456: 2000, Cl. 26.2)**;

$L_d = \frac{0.87 \times f_y \times Ø}{4 \times \tau_{bd}}$

Or, $L_d = \frac{0.87 \times 500 \times 8}{4 \times 1.6 \times 1.4} = 338.393$

Also from **IS456:2000 Cl. 26.2.3.3**

$L_d \leq \frac{1.3 \times M_l}{V_u} + l_0$

Here M_l = moment of resistant of the section assuming all the reinforcement at the section to be stressed to f_d.

$M_l = 0.87 \times f_y \times A_{st}^{Provided} \times d \times \left(1 - \frac{A_{st}^{Provided}}{bd} \times \frac{f_y}{f_{ck}}\right)$

$= 0.87 \times 500 \times 201.062 \times 135 \times \left(1 - \frac{201.062 \times 500}{1000 \times 135 \times 25}\right)$

Therefore, M_l = 11.456 kN-m

$\frac{1.3 \times M_l}{V_u} + l_0 = \frac{1.3 \times 11.456 \times 10^3}{17.915} + 8 \times 8$ = 831.303 mm > L_d **OK.**

Corner Reinforcement:

Area of each layer of reinforcement = 75% of area of the total reinforcement provided.

= 0.75×218.743 = 164.057 mm^2 (< A_{st}^{min} = 180 mm^2)

Hence, provide 8mm Ø bars @ 300mm C/C along both span in four layers in corner.

Design for another slab panel are shown in table below:

Design of Slab:

Slab ID	l_x	l_y	l_y/l_x	t (mm)	Live Load (LL)	Floor Finish (FF)	Self Wt. (DL)	Partition (PL)	Total Factored Load (w)	α_x (+ve)	α_y (+ve)	α_x (-ve)	α_y (-ve)	$M_x=\alpha_{x(+)}wl_x^2$	$M_y=\alpha_{y(+)}wl_x^2$	$M_x=\alpha_{x(-)}wl_x^2$	$M_y=\alpha_{y(-)}wl_x^2$	Required d (mm)	A_{st} (mm^2)	$A_{st,min}$ (mm^2)	Min. Spacing Required (mm)	Spacing Provided (mm)	$A_{st,Provided}$ (mm^2)
34CD	4.343	4.801	1.11	150	3	1.5	3.75	0	12.375	0.0282	0.024	0.0373	0.032	6.586	5.603	8.712	7.471	51.01	151.78	180	279.253	250	201.062
23BC	4.343	5.029	1.16	150	2	1.5	3.75	0	10.875	0.0303	0.024	0.0405	0.032	6.220	4.924	8.304	6.565	49.80	144.51	180	279.253	250	201.062
23AB	3.277	4.343	1.33	150	2	1.5	3.75	0	10.875	0.0448	0.028	0.0485	0.037	5.227	3.269	5.667	4.320	41.14	97.92	180	279.253	250	201.062
12AB	3.277	3.962	1.21	150	2	1.5	3.75	0	10.875	0.0454	0.035	0.0605	0.047	5.297	4.086	7.060	5.487	45.92	122.45	180	279.253	250	201.062
12BC	3.962	5.029	1.27	150	2	1.5	3.75	1	12.375	0.0425	0.028	0.0555	0.037	8.250	5.440	10.776	7.189	56.73	188.81	180	266.229	250	201.062
56AB	3.277	3.353	1.02	150	2	1.5	3.75	1	12.375	0.0292	0.028	0.0386	0.037	3.875	3.720	5.132	4.916	39.15	88.56	180	279.253	250	201.062

6.2 Design of Beams

Beams are structural members assigned to transmit the loads from slab to the column through it. Specially, flexure is more dominant than shear in the beam.

There are three types of reinforced concrete beams:

1. Singly reinforced beams
2. Doubly reinforced beams
3. Singly or doubly reinforced flanged beams

In singly reinforced simply supported beams, reinforcements are placed at the bottom of the beam whereas on top in case of cantilever beams.

A doubly reinforced concrete beam is reinforced in both compression and tension regions. The necessity of using steel in compression region arises when depth of the section is restricted due to functional or aesthetic requirements.

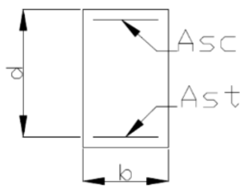
A complete design of beam involves consideration of safety under ultimate limit state in flexure, shear, torsion and bond as well as consideration of serviceability limit states of deflection, crack width, durability etc.

Basically, two types of works are performed namely, analysis of section and design of section.

In the analysis of a section, it is required to determine the moment of resistance knowing the cross section and reinforcement details.in the design of sections, it is required to determine the cross section and amount of reinforcement knowing the factored design loads.

Concrete Grade = M25

Steel Grade = Fe500



Detail Design of Beam
BEAM ID: 7BC, 1st floor beam

Reference	Step	Calculations	Remarks
	1	**Known Data:**	
		Characteristics Strength of Concrete(f_{ck})=25MPa	D=500mm
		Grade of Steel($f_{y)=}$ 500MPa	B=300mm
		Overall Depth of Beam, D=500mm	
		Width of Beam, B=300mm	d=465mm
		Keep nominal cover = 25 mm	
		Take 20 mm dia. bar	
		Effective depth, d=500-25-20/2mm=465mm	
IS13920:1993		Check for member size	
cl.6.1.3,		Width of beam, B=300mm > 200mm	
		Depth of beam, D=500mm	
cl.6.1.2		B/D = 300/500 = 0.6> 0.3	
		Hence, OK	
		Clear Length, L=5.0292m	
cl.6.1.4		L/D = 5.0292/0.5 = 10.058> 4 OK	
cl. 6.1.1		**Check of axial stress:**	
		Axial stress = $\frac{P}{A}$=$\frac{0}{0.3*0.5}$=0 < 0.1f_{ck} (2.5N/mm^2)	
		Hence, ok.	
		From SAP Analysis	
	2	Maximum –ve moment at left support = 210.4014KNm	
		Maximum +ve moment at left support = 120.7434KNm	
		Maximum –ve moment at mid span= 0	
		Maximum +ve moment at mid span = 51.090KNm	
		Maximum –ve moment at right support =219.1479KNm	
		Maximum +ve moment at right support =119.885KNm	
		Factored torsion (T) = 0.898KNm	

		Factored shear force at support =131.957KN	
IS13920:1993 cl.6.2.1b IS13920:1993 cl.6.2.2	**3**	**Check for Limiting Longitudinal Reinforcement** Min. Reinforcement $A_{stmin}= 0.24\frac{\sqrt{f_{ck}}}{f_y}*500*300 = 0.24\frac{\sqrt{25}}{500}*500*300$ $= 360mm^2$ Max. Reinforcement, $A_{st,max} = 0.025bD$ $= 0.025 \times 300 \times 500$ $= 3750mm^2$	A_{stmin}=360mm^2 $A_{st,max}$=3750mm^2
IS 456:2000 Cl. 41.4.2.	**4**	**Design for Flexure** $M_{ulim} = 0.1336f_{ck}\, bd^2$ $= 0.1336 * 25*300*465^2$ $= 216.65KN\text{-}m$ $M_t = T(\frac{1+\frac{D}{b}}{1.7}) = 0.898(\frac{1+500/300}{1.7}) = 1.408KNm$ Which is less than M_u available at each section of beam	M_{ulim}=216.65KN-m
(IS 456-2000 ANNEX G. G.1.1 b)		Beam ID:7BC (First floor) <u>At left end</u> For negative moment M_u= -210.4014x10^6 N-mm M_u<M_{ulim} i.e. singly reinforced section. We have, Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) Solving this we get, Area of top bar(Ast) = 1272.22mm^2 For Positive Moment M_u = 120.7434x10^6 N-mm M_u<M_{ulim} i.e. singly reinforced section. We have, Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) Solving this we get, Area of bottom bar(Ast) = 659.24mm^2	Singly Reinforced Section Singly Reinforced Section

		∴ Area of top bars = 1272.22mm^2	
		∴ Area of bottom bars = 659.24mm^2	
		Provide 5 nos. 20mm top bars.	
		Provide 3 nos. 20mm bottom bars.	
		<u>At 0.25L,</u>	
		For Negative Moment	
		M_u= -70.0306x10^6 N-mm	
		M_u<M_{ulim} i.e. singly reinforced section	Singly Reinforced Section
		We have,	
		Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck}))	
		Solving this we get,	
		Area of top bar = 365.35mm^2	
		∴ Area of top bar =365.35mm^2	
		For Positive Moment	
		M_u = 87.28x10^6 N-mm	
		M_u<M_{ulim} i.e. singly reinforced section	Singly Reinforced Section
		We have,	
		Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck}))	
		Solving this we get,	
		Area of bottom bar Ast = 462.11 mm^2	
		∴ Area of top bars = 365.35mm^2	
		∴ Area of bottom bars = 462.11 mm^2	
		Provide 2 no. 20mm top bars.	
		Provide 2 nos. 20mm bottom bars.	
		<u>At 0.50L,</u>	
		For Negative Moment	
		M_u=0 N-mm	
		For Positive Moment (+ve Moment)	
		M_u = 51.1x10^6 N-mm	Singly Reinforced Section
		M_u<M_{ulim} i.e. singly reinforced section.	
		We have,	Singly Reinforced Section
		Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck}))	

SP 16(table 55)		Solving this we get, Area of bottom bar Ast = 262.51 mm^2<Ast_{min} ∴ Area of top bars =Ast_{min} =360 mm^2 ∴ Area of bottom bars = 360 mm^2 Provide 2 nos. 20mm top bars. Provide 2 nos. 20mm bottom bars. <u>At 0.75L,</u> For Negative Moment M_u= -74.5749 x10^6 N-mm M_u<M_{ulim} i.e. singly reinforced section. We have, Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) Solving this we get, Area of top bar = 390.55mm^2 For Positive Moment(+ve Moment) M_u = 87.0155x10^6 N-mm^2 M_u<M_{ulim} i.e. singly reinforced section. We have, Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) Solving this we get Area of bottom bar = 460.6mm^2 ∴ Area of top bars = 390.55mm^2 ∴ Area of bottom bars = 460.6mm^2 Provide 2 nos. 20mm top bars. Provide 2 nos. 20mm bottom bars. <u>At right end,</u> For Negative Moment M_u=-219.1479x10^6 N-mm M_u>M_{ulim} i.e. doubly reinforced section. So, compression bar should be designed. For M_u/bd^2=3.38 and d'/d=0.075 P_t = 0.9575% (top) and P_c = 0.0145% (bottom) Area of top bar = $\frac{0.9575}{100} * 300 * 500$ = 1436.25 mm^2	Singly Reinforced Section Singly Reinforced Section Doubly Reinforced Section

		Area of bottom bar = $\frac{0.0145}{100} * 300 * 500$ =21.75 mm^2 For Positive Moment M_u = 119.885x10^6 N-mm M_u<M_{ulim} i.e. singly reinforced section. We have, Mu = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) Solving this we get Area of bottom bar = 654mm^2 ∴ Area of top bars = 1436.25 mm^2 ∴ Area of bottom bars = 654 mm^2 Provide 5 nos. 20mm top bars. Provide 3 nos. 20mm bottom bars.	Singly Reinforced Section
Cl. 23.2.1; IS 456 2000		**<u>Check for deflection:</u>** Effective length=5.0292+0.465=5.4942m d=0.465mm l/d=5.4942/0.465=11.82 α=26 ,β=1, γ= 0.65, δ=1.16, λ=1 αβγδλ = 19.604 >11.82 (ok)	
Cl 26.2.1; IS 456 2000		**<u>Check for development length:</u>** $L_d = \frac{0.87 f_y \emptyset}{4\tau_{bd}} = \frac{0.87x500x20}{4x1.4x1.6}$ =970.98mm M_l = 0.87*f_y*Ast*d*(1-(Ast*f_y/b*d*f_{ck})) = 0.87*500*1570.8*465*$(1 - \frac{1570.8*500}{300*465*25})$ = 246.17KNm $L_d = 1.3x\frac{Ml}{Vu} + Lo = 1.3x\frac{246.17x10^3}{131.957} + 325$ = 2425.51mm >970.98mm	

6.4.2 Main Beam (Shear)

Concrete Grade: M25

Reference	Steps	Calculation	Remarks
		Tensile Steel Provided at left end = 1.12%	
		For f_{ck}=25 MPa, τ_{cmax}=3.1 N/mm^2	
		Permissible shear stress of concrete	
IS 456:2000		τ_c =0.6688N/mm^2	
Table 19		Design shear strength of concrete	
		$\tau_c$bd = 0.6688x300x465/1000 = 93.2976KN	
		Tensile Steel Provided at mid span = 0.45%	
		Permissible shear strength of concrete	
IS 456:2000		τ_c = 0.464N/mm^2	
Table 19		Design shear strength of concrete	
		$\tau_c$bd = 0.464x300x465/1000 = 64.728KN	
		Tensile Steel Provided at right end = 1.12%	
		Permissible shear strength of concrete	
IS 456:2000		τ_c = 0.6688N/mm^2	
Table 19		Design shear strength of concrete	
		$\tau_c$bd = 0.6688x300x465/1000 =93.2976KN	
		Design shear force,	
		For left end,	
		➔Shear force from Plastic hinge analysis	
IS 13920:1993 Cl. 6.3.2		i) Sway to right:	
		$V_{u,a=}\ V_a^{D+L}-1.4\left[\frac{M_{u,lim}{}^{As}+M_{u,lim}{}^{Bh}}{L_{AB}}\right]$	
		$= -63.942-1.4\left[\frac{164.88+246.17}{5.0292}\right]$	
		= -178.36KN	
		ii) Sway to the left:	
		$V_{u,a=}\ V_a^{D+L}+1.4\left[\frac{M_{u,lim}{}^{Ah}+M_{u,lim}{}^{Bs}}{L_{AB}}\right]$	
		$=-\ 63.942+1.4\left[\frac{246.17+164.88}{5.0292}\right]$	
		=50.48 KN	
		➔Factored shear force from analysis	
		V_a=131.957KN	

IS 456:2000 Cl. 41.3.1		Torsion=0.898KNm Equivalent Shear =V_u+1.6 $\left[\frac{Tu}{b}\right]$ =131.957 +1.6*0.898/0.3 = 136.746KN Taking maximum absolute value of the three: **V_a= 178.36KN** **For right end,** ➔Shear force from Plastic hinge analysis i) Sway to right: $V_{u,b=}$ V_b^{D+L}+1.4$\left[\frac{M_{u,lim}{}^{As}+M_{u,lim}{}^{Bh}}{L_{AB}}\right]$ =66.185+1.4*$\left[\frac{164.88+246.17}{5.0292}\right]$ = 180.39KN ii) Sway to the left: $V_{u,b=}$ V_b^{D+L}-1.4$\left[\frac{M_{u,lim}{}^{Ah}+M_{u,lim}{}^{Bs}}{L_{AB}}\right]$ = -48.1KN ➔Factored shear force from analysis V_b=131.957KN Torsion=0.898KNm Equivalent Shear= V_u+1.6 $\left[\frac{Tu}{b}\right]$ =131.957+1.6*0.898/0.3 =136.74KN Taking maximum absolute value of the three: **V_b= 180.39KN** **For mid span, (Factored load from analysis)** V_u = 65.97 KN Torsion=0.898KNm Equivalent Shear =65.97+1.6*0.898/0.3 = 70.76KN Taking maximum absolute value We have,	

IS 456:2000 Cl. 40.4 IS 456:2000 Cl. 40.4 IS 13920:1993 Clause 6.3.5		$\mathbf{V_m}$ = 70.76KN **Spacing of stirrup** At left end V_u = 178.36KN τ_{uv} = 178.36 *1000/(300*465) = 1.28KN/mm^2 Here, $\tau_{uv} > \tau_{uc}$ $< \tau_{uc,max}$ Hence, design shear reinforcement. V_{us} = 178.36- 93.2976 = 85.1KN Assuming 2-legged 8 mm ϕ stirrups, A_{sv} =2x50.27 mm^2 =100.54mm^2 $S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$ = 238.97mm But, S_v should be $\leq$ d/4 and 8d_b. i.e $\leq$116.25mm and 160mm Hence, take Sv = 100mm **Provide 2L- 8 dia stirrups @ 100mm c/c**	
IS 456:2000 Cl. 40.4 IS 456:2000 Cl. 26.5.1.6		At right end V_u = 180.39KN τ_{uv} = 180.39*1000/(300*465) = 1.29KN/mm^2 Here, $\tau_{uv} > \tau_{uc}$ $< \tau_{uc,max}$ Hence, design shear reinforcement. V_{us} = 180.39 - 93.2976 = 87.1KN Assuming 2-legged 8 mm ϕ stirrups, A_{sv} =2x50.27 mm^2 $S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$ =233.48 mm	

		But, S_v should be ≤ d/4 and $8d_b$.	
		i.e ≤116.25mm and 160mm	
		Hence, take Sv = 100mm	
		Provide 2L- 8 dia stirrups @ 100mm c/c	
		At mid	
		V_u= 70.76KN	
		τ_{uv} = 70.76*1000/(300*465)	
		= 0.51KN/mm^2	
		Here, $\tau_{uv} > \tau_{uc}$	
		$< \tau_{uc,max}$	
		Hence, design shear reinforcement.	
		V_{us} = 70.76 - 64.728	
		=6.032KN	
IS		Assuming 2-legged 8 mm ϕ stirrups, A_{sv} =2x50.27	
13920:1993		mm^2	
Cl. 6.3.5		$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$ =3371.47mm>300mm	
		Hence, not ok.	
		Sv = least of 300mm, 0.75d (0.75*465 =348.75)	
		= 300mm	
SP 34		But, S_v should not be > d/2 i.e. 232.5mm	
		Hence, take Sv = 200mm	
		Provide 2L- 8 dia stirrups @ 200mm c/c	
IS 13920:1993 Clause 6.3.5		**Maximum Spacing of stirrup**	
		i. 0.75d = 348.75 mm	
		ii. 450mm	
		So ok	
		Spacing of hoop over a length of 2d	
		Least of	
		i. d/4 = 465/4 = 116.25mm	
		ii. 8X20 = 160 mm	

		But greater than 100 Length of hoop = 2X465 = 930 mm So, Provide 2L- 8 dia stirrups @ 100mm c/c to a length of 1m.	

6.3. Design of Column

Columns are vertical structural members which are predominantly subjected to axial forces. Columns support the beams and slabs and transfer the load to the foundation.

On the basis of whether slenderness effects are considered insignificant or not, the column may be classified as either a short column or a long column respectively. A short column generally fails by direct compression whereas a long column fails by buckling. Slenderness expressed in terms of the slenderness ratio, which is the ratio of the effective length to the least lateral dimension of the column.

Based on the nature of loading, columns may be classified as either axially loaded, uniaxially loaded or biaxially loaded columns. Axially loaded columns are under pure axial compression whereas uniaxially and biaxially loaded columns have eccentric loading in one or both directions respectively. Columns in framed structures under seismic loads are generally biaxially loaded and hence designed accordingly.

The following steps were followed in the design of columns.

Step 1: Preliminary Design

The preliminary sizing of the column members is carried out by using the tributary area method. The dead load and live load acting within the influence area of the column is calculated and factored by 1.5 and the size of column is determined by designing the column as an axially loaded column with a certain amount of longitudinal reinforcement (2%).

Factored Load $P_u = 1.5 \times P$

Ultimate axial load on a column is given by,

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

Or, $P_u = 0.4\ f_{ck}\ A\ (1\text{-}p/100) + 0.67\ f_y\ A\ (p/100)$

Where,
P_u = Ultimate load of the column
f_{ck}= Yield strength of concrete
A_c = Cross-sectional area of concrete in column
f_y = Yield strength of steel
A_s = Cross-sectional area of steel in column

The equation is solved for the sectional area A and the column dimensions are determined.

Step 2: Calculate effective length of column and check for long/short column.

The effective length of column is determined based on the end supports and the sway/no sway condition. Depending on the ratio of the effective length to the least lateral dimension of the column, the column is classified as either a short column or a long column. A column is long if the ratio of its effective length to its least lateral dimension is greater than 12.

Step 3: Check for eccentricity

In columns, eccentricity refers to the deviation of the point of application of axial load from the center of the column. Eccentric load causes the column to bend towards loaded point and hence generates a bending moment in the column.

I.S. 456-2000 says, the eccentricity which we have to consider for design must be taken as the greater of the following.

i) 20mm.

ii) (L_{eff}/500) + (b/30)

Where,

L_{eff} = Effective Length of the Column

b = Lateral Dimension of the Column (We have to calculate two separate values for two sides in case of rectangular column)

Permissible Eccentricity: 0.05b where b is the dimension of a side of a column, we have to check for two sides separately in case of rectangular column.

When the column is loaded with a bending moment a swell, its eccentricity effect must also be taken into consideration. Depending on the eccentricity, the column is classified as being under compression, uniaxial bending or biaxial bending.

Step 4: Design of longitudinal reinforcement

The amount of longitudinal reinforcement required is then determined as a percentage of the gross sectional area.

Step 5: Design of Lateral Ties

The diameter and spacing of lateral ties is then determined based on the design shear strength.

The diameter of the ties shall not be lesser than the greatest of the following two values

1. 5mm
2. 1/4th of the Diameter of the Largest Diameter Bar

The Spacing of Ties shall not exceed the least of the followings three values

1. Least Lateral Dimension
2. 16 Times of the Diameter of the Smallest Diameter Longitudinal Bar
3. 48 Times of the Diameter of Ties

Calculation of Stability Index

To determine whether a storey is in a sway or no sway condition, the stability index of each floor is determined as per IS 456:2000 clause E-2. The column is in a no sway condition only if the stability index is less than or equal to 0.04.

Along X-Direction									
Floor	Seismic Weight Wi	∑Pu=∑Wi	Height Hi	Absolute Displacement	Relative Displacement	Qi (KN)	Vi(KN)	Qsi	Remarks
11(Terrace)	991.674	991.674	2.8956	0.046	0.001	107.063	107.063	0.003	No Sway
10	5664.235	6655.909	3.2004	0.045	0.0019	521.188	628.251	0.006	No Sway
9	6417.166	13073.074	3.2004	0.043	0.0028	486.862	1115.114	0.010	No Sway
8	6417.166	19490.240	3.2004	0.040	0.0036	393.243	1508.357	0.015	No Sway
7	6417.166	25907.406	3.2004	0.036	0.0043	309.611	1817.968	0.019	No Sway
6	6417.166	32324.571	3.2004	0.032	0.0048	235.966	2053.934	0.024	No Sway
5	6417.166	38741.737	3.2004	0.027	0.005	172.307	2226.241	0.027	No Sway
4	6417.166	45158.903	3.2004	0.022	0.0053	118.636	2344.877	0.032	No Sway
3	6417.166	51576.068	3.2004	0.017	0.0053	74.951	2419.827	0.035	No Sway
2	6417.166	57993.234	3.2004	0.012	0.0052	41.253	2461.080	0.038	No Sway
1	6487.062	64480.296	3.2004	0.006	0.0043	17.732	2478.812	0.035	No Sway
Ground	6514.456	70994.752	2.798	0.002	0.002	3.875	2482.686	0.020	No Sway

Along Y-Direction									
Floor	Seismic Weight Wi	∑Pu=∑Wi	Floor Height	Absolute Displacement	Relative Displacement	Qi (KN)	Vi(KN)	Qsi	Remarks
11(Terrace)	991.674	991.67399	2.8956	0.0436	0.0008	107.063	107.063	0.00256	No Sway
10	5664.235	6655.9089	3.2004	0.0428	0.0016	521.188	628.251	0.0053	No Sway
9	6417.166	13073.074	3.2004	0.0412	0.0026	486.862	1115.11	0.00952	No Sway
8	6417.166	19490.24	3.2004	0.0386	0.0033	393.243	1508.36	0.01332	No Sway
7	6417.166	25907.406	3.2004	0.0353	0.0041	309.611	1817.97	0.01826	No Sway
6	6417.166	32324.571	3.2004	0.0312	0.0045	235.966	2053.93	0.02213	No Sway
5	6417.166	38741.737	3.2004	0.0267	0.0049	172.307	2226.24	0.02664	No Sway
4	6417.166	45158.903	3.2004	0.0218	0.0052	118.636	2344.88	0.03129	No Sway
3	6417.166	51576.068	3.2004	0.0166	0.0052	74.9506	2419.83	0.03463	No Sway
2	6417.166	57993.234	3.2004	0.0114	0.0051	41.2525	2461.08	0.03755	No Sway
1	6487.062	64480.296	3.2004	0.0063	0.0043	17.7322	2478.81	0.03495	No Sway
Ground	6514.456	70994.752	2.798	0.002	0.002	3.87452	2482.69	0.02044	No Sway

Since all the columns are no sway columns, the effective length can be taken as 0.65L where L is the unsupported height of the column.

Column D4

Floor: Basement

Ref.	Step	Calculation	Remarks
IS 456:2000 Table 28	1	**Known data** Strength of concrete (f_{ck})=25Mpa Grade of steel=Fe500 Preliminary Dimension of column=540mm×540mm Floor height=3.2004m Unsupported height of column, h=2.7004 Effective height of column h_{eff} =0.65h=0.65*2.7004=1.755m Design axial load, P_u=4055.019 kN Design moment M_{ux}=235.246 kNm M_{uy}=233.771 kNm	
	2	**Assumptions** Clear Cover = 40mm Longitudinal bar diameter = 28mm Lateral tie diameter = 8mm Effective cover d' = 40 + 28/2 + 8 = 62mm	
IS13920:1993 C1.7.1.1	**3**	**Check for Axial Stress** Axial Stress = $\frac{4055.019\times10^3}{540\times540} = 13.91\text{N/mm}^2$ 0.1 f_{ck} =2.5 N/mm^2	Axial Stress > 0.1 fck OK
IS13920:1993 C1.7.1.2 & Cl.7.1.3	**4**	**Member Size Check** D = 540mm > 300mm B/D = 540/540 = 1 > 0.4	
	5	**Slenderness Ratio Check** h_{eff}/D = 1.755 / 0.54 = 3.25 < 12	Column is Short
IS 456:2000 Cl. 26.1.2 & Cl. 26.5.3.1	**6**	**Limiting Longitudinal Reinforcement** Minimum Reinforcement = 0.8% of BD = 2332.8mm^2 Maximum Reinforcement = 4% of BD = 11664 mm^2	

IS SP-16 3.1	**7**	**Check for Eccentricity** Minimum Eccentricity e_{min} = h/500 + D/30 = 2700.4/500 + 540/30 = 23.4mm > 20mm Applied Eccentricity $e_x = \frac{M_{ux}}{P_u} = \frac{235.246 \times 10^6}{4055.019 \times 10^3} = 58.01\text{mm}$ $e_y = \frac{M_{uy}}{P_u} = \frac{233.771 \times 10^6}{4055.019 \times 10^3} = 57.65\text{mm}$ Hence, column is to be designed as a biaxially loaded short column.	$e_x > e_{min}$ $e_y > e_{min}$
IS 456:2000 Cl. 39.6	**8**	**Design of Longitudinal Bar** The reinforcement is to be distributed equally on all four sides. d'/D = 62/540 = 0.115 (Take 0.15) $\frac{P_u}{f_{ck}bD} = \frac{4055.019 \times 10^3}{25 \times 540 \times 540} = 0.556$ **Trial 1: p=2.5%** $\frac{p}{f_{ck}} = \frac{2.5}{25} = 0.1$ From Chart 49 of SP-16, $\frac{M_u}{f_{ck}bD^2} = 0.089$ $M_{ux,\,lim} = M_{uy,\,lim} = 0.089 \times 25 \times 540^3 \times 10^{-6} = 354.294$ kNm $P_{uz}=0.45\ f_{ck}\ A_c + 0.75\ f_y\ A_s$ $=0.45 \times 25 \times 540^2 \times 0.975 + 0.75 \times 500 \times 540^2 \times 0.025$ =5932.238 kN P_u/P_{uz}=4055.019 / 5932.238 = 0.684 $\propto_n = 0.667 + 1.667 * \frac{P_u}{P_{uz}} = 1.806$ $\left(\frac{M_{ux}}{M_{ux,l}}\right)^{\propto_n} + \left(\frac{M_{uy}}{M_{uy,l}}\right)^{\propto_n} = 0.968 < 1 \text{ OK}$ Therefore, Required longitudinal steel = 2.5% < 4% OK Area of steel required = 2.5/100 $\times 540^2$ = 7290 mm^2 Provide 12-28 Ø bars Provided area = 7389mm^2	

IS13920:1993 Cl. 7.3.4 IS 456:2000 Table 19 & 20 IS 456:2000 Cl. 40.2.2	**9**	**Design for Shear** Design Shear Force (V_{uv}) =119.901kN or 1.4(164.88+246.17)/3.2004=179.812kNm So, V_{uv}=179.812kNm Design Shear Stress (τ_{uv}) $= \frac{V_{uv}}{bd} = 0.617\ \mathrm{N/mm^2}$ Design shear strength of concrete, $\tau_c = 0.88\mathrm{N/mm^2}$ Max Shear strength of concrete, $\tau_{c,max} = 3.1\mathrm{N/mm^2}$ Considering P_u = 4055.019 kNm, For member subjected to axial compression Pu, the design shear strength of concrete (τ_c) shall be multiplied by the following factor: $\delta=1+3*P_u/(A_g*f_{ck})$ =2.669>1.5 or, δ=1.5 Design Shear Strength of concrete = $\delta \times \tau_c = 1.5\times0.88 = 1.32\ \mathrm{N/mm^2}$ Shear capacity of section, $V_{uc}= 1.32/1000\times540^2$ =384.912 kN As $V_{uc} > V_{uv}$, minimum shear reinforcement is to be provided in the form of lateral ties.	

IS 456:2000 Cl. 26.5.1.6 IS 456:2000 Cl. 26.5.3.2 c IS 456:2000 Cl. 26.5.3.2 b	**10**	**Design of lateral ties** Diameter of ties: $\varnothing_{tr} \geq 6\text{mm}$ $\varnothing_{tr} \geq 0.25 \times \text{Max. Longitudinal Bar Diameter} = 7\text{mm}$ Adopt 8 mm diameter tie bar. Spacing of tie bar: For minimum shear reinforcement: Considering 8 mm ϕ two legged lateral ties. $S_v \leq 2 \times \frac{0.87 f_y A_{sv}}{0.4b} = 2 \times \frac{0.87 \times 500 \times 50.26}{0.4 \times 540} = 202.436mm$ Where, $A_{sv} = \frac{\pi}{4} d^2 = 50.26 \text{ mm}^2$ Pitch is least of 1. 540 mm 2. 16*28=448 3. 300 mm Thus, provide 8 mm dia lateral ties @ 200 mm C/C. Spacing between longitudinal bars = (540 – 40*2 – 8*2 – 28/2)/3=143.33mm > 75mm Additional ties need to be provided.	
IS 13920:1993 Cl. 7.4.8	**11**	**Special Confining Reinforcement** Design of link near support: Area of cross-sectional of bar forming rectangular hoop to be used as confining links $A_{sh} = 0.18\, Sh\, \frac{f_{ck}}{f_y} \left[\frac{A_g}{A_k} - 1\right]$ Where, A_k= area of confined concrete core in the rectangular hoop measured to its outer dimension = $(540\text{-}80)^2$=211600 mm^2 h = 143.33mm $A_{sh} = \pi \times 8^2/4 = 50.26 \text{ mm}^2$ Then, $50.26 = 0.18 * S * 143.33 * \frac{25}{500}\left(\frac{291600}{211600} - 1\right)$	

IS 13920:1993 Cl. 7.4.6 IS 13920:1993 Cl. 7.4.1		S = 103.05mm>100mm Spacing of hoop should be less than 100mm and minimum of 1/4 of B or D whichever is less. But, the spacing need not be less than 75mm. Adopt 8 mm @ 100 mm as special confining ties at a distance Lo. Lo is given by larger of followings: a) Larger lateral dimension = 540mm b) 1/6 of clear span = 2700.4 /6 = 450.07mm c) 450mm Hence provide 8mm diameter links @ 100mm c/c for a distance 540 mm on either side from the joint and 8 mm diameter lateral ties @200mm c/c in central portion.	
IS 456:2000 Cl. 26.2.5.1 IS 456:2000 Cl. 26.2.1	**12**	**Splicing of Longitudinal Reinforcement** Maximum 50 % of the bars is to be spliced at one section. Splicing should be done in the middle half of the column height. Clear Length of Lap = Development Length or 24ϕ, whichever is greater. $L_d = \frac{0.87\ f_y \phi}{4\ \tau_{bd}} = \frac{0.87 \times 500 \times 28}{4 \times (1.4 \times 1.6 \times 1.25)} = 1088\text{mm} > 24\phi$	

Floor		Trial	Actual			Permissible		Minimum		Design		p%	$P_u/f_{ck}bD$	p/f_{ck}	$M_u/f_{ck}bD^2$	Mu	Puz	α_n	$\left(\frac{M_{ux}}{M_{ux,l}}\right)^{\alpha_n}+\left(\frac{M_{uy}}{M_{uy,l}}\right)^{\alpha_n}$	Result
			Mux	Muy	Pu	ex	ey	Mux	Muy	Mux	Muy									
Basement		1	235.246	233.771	4055.019	23.401	23.401	94.891	94.891	235.246	233.771	0.800	0.556	0.032	0.005	19.683	4129.056	2.000	283.902	NOT OK
b=	540	2	235.246	233.771	4055.019	23.401	23.401	94.891	94.891	235.246	233.771	1.000	0.556	0.040	0.016	62.986	4341.195	2.000	27.725	NOT OK
d=	540	3	235.246	233.771	4055.019	23.401	23.401	94.891	94.891	235.246	233.771	1.500	0.556	0.060	0.053	208.640	4871.543	2.000	2.527	NOT OK
		4	**235.246**	**233.771**	**4055.019**	**23.401**	**23.401**	**94.891**	**94.891**	**235.246**	**233.771**	**2.500**	**0.556**	**0.100**	**0.089**	**350.357**	**5932.238**	**1.806**	**0.968**	**OK**
Ground		1	223.355	208.704	3649.789	23.401	23.401	85.409	85.409	223.355	208.704	1.000	0.501	0.040	0.035	137.781	4341.195	2.000	4.922	NOT OK
b=	540	**2**	**223.355**	**208.704**	**3649.789**	**23.401**	**23.401**	**85.409**	**85.409**	**223.355**	**208.704**	**2.000**	**0.501**	**0.080**	**0.082**	**322.801**	**5401.890**	**1.793**	**0.974**	**OK**
d=	540																			
First		1	208.352	199.240	3280.716	22.067	22.067	72.396	72.396	208.352	199.240	1.000	0.525	0.040	0.027	84.375	3721.875	2.000	11.674	NOT OK
b=	500	2	208.352	199.240	3280.716	22.067	22.067	72.396	72.396	208.352	199.240	2.000	0.525	0.080	0.076	237.500	4631.250	1.848	1.508	NOT OK
d=	500	3	208.352	199.240	3280.716	22.067	22.067	72.396	72.396	208.352	199.240	2.100	0.525	0.084	0.08	250.000	4722.188	1.825	1.378	NOT OK
		4	**208.352**	**199.240**	**3280.716**	**22.067**	**22.067**	**72.396**	**72.396**	**208.352**	**199.240**	**2.500**	**0.525**	**0.100**	**0.098**	**306.250**	**5085.938**	**1.742**	**0.984**	**OK**
Second		1	210.539	199.969	2920.029	22.067	22.067	64.436	64.436	210.539	199.969	0.800	0.467	0.032	0.042	131.250	3540.000	2.000	4.894	NOT OK
b=	500	2	210.539	199.969	2920.029	22.067	22.067	64.436	64.436	210.539	199.969	1.500	0.467	0.060	0.069	215.625	4176.563	1.832	1.828	NOT OK
d=	500	3	210.539	199.969	2920.029	22.067	22.067	64.436	64.436	210.539	199.969	2.000	0.467	0.080	0.089	278.125	4631.250	1.718	1.187	NOT OK
		4	210.539	199.969	2920.029	22.067	22.067	64.436	64.436	210.539	199.969	2.300	0.467	0.092	0.1	312.500	4904.063	1.660	0.996	OK
Third		1	210.021	201.988	2533.312	22.067	22.067	55.903	55.903	210.021	201.988	0.800	0.405	0.032	0.055	171.875	3540.000	1.860	2.802	NOT OK
b=	500	2	210.021	201.988	2533.312	22.067	22.067	55.903	55.903	210.021	201.988	1.000	0.405	0.040	0.063	196.875	3721.875	1.802	2.171	NOT OK
d=	500	3	210.021	201.988	2533.312	22.067	22.067	55.903	55.903	210.021	201.988	1.500	0.405	0.060	0.082	256.250	4176.563	1.678	1.387	NOT OK
		4	**210.021**	**201.988**	**2533.312**	**22.067**	**22.067**	**55.903**	**55.903**	**210.021**	**201.988**	**2.100**	**0.405**	**0.084**	0.104	**325.000**	**4722.188**	**1.561**	**0.982**	**OK**
Fourth		1	205.632	198.421	2180.202	22.067	22.067	48.111	48.111	205.632	198.421	0.800	0.349	0.032	0.067	209.375	3540.000	1.694	1.883	NOT OK
b=	500	2	205.632	198.421	2180.202	22.067	22.067	48.111	48.111	205.632	198.421	1.000	0.349	0.040	0.074	231.250	3721.875	1.643	1.602	NOT OK
d=	500	3	205.632	198.421	2180.202	22.067	22.067	48.111	48.111	205.632	198.421	1.500	0.349	0.060	0.092	287.500	4176.563	1.537	1.163	NOT OK
		4	205.632	198.421	2180.202	22.067	22.067	48.111	48.111	205.632	198.421	2.000	0.349	0.080	0.11	343.750	4631.250	1.452	0.925	OK
Fifth		1	196.259	190.049	1830.430	22.067	22.067	40.392	40.392	196.259	190.049	0.800	0.293	0.032	0.075	234.375	3540.000	1.529	1.488	NOT OK
b=	500	2	196.259	190.049	1830.430	22.067	22.067	40.392	40.392	196.259	190.049	1.200	0.293	0.048	0.089	278.125	3903.750	1.449	1.179	NOT OK
d=	500	**3**	**196.259**	**190.049**	**1830.430**	**22.067**	**22.067**	**40.392**	**40.392**	**196.259**	**190.049**	**1.600**	**0.293**	**0.064**	0.104	**325.000**	**4267.500**	**1.382**	**0.974**	**OK**
Sixth		1	181.453	176.278	1483.710	22.067	22.067	32.741	32.741	181.453	176.278	0.800	0.237	0.032	0.081	253.125	3540.000	1.366	1.245	NOT OK
b=	500	2	181.453	176.278	1483.710	22.067	22.067	32.741	32.741	181.453	176.278	1.000	0.237	0.040	0.089	278.125	3721.875	1.332	1.111	NOT OK
d=	500	**3**	**181.453**	**176.278**	**1483.710**	**22.067**	**22.067**	**32.741**	**32.741**	**181.453**	**176.278**	**1.300**	**0.237**	**0.052**	**0.1**	**312.500**	**3994.688**	**1.286**	**0.976**	**OK**
Seventh		1	160.400	156.184	531.635	22.067	22.067	11.732	11.732	160.400	156.184	0.800	0.085	0.032	0.075	234.375	3540.000	0.917	1.395	NOT OK
b=	500	**2**	160.400	156.184	531.635	22.067	22.067	11.732	11.732	160.400	156.184	1.200	0.085	0.048	0.093	290.625	3903.750	0.894	1.162	NOT OK
d=	500	**3**	**160.400**	**156.184**	**531.635**	**22.067**	**22.067**	**11.732**	**11.732**	**160.400**	**156.184**	**1.700**	**0.085**	**0.068**	0.115	**359.375**	**4358.438**	**0.870**	**0.980**	**OK**
Eighth		1	133.269	129.862	355.967	22.067	22.067	7.855	7.855	133.269	129.862	0.800	0.057	0.032	0.069	215.625	3540.000	0.835	1.324	NOT OK
b=	500	2	133.269	129.862	355.967	22.067	22.067	7.855	7.855	133.269	129.862	1.200	0.057	0.048	0.088	275.000	3903.750	0.819	1.093	NOT OK
d=	500	**3**	**133.269**	**129.862**	**355.967**	**22.067**	**22.067**	**7.855**	**7.855**	**133.269**	**129.862**	**1.500**	**0.057**	**0.060**	**0.102**	**318.750**	**4176.563**	**0.809**	**0.977**	**OK**
Ninth		1	92.975	90.239	184.137	22.067	22.067	4.063	4.063	92.975	90.239	0.800	0.029	0.032	0.061	190.625	3540.000	0.754	1.151	NOT OK
b=	500	**2**	**92.975**	**90.239**	**184.137**	**22.067**	**22.067**	**4.063**	**4.063**	**92.975**	**90.239**	**1.100**	**0.029**	**0.044**	**0.077**	**240.625**	**3812.813**	**0.748**	**0.972**	**OK**
d=	500																			
Tenth		**1**	**55.266**	**87.641**	**51.485**	**22.067**	**22.067**	**1.136**	**1.136**	**55.266**	**87.641**	**0.800**	**0.008**	**0.032**	**0.063**	**196.875**	**3540.000**	**0.691**	**0.987**	**OK**
b=	500																			
d=	500																			

Floor	p	Column Area (mm^2)	Required Area (mm^2)	Longitudinal Reinforcement	Provided Area (mm^2)
Basement	2.5	291600	7290	12-28⌀	7389.026
Ground	2	291600	5832	12-28⌀	7389.026
First	2.5	250000	6250	6-28⌀ + 6-25⌀	6639.756
Second	2.3	250000	5750	12-25⌀	5890.486
Third	2.1	250000	5250	12-25⌀	5890.486
Fourth	2	250000	5000	12-25⌀	5890.486
Fifth	1.6	250000	4000	6-25⌀ + 6-20⌀	4830.199
Sixth	1.3	250000	3250	6-25⌀ + 6-20⌀	4830.199
Seventh	1.7	250000	4250	6-25⌀ + 6-20⌀	4830.199
Eighth	1.5	250000	3750	12-20⌀	3769.911
Ninth	1.1	250000	2750	12-20⌀	3769.911
Tenth	0.8	250000	2000	12-20⌀	3769.911

6.4. Design of staircase

The staircase is designed as a longitudinal staircase and modelled as a slab supported simply at the first riser and the end of landing.

Design parameters:

Storey height = 10’6” = 3.2004m

Riser = 6” = 0.1524m

Tread = 1’ = 0.3048m

Live load = 3kN/m^2

Specific weight of concrete = 25kN/m^3

Floor finish = 1.5kN/m^2

Lower flight:

Number of risers = 8

Number of treads = 7

Going length = 7*1’ = 7’ = 2.1336m

Landing length = 4’3” = 1.2954m

Total span = 7’ + 4’3” = 11’3” = 3.429m

Effective span = Total span + Bearing = 11’3” + 9”/2 = 11’7.5” = 11*12*2.54cm + 7.5*2.54cm = 354.33cm

Upper flight:

Number of risers = 7

Number of treads = 6

Going length = 6*1’ = 6’ = 1.8288m

Landing length = 4’3” = 1.2954m

Total span = 6’ + 4’3” = 10’3” = 3.1242m

Effective span = Total span + Bearing = 10’3” + 9”/2 = 10’7.5” = 10*12*2.54cm + 7.5*2.54cm = 323.85cm

Intermediate flight:

Number of risers = 7

Number of treads = 6

Going length = 6*1’ = 6’ = 1.8288m

Landing length = 4’3” = 1.2954m

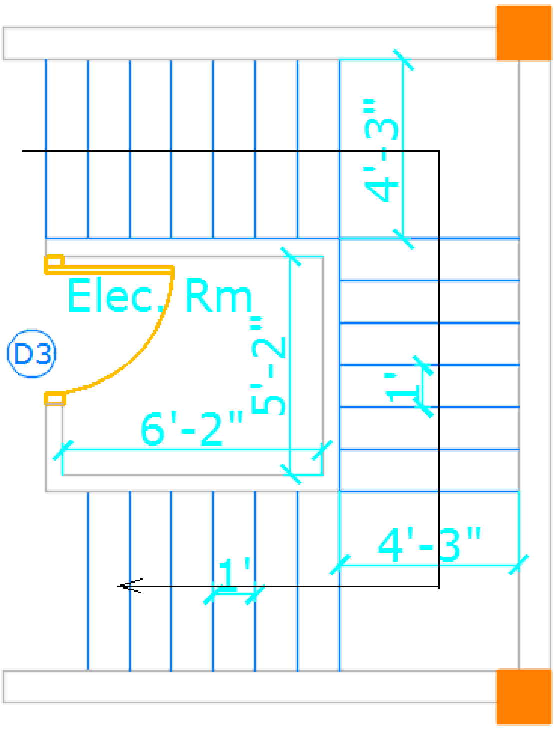
Total span = 6’ + 4’3” = 10’3” = 3.1242m

Effective span = Total span + Bearing = 10’3” + 9”/2 = 10’7.5” = 10*12*2.54cm + 7.5*2.54cm = 323.85cm

The flight with the greatest span is taken for design of all flights.

Thus, lower flight is analysed and designed.

Design of lower flight:



Given waist slab depth D = 150mm

Each step is treated as an equivalent rectangular section of $\frac{D_1}{2}$ depth and ‘b’ width defined as follows:

$$D_1 = b + \frac{TR}{b}$$

$$b = \sqrt{T^2 + R^2}$$

Here, Tread T = 1’ = 12” = 12*2.54cm = 30.48cm

And, Riser R = 6” = 6*2.54cm = 15.24cm

Thus, $b = \sqrt{30.48^2 + 15.24^2}$ = 34.08cm

And, $D_1 = 34.08 + \frac{30.48*15.24}{34.08}$ = 47.71cm

Now,

DL on landing

= Self-weight + Floor finish

= 25*0.15 + 1.5

= 5.75kN/m^2

So, *UDL due to DL on landing = 5.75kN/m^2 * 1.2954m = 7.45kN/m*

Then,

DL on going

= Self weight of waist slab + Self weight of steps + Floor finish

Here,

Self-weight of steps = (25*(0.4771/2*0.3408*(1.2954))) *8 kN = 21.06kN

Self-weight of waist slab = 25*0.15/cosθ*(1.2954)*Going = $\frac{25*0.15}{T/\sqrt{T^2+R^2}}$ * 1.295 * 7’ = 11.59kN

Floor finish = 1.5*(1.2954) *2.1336 kN = 4.15kN

Therefore,

Total DL on going = 21.06+11.59+4.15 = 39.17kN

So, *UDL due to DL on going = 39.17kN/2.1336 = 18.36kN/m*

Again,

LL = 3kN/m^2

UDL due to LL = 3*(1.2954) = 3.89kN/m

Finally,

UDL on landing = UDL due to DL + UDL due to LL = 7.45 + 3.89 = 11.34kN/m

UDL on going = UDL due to DL + UDL due to LL = 18.36 + 3.89 = 22.25kN/m

*Factored UDL on landing = 1.5*11.34 = 17.01kN/m*

*Factored UDL on going = 1.5*22.25 = 33.38kN/m*

Design table:

Ref	Calculations	Remarks
	Analysis: Assuming the flight to be simply supported on both ends and is loaded with a UDL, maximum moment is found at mid span as: $M_{max} = W_u l^2/8$ Here, W_u = Average UDL along the flight = (17.01*4'3"+33.38*7')/(4'3"+7') = 27.20kN/m Thus, M_{max} = 27.20*(3.5433)^2/8 ≅ 43kNm And, V_{max} = 27.2*(3.5433)/2 ≅ 48.2kN	
IS 456:2000 Annex G.1.1.b IS 456:2000 Clause 26.3.3.b.1	**Reinforcement:** Check if d > $d_{bal} = \sqrt{\frac{M_u}{Qb}}$ where, M_u = 43kNm Q = $0.36 f_{ck} x_{u,l}/d*(1-0.416*x_{u,l}/d)$ = 3.3477 for M25 and Fe500 b = 4'3" = 1.2954m Here, d_{bal} = 96mm Providing 20mm clear cover and 16mm bars, d = D – 20 – 16/2 = 150-20-8 = 122mm > d_{bal} Ok. Then, $A_{st} = \frac{M_u}{0.87 f_y (d-0.416 x_u)}$ and $x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$ Solving, A_{st} = 917.11mm^2 > $A_{st,min}$ = 0.12% of bD = 0.0012 * 1.2954 * 1000 * 150 = 233.17mm^2 Ok. Number of 8mm bars = 843.54/(π*16^2/4) = 19 Spacing (S) = b/5 = 1295.4/19 = 68mm say 60mm < Min(3d,300mm) = 300mm Ok. Provide 8mm dia. bars @ 60mm c/c throughout the width of waist slab	$d>d_{bal}$ Ok. 60mm<300mm Ok.

IS 456:2000 Clause 26.3.3.b.2	**Distribution bars:** Provide minimum reinforcement as distribution bars: $A_{st} = A_{st,min} = 233.17mm^2$ Adopting 8mm bars for distribution reinforcement, Number of bars = $233.17/(\pi*8^2/4) = 5$ Spacing (S) = b/5 = 1295.4/5 = 259mm say 220mm < Min(5d,450mm) = 450mm Ok. Provide 8mm dia. bars @ 220mm c/c throughout the span of waist slab	220mm<450mm Ok.
IS 456:2000 Table 19&20	**Check for shear:** Shear stress in waist slab $\tau_{uv} = V_{u,max}/bd$ = 48.2*1000/(122*1295.4) = 0.305N/mm² Allowable shear stress = k τ_{uc} , where k=1.3 for D=150mm For τ_{uc} , percentage reinforcement $\%p_t$ is required $\%p_t = 100A_s/bd$ = 100*917.11/(1295.4*122) = 0.5803% For M25 grade concrete, from Table 19 of IS456:2000, $\tau_{uc} = 0.515$ Since $\tau_{uv} = 0.305N/mm^2 < k\ \tau_{uc} = 1.3*0.515 = 0.670N/mm^2$, safe in shear.	For 150 mm slab, k=1.3
IS 456:2000 Clause 23.2	**Check for deflection:** Effective span(L)/Effective depth(d) ≤ $\alpha\beta\gamma\delta\lambda$ Where, Nominal span effective depth ratio (α) = 26 for continuous slab Length correction factor (β) = 1 for L ≤ 10m Tensile steel modification factor (γ) : For γ, fig. 4 of IS456:2000 requires f_s: $f_s = 0.58*f_y* {}_{Astrequired}/A_{st}^{provided} = 0.58*f_y*S^{provided}/S^{required}$ = 0.58*500*60/68 = 255.88 $\%p_t = 0.5803\%$ Then, from fig. 4, $\gamma \cong 1.2$ Compression steel modification factor (δ) = 1 assuming no compression steel Flange beam modification factor (λ) = 1 for rectangular slab section Thus, $\alpha\beta\gamma\delta\lambda$ = 26*1*1.2*1*1 = 31.2 L/d = (3543.3)/122mm = 29 Since L/d ≤ $\alpha\beta\gamma\delta\lambda$, serviceable in deflection.	L/d ≤ $\alpha\beta\gamma\delta\lambda$ Ok.

6.5. Design of basement wall

Basement wall is constructed to retain the earth and to prevent moisture from seeping into the building. Since the basement wall is supported by the mat foundation, the stability is ensured and the design of the basement wall is limited to the safe design of vertical stem.

Basement walls are exterior walls of underground structures (tunnels and other earth sheltered buildings), or retaining walls must resist lateral earth pressure as well as additional pressure due to other type of loading. Basement walls carry lateral earth pressure generally as vertical slabs supported by floor framing at the basement level and upper floor level. The axial forces in the floor structures are, in turn, either resisted by shear walls or balanced by the lateral earth pressure coming from the opposite side of the building.

Although basement walls act as vertical slabs supported by the horizontal floor framing , keep in mind that during the early construction stage when the upper floor has not yet been built the wall may have to be designed as a cantilever.

The basement wall is designed as the cantilever wall with the fixity provided by the mat foundation.

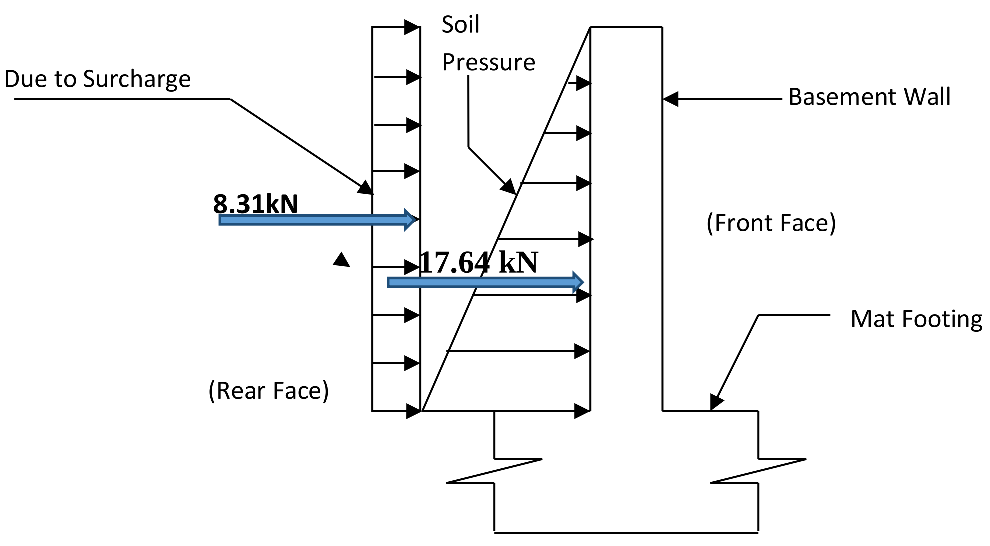


Fig: Basement Wall

Design of basement wall

Concrete Grade = M25 Steel Grade = Fe500

Ref.	Step	Calculation	Output
	1	**Design Constants** Clear height between the floor (h) =2.497 m unit weight of soil, γ = 17 KN/m^3 Angle of internal friction of the soil, $\theta = 30^0$ surcharge produced due to vehicular movement is Ws = 10 KN/m^2	
	2	**Moment calculation** $K_a = \frac{1-\sin\theta}{1+\sin\theta} = \frac{1-\sin 30}{1+\sin 30} = 0.333$ Lateral load due to soil pressure, Pa = Ka x γ x h^2/2 = 0.333x17x2.497^2/2 = 17.64 KN/m width of wall Lateral Load due to surcharge load, Ps = Ka x Ws x h = 0.333x10x2.497 = 8.31 KN/m width of wall Bending moment at the base of wall can be calculated as M_x= 17.64*2.497/3+8.31*2.497/2 =25.05KNm Factored moment(M_u) = 25.05*1.5= 37.58KNm	
IS456:2000 Cl.32.3 **IS456:2000 Cl.32.5.a**	3	**Design of section** Assume unit width of wall Balanced depth $d_{bal} = \sqrt{\frac{M}{Qb}}$ where, Q = $0.36 f_{ck} x_{u,l}/d*(1-0.416 x_{u,l}/d)$ For Fe500, $x_{u,l}/d = 0.46$ So, for M25 concrete Q = 3.347 $d = \sqrt{\frac{37.58 * 10^6}{3.347 * 1000}}$ d= 105.98mm Provide D= 200 mm with clear cover 30mm and 12mm dia. Bars. So, d=200-30-12/2=164mm Design of main reinforcement $A_{st} = \frac{M_u}{0.87 f_y (d-0.416 x_u)}$ and $x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$ where, b=1000mm and d=164mm	

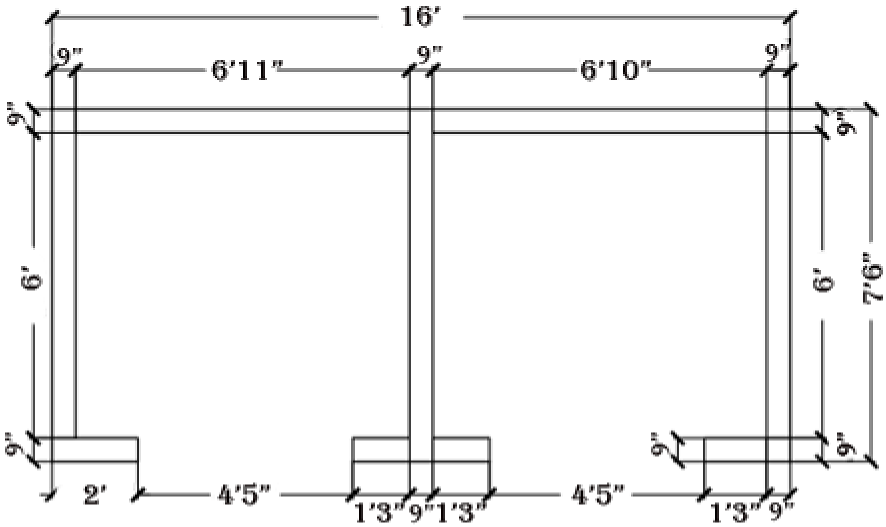
		On solving we get, A_{st}=565.81mm^2	**A_{st}> $A_{st,min}$**
IS456:2000 Cl.26.5.2.2	**4**	**Check for minimum reinforcement and max. diameter** $A_{st,min}$=0.0015*b*D =0.0015*1000*200=300mm^2 < 565.81 mm^2 Maximum diameter of bar =D/8=200/8 =25mm>12mm	
IS456:2000 Cl.32.5.b		A_b=π*12^2/4=113mm^2 Spacing of bar = 1000*113/565.81 = 172.04mm <3D or 450mm (600 or 450mm) Provide 12mm dia. bars @ 160mm c/c at earth face. Provided A_{st}=1000*113/160=706.25mm^2	
IS456:2000 Cl.32.5.1		Since thickness of wall is taken as 200 mm, horizontal and vertical reinforcement are necessary on each face of the wall. Provide 12mm dia. bars @ 300mm c/c at inner face.	
IS456:2000 Cl.32.5.c.2	**5**	**Calculation of horizontal reinforcement** Minimum reinforcement required=0.0025*D*h =0.0025*200*2497 =1248.50 mm^2 As the temperature change occurs at earth face of basement wall, 2/3 of horizontal reinforcement is provided at earth face and 1/3 of horizontal reinforcement is provided at inner face. Horizontal Reinforcement steel at inner face, =1/3*1248.50=416.17mm^2 Spacing of 12mm dia bar =1000*113/416.17=271mm Provide 12 mm dia bar @ 250mm c/c Horizontal Reinforcement steel at earth face, =2/3*1248.50=832.33mm^2 Spacing of 12 mm dia bar =1000*113/823.33=137mm Provide 12mm dia bar @ 120mm c/c	
	6	**Check for shear** Assuming the section will be critical the bottom of wall. Shear force at that section is $V_u=1.5(K_a*Ws*Z+K_a*Z^2*\gamma/2)$ =1.5(0.333*10*2.497+0.333*17*2.497^2/2) =38.94KN	

IS456:2000 Table-19 **IS456:2000 Cl.22.2.c** **IS456:2000 Cl.23.2.a** **IS456:2000 Cl.26.2.1.1** **IS456:2000 Cl.32.5.b**	**7** **8**	Nominal shear stress, τ_u =38.94*10^3/(1000*164) =0.2374N/mm^2 For P_t=100*706.25/(1000*164)=0.430% and M25 concrete, Permissible shear stress, τ_c= 0.48N/mm^2> 0.2374N/mm^2 Ok **Check for deflection** Effective height=2.497+0.164/2=2.579m Allowable deflection = 2.579/250=10.316mm Actual deflection=$\frac{P_{sur} h_e^4}{8EI} + \frac{P_{soil} h_e^4}{30EI}$ =$\frac{2579^4 * 12}{1000 * 200^3 * 5000\sqrt{25}}$(10/8+17*2.497/30)*0.333 2.355mm Ok **Curtailment of vertical reinforcement** Development length, L_d=$\frac{0.87 f_y \phi}{4\tau_{bd}}$ =(0.87*500* Φ)/(4*1.6*1.4) =48.6 Φ=48*16=777mm No bars can be curtailed in less than L_d distance from the bottom of stem. Taking one third height from base (1.66m from top) for the curtailment. Calculation of moment at curtailment point: Lateral load due to soil pressure, Pa = Ka x γ x h^2/2 = 0.333x17x1.66^2/2 = 7.80 KN/m Lateral Load due to surcharge load, Ps = Ka x Ws x h = 0.333x10x1.66 = 5.52 KN/m Characteristic Bending moment at the point of curtailment: M_x= 7.80*1.66/3+5.52*1.66/2 =8.89KNm Factored moment = 8.89*1.5= 13.35KNm Bending moment, M=0.87$f_y A_{st}$(d-$\frac{fyAst}{fckb}$) So, 13.35*10^6=0.87*500* A_{st} (164-500 A_{st}/25*1000) On solving we get, A_{st}=191.60mm^2< $A_{st,min}$=300mm^2 So provide minimum reinforcement	τ_c> τ_u ok τ_{bd}= 1.4 for M25

		Spacing of bar = 1000*113/300 = 377mm <3D or 450mm (450 or 450mm) Provide 12mm dia. Bars @ 350mm c/c at earth face above the point of curtailment.	

6.6. Design of shear wall (lift):

The term shear wall refers to a wall that opposes lateral wind or earthquake loads acting parallel to the plane of the wall in addition to the gravity loads from the floors and roof adjacent to the wall. However, in this project we have dealt the lift wall as the isolated structure of shear wall so that it only bears its own load. They are designed as per the procedure given in IS-456:2000 . According to IS-13920:1993 , clause 9.1.2 , the minimum thickness of the shear wall should be 150 mm. As per IS-456:2000 , clause 32.2.2 , the design of wall shall take account of the actual eccentricity of the vertical force subject to a minimum



value of 0.05t.

Design:
Total length of the wall = 192 + 90*3+15*4+9*2= 549 in. = 13.9446 m.
Floor height = 3.2004 m.
Wall thickness = 9 in. = 0.2286 m.

Check for slenderness ratio:

Eff. Height of wall, $h_e = 0.75H = 0.75*3.2004 = 2.4003m$
Slenderness ratio, $h_e/t = 2.4003/0.2286 = 10.50 < 30$ OK.
Min. eccentricity, $E_{min} = e = 0.05t$ **(Clause 32.2.2, IS 456:2000)**
$= 0.05*0.2286=0.01143m = 11.43mm$
Additional eccentricity $(e_a) = h_e^2/2500t$
$= 2.4003^2/ (2500*0.2286) = 0.010813m = 10.813$ mm.

Calculation of load:

1. Ground floor :
   Length = 13.9446 m
   Height =$\frac{2.798}{2} + \frac{3.2004}{2}$ = 2.9992m.
   Load = 25*13.9446*2.9992*0.2286 = **239.01** KN

2. Typical Floor :
   Length = 13.9446 m
   Height = $\frac{3.2004}{2} + \frac{3.2004}{2}$ = 3.2004 m
   Load = 25*13.9446*3.2004*0.2286 = **255.05** KN

3. Second last Floor:
   Length = 13.9446 m.
   Height = $\frac{3.2004}{2} + \frac{2.8956}{2}$ = 3.048m.
   Load = 25 * 13.9446 * 3.048 * 0.2286 = **242.90** KN

4. Top Floor :
   Length = 13.9446 m
   Height = $\frac{2.8956}{2}$ = 1.4478
   Load = 25*13.9446*1.4478*0.2286 = 115.3808 KN
   Roof load:
      Plan area = 192" * 90" = 4.8768 m * 2.286 m = 11.1483 m^2.
      Slab thickness = 150mm = 0.15m
      Slab load = 11.1483*0.15*25 = 41.80 KN.
   Total Top Floor Load = 115.3808 + 41.80 =**157.18 KN**

   Total load = 239.01+9*255.05+242.90+157.18 = **2934.54 KN**

Calculation of base shear:
Total seismic weight of lift (**W**) = **2934.54 KN**
Height, h = **37.698m**

Base shear, $V_b = A_h$*W **(Clause 7.5.3, IS 1893 (Part 1) : 2002)**
Where,
   A_h=design horizontal acceleration spectrum
   W=seismic weight as per **(Clause 7.4.2, IS 1893 (Part 1) : 2002)**

Now,

$$A_h = \frac{ZIS_a}{2Rg}$$ **(Clause 6.4.2, IS 1893 (Part 1) : 2002)**

Where,

Z=zone factor = 0.36 for Seismic Zone V **(Table 2, IS 1893 (Part 1) : 2002)**

I=importance factor = 1 **(Table 6, IS 1893 (Part 1) : 2002)**

R=response reduction factor=5 **(Table 7, IS 1893 (Part 1) : 2002)**

S_a/g=average response acceleration coefficient

Width of Shear wall:

D_Y = 4.8768 m.

D_X = 2.2860 m

Time Period (T_A) = $\frac{0.09h}{\sqrt{d}}$ **(Clause 7.6.2, IS 1893 (Part 1) : 2002)**

$T_{Ay} = \frac{0.09*37.698}{\sqrt{4.8768}}$

=1.53 sec.

$T_{Ax} = \frac{0.09*37.698}{\sqrt{2.2860}}$

= 2.24 sec.

For soil type of type II

For T_{Ay} =1.53 sec.

$(S_a/g)_Y = \frac{1.36}{1.53} = 0.88$

A_{hy}=0.36*1*0.88 / (2*5)

=0.031

Again, For T_{Ax} = 2.24 sec.

$(S_a/g)_X = \frac{1.36}{2.24}$ =0.607

A_{hx} =0.36*1*0.607 / (2*5)

=0.022

Now,

Base shear (V_{by}) = A_{hy}*W = 0.033*2934.54 = 90.97 KN

Base shear (V_{bx}) = A_{hx}*W = 0.022*2934.54 = 64.56 KN

Floors	Seismic Wt of Floors	Height	Cum Height	Wi*Hi*Hi	Wi*Hi*Hi/∑WiHiHi	Qix	Qiy	Shear Force in X direction	Shear Force in Y direction	Qix*Hi	Qiy*Hi	Moment (Mix)	Moment (Miy)
Basement	0	0	0	0	0	0	0	64.56	91.78081	0	0	1840.876	2594.384
Ground	358.515	2.9992	2.9992	3224.914	0.001443134	0.093169	0.13	64.56	91.78081	0.279432	0.389896	1647.28	2321.599
1	382.575	3.2004	6.1996	14704.29	0.006580099	0.424811	0.6	64.46683	91.65081	2.633659	3.71976	1440.996	2030.879
2	382.575	3.2004	9.4	33804.33	0.015127277	0.976617	1.38	64.04202	91.05081	9.1802	12.972	1236.071	1742.074
3	382.575	3.2004	12.6004	60741.46	0.027181519	1.754839	2.47	63.0654	89.67081	22.11167	31.12299	1034.272	1457.674
4	382.575	3.2004	15.8008	95515.69	0.042742824	2.759477	3.89	61.31056	87.20081	43.60194	61.46511	838.086	1181.187
5	382.575	3.2004	19.0012	138127	0.061811193	3.990531	5.62	58.55109	83.31081	75.82487	106.7867	650.7314	917.144
6	382.575	3.2004	22.2016	188575.4	0.084386624	5.448	7.68	54.56056	77.69081	120.9543	170.5083	476.1464	671.098
7	382.575	3.2004	25.402	246861	0.110469118	7.131886	10.05	49.11256	70.01081	181.1642	255.2901	318.9971	449.6195
8	382.575	3.2004	28.6024	312983.6	0.140058676	9.042188	12.74	41.98067	59.96081	258.6283	364.3946	184.6699	260.3031
9	382.575	3.2004	31.8028	386943.3	0.173155296	11.17891	15.75	32.93848	47.22081	355.5205	500.8941	79.28077	111.7634
10	364.35	3.048	34.8508	442531.6	0.198030806	12.78487	18.01	21.75958	31.47081	445.5629	627.6629	12.98677	18.3089
Roof	235.77	1.4478	36.2986	310647.8	0.139013434	8.974707	12.65	8.974707	13.46081	325.7693	459.1773	0	0
		36.2986		**2234660**		**64.56**	**90.97**			**1841.231**	**2594.384**		

The deign axial strength of a wall per unit length,
$P_{uw} = 0.3(t-1.2e-2e_a)f_{ck}$ **(Clause 32.2.5, IS 456 : 2000)**
Where, t= thickness of the wall
e = eccentricity
e_a= additional eccentricity due to slenderness effect taken as $H_{we}^2/2500t$.
P_{uw}=0.3(228.60-1.2*11.43-2*10.813)*25 = 1460.41 N/mm.

Calculation for main vertical reinforcement:
Assume clear cover 15 mm. and 12mm dia. bars.
When lateral load is acting along X - direction:
$M_u/3= \frac{1.5*1840.876}{3}$ = 920.438 KNm
$V_u/3= \frac{1.5*64.56}{3}$ = 32.28 KN
$P_u/3= \frac{1.5*2934.54}{3}$ = 1467.27 KN
$d'/D = \frac{(15+6)}{4876.80}$ = 0.0043. (Adopt 0.05)

$M_u/f_{ck}bd^2$ = 920.438*10^6/ (25*228.60*2286^2) = 0.0308
$P_u/f_{ck}bd$ = 1467.27*1000/ (25*2286*228.60) = 0.1123
Using chart 35 SP 16:
p/f_{ck} = 0.00
Check for minimum reinforcement:
$A_{st,\ min}$ = 0.0025 * bD = 0.0025*228.60*2286 = 1306.45 mm^2.
$A_b = \pi * 12^2/4$ = 113.0973 mm^2
Spacing of bars = 2286 * 113.0973 / 1306.45 = 197.89 mm.
Check for spacing of bar
Spacing≤ 3t or 450 mm whichever is less
=3*228.6 or 450mm
=685.8 or 450 **OK**
To take account of opposite phenomena, Provide 12 mm dia bar @ 180mm c/c on both sides.

When lateral force is acting along Y-direction
M_u= 1.5 * 2761.59 = 3891.576 KNm
V_u=1.5 * 96.381 = 136.455 KN
P_u= 1.5 * 2934.54 = 4401.81 KN
$d'/D = \frac{(15+6)}{2286}$ = 0.0091. Adopt 0.05.

$M_u/f_{ck}bd^2$ = 3891.576*10^6/ (25*228.60*4876.80^2) = 0.029
$P_u/f_{ck}bd$ = 4401.81*1000/ (25*4876.80*228.60) = 0.157
Using chart 35 SP 16:

$p/f_{ck} = 0$
$A_{st, min} = 0.0025*228.60*4876.80=2787.09mm^2$
$A_b = \pi*12^2/4 = 113.0973\ mm^2$
Spacing of bars = 4876.80*113.0973/2787.09= 197.89mm
Check for spacing of bar
Spacing≤ 3t or 450 mm whichever is less.
=3*228.6 or 450mm
=685.8 or 450 OK
To take account of opposite phenomena, Provide 12 mm dia bar @ 180mm c/c on both sides.

Calculation of Horizontal steel reinforcement:
Area of horizontal steel reinforcement = 0.25% bH = 0.0025*228.60*3200.4 = 1829.0286 mm^2.
Provide 12mm dia. bars.
$A_b = \pi *12^2/4 = 113.0973\ mm^2$.
Spacing of bars = 3200.4*113.0973/1829.0286 = 197.90 mm.
Provide 12mm dia. bars @180mm c/c on both face.

Check for shear:
Along Y- direction (long wall):
As per Clause 32.4.2, IS 456 : 2000
Nominal shear stress, $\tau_v = V_u/td$
Where, V_u = Shear force due to design loads.
t = wall thickness.
d = 0.8 * L_w where L_w is the length of the wall.
Here, $\tau_v = V_u/ (t*0.8*L_w) = 144.57*10^3/ (228.60*0.8*4876.80) =0.162\ N/mm^2$
Allowable shear stress, $\tau_a = 0.17f_{ck} = 0.17*25 = 4.25\ N/mm^2 > \tau_v$.
Design shear strength of concrete:
$H_w/L_w = 3200.4/4876.80 = 0.6563 < 1$.
$\tau_{cw}= (3.0-H_w/L_w)\ K_l \sqrt{f_{ck}} = (3.0-0.6563)*0.2*\sqrt{25} = 2.34\ N/mm^2 > \tau_v$.
Hence safe.
Along X- direction (short wall):
As per Clause 32.4.2, IS 456 : 2000
Nominal shear stress, $\tau_v = V_u/td$
Where, V_u = Shear force due to design loads.
t = wall thickness.
d = 0.8 * L_w where L_w is the length of the wall.

Here, $\tau_v = V_u/td = V_u/ (t*0.8*L_w) = 96.84*10^3/ (228.60*0.8*2286)$
$=0.2316\ N/mm^2$
Allowable shear stress, $\tau_a = 0.17f_{ck} = 0.17*25 = 4.25\ N/mm^2 > \tau_v$.
Design shear strength of concrete:

H_w/L_w = 3200.4/2286 = 1.4 > 1.

$\tau_{cw} = \frac{\frac{Hw}{Lw}+1}{\frac{Hw}{Lw}-1} K_2\sqrt{f_{ck}} = \frac{1.4+1}{1.4-1}*0.045*\sqrt{25} = 1.35\ N/mm^2 > \tau_v$.

Hence safe.

Summary:

Vertical reinforcement:

Provide 12 mm dia bar @ 180 mm c/c on both sides along X-direction.

Provide 12 mm dia bar @ 180 mm c/c on both sides along Y-direction.

Horizontal reinforcement:

Provide 12mm dia. bars @180 mm c/c on both face.

Anchorage Length:

$L_d + 10b_d = \frac{0.87*f_y*\Phi}{4\,\tau_{bd}} + 10*12 = \frac{0.87*500*12}{4*1.4*1.6} + 10*12 = 702.59mm.$

6.7. Design of Foundation:

Foundation are structural elements that transfer load from the building or individual column to the earth below. If these loads are to be transmitted properly, foundations should be designed to prevent excessive settlement and rotation, to minimize differential settlement and to provide adequate safety against sliding and overturning. Foundation can be classified as:

(1) Isolated footing under individual columns. These may be rectangular, square of circular in plan.
(2) Strip foundation or Wall foundation
(3) Combined footing supporting two or more column load.
(4) Mat or Raft foundation
(5) Plie Foundation
(6) Well Foundation.

Raft foundation is a sub structure supporting an arrangement of columns or walls in a row or rows and transmitting the load to the soil by means of a continuous slab with or without depressions or openings. Such types of foundations are found useful where soil has low bearing capacity.

Detail Designing of Raft Foundation:

Design Constants:

Unit weight of soil (γ) = 18 KN/m^3

Service Load (P) = 83615.406 kN

Service load includes the total axial forces of column, weight from lift wall, and load from basement walls.

Grade of Concrete = M25

Grade of steel = Fe500

Bearing Capacity (q) = 150 KN/m^2

Angle of Repose of soil (Ø) = 30^o

As per **IS 1893: 1 Cl 6.3.5.2** allowable bearing pressure in soil can be increased depending upon type of foundation thus bearing capacity of soil is increased by 50% assuming it will be Raft foundation.

Then, q = 1.5×150 = 225 kN/m^2 and applying factor of safety of 1.2, q = 187.5 kN/m^2

Depth of raft foundation shall generally be not less than 1m **(IS 2950 Part 1, Cl. 4.3)**

$D_f = \frac{q_u}{\gamma_s} \times \frac{(1-sin\emptyset)^2}{(1+sin\emptyset)^2} = \frac{187.5}{18} \times \frac{(1-sin30)^2}{(1+sin30)^2}$ = 1.157 m > 1 m **OK.**

However, the lower face of the designed footing will be placed at a level of 1m below which soil is free from seasonal volumetric change.

If above reaction from superstructure is taken as non-eccentric surcharge to the soil, area of foundation required for safe transmission of load is given by:

Area of foundation required = $\frac{\sum P + 10\%\ of\ \sum P}{q} = \frac{1.1 \times 83615.406}{187.5}\ m^2$ = 490.544 m^2

Plinth area of the building = 519.362 m^2

Hence, % Area of required footing = (490.544/519.362)×100 = 94.45 % > 50%

Consider the raft having same shape of the superstructures with 500 mm projection along the building periphery for critical shear section consideration.

∴ Area of Foundation provided = 566.021 m^2

Location of geometric C.G.: X = 11.258m, Y = 12.581m

Calculation of Eccentricity:

SN	Column ID	Force (kN)	X (m)	Y (m)	F×X	F×Y
1	A1	2587.649	0.770	0.770	1992.490	1992.490
2	B1	2935.903	4.047	0.770	11881.599	2260.645
3	C1	2781.536	9.076	0.770	25245.221	2141.783
4	D1	2806.515	13.419	0.770	37660.625	2161.017
5	E1	3105.647	18.448	0.770	57292.976	2391.348
6	F1	2587.336	21.725	0.770	56209.875	1992.249
7	A2	3199.08	0.770	4.732	2463.292	15138.047
8	B2	3499.012	4.047	4.732	14160.502	16557.325
9	C2	3203.346	9.076	4.732	29073.568	15158.233

SN	Column ID	Force (kN)	X (m)	Y (m)	F×X	F×Y
10	D2	3213.465	13.419	4.732	43121.487	15206.116
11	E2	3524.241	18.448	4.732	65015.198	16676.708
12	F2	3208.059	21.725	4.732	69695.082	15180.535
13	A3	3434.777	0.770	9.076	2644.778	31174.036
14	B3	3672.377	4.047	9.076	14862.110	33330.494
15	C3	3998.855	9.076	9.076	36293.608	36293.608
16	D3	4055.019	13.419	9.076	54414.300	36803.352
17	E3	3923.999	18.448	9.076	72389.934	35614.215
18	F3	3481.08	21.725	9.076	75626.463	31594.282
19	A4	3392.045	0.770	13.876	2611.875	47068.016
20	B4	3546.688	4.047	13.876	14353.446	49213.843
21	C4	3863.898	9.076	13.876	35068.738	53615.449
22	D4	3918.07	13.419	13.876	52576.581	54367.139
23	E4	3792.984	18.448	13.876	69972.969	52631.446
24	F4	3436.525	21.725	13.876	74658.506	47685.221
25	A5	3157.637	0.770	17.763	2431.380	56089.106
26	B5	3340.177	4.047	17.763	13517.696	59331.564
27	C5	3040.652	9.076	17.763	27596.958	54011.101
28	D5	3052.109	13.419	17.763	40956.251	54214.612
29	E5	3370.072	18.448	17.763	62171.088	59862.589
30	F5	3168.835	21.725	17.763	68842.940	56288.016
31	A6	2951.141	0.770	21.115	2272.379	62313.342
32	B6	3049.372	4.047	21.115	12340.808	64387.490
33	C6	2622.13	9.076	21.115	23798.452	55366.275
34	D6	2624.002	13.419	21.115	35211.483	55405.802
35	E6	3054.329	18.448	21.115	56346.261	64492.157
36	F6	2952.329	21.725	21.115	64139.348	62338.427
37	A7	2447.416	0.770	24.392	1884.510	59697.371
38	B7	2939.454	4.047	24.392	11895.970	71699.162
39	C7	2691.198	9.076	24.392	24425.313	65643.702
40	D7	2722.917	13.419	24.392	36538.823	66417.391
41	E7	3128.916	18.448	24.392	57722.242	76320.519
42	F7	2446.052	21.725	24.392	53140.480	59664.100
43	LIFT	2530.955	5.135	11.480	12996.454	29055.363
	SUM	136457.799			1514517.604	1719790.324

$\bar{X} = \frac{\sum F_i \times X_i}{\sum P}$ = 11.099 m

$\bar{Y} = \frac{\sum F_i \times Y_i}{\sum P}$ = 12.603 m

Load Centroid (X, Y) = (11.099m, 12.603m)

e_x = -0.159 m

e_y = 0.022 m

M_{ex} = 3014.755 kNm

M_{ey} = -21724.297 kNm

I_{xx} = $BD^3/12$ = 29863.467 m^4

I_{yy} = $DB^3/12$ = 23868.323 m^4

Soil pressure calculation for different points, i.e. the point through which the load of superstructure is transmitted to the foundation.

$$\sigma = \frac{\sum P}{A} \pm \frac{M_{yy}}{I_{yy}} \times X \pm \frac{M_{xx}}{I_{xx}} \times Y$$

Soil Pressure at different Points are as follows:

Col. ID	P/A (kN/m^2)	I_{xx} (m^4)	I_{yy} (m^4)	X (m)	Y (m)	M_{xx}×Y/I_x (kN/m^2)	M_{yy}×X/I_{yy} (kN/m^2)	SOIL PRESSURE (kN/m^2)
A1	147.725	29863.467	23868.323	-10.490	-11.81	-1.192	9.548	156.080
B1	147.725	29863.467	23868.323	-7.214	-11.81	-1.192	6.566	153.099
C1	147.725	29863.467	23868.323	-2.184	-11.81	-1.192	1.988	148.520
D1	147.725	29863.467	23868.323	2.184	-11.81	-1.192	-1.988	144.545
E1	147.725	29863.467	23868.323	7.200	-11.81	-1.192	-6.553	139.979
F1	147.725	29863.467	23868.323	10.476	-11.81	-1.192	-9.535	136.998
A2	147.725	29863.467	23868.323	-10.490	-7.849	-0.792	9.548	156.480
B2	147.725	29863.467	23868.323	-7.214	-7.849	-0.792	6.566	153.499
C2	147.725	29863.467	23868.323	-2.184	-7.849	-0.792	1.988	148.920
D2	147.725	29863.467	23868.323	2.184	-7.849	-0.792	-1.988	144.945
E2	147.725	29863.467	23868.323	7.200	-7.849	-0.792	-6.553	140.379
F2	147.725	29863.467	23868.323	10.476	-7.849	-0.792	-9.535	137.398
A3	147.725	29863.467	23868.323	-10.490	-3.505	-0.354	9.548	156.919
B3	147.725	29863.467	23868.323	-7.214	-3.505	-0.354	6.566	153.937
C3	147.725	29863.467	23868.323	-2.184	-3.505	-0.354	1.988	149.359
D3	147.725	29863.467	23868.323	2.184	-3.505	-0.354	-1.988	145.383
E3	147.725	29863.467	23868.323	7.200	-3.505	-0.354	-6.553	140.818
F3	147.725	29863.467	23868.323	10.476	-3.505	-0.354	-9.535	137.836
A4	147.725	29863.467	23868.323	-10.490	-1.296	-0.131	9.548	157.142
B4	147.725	29863.467	23868.323	-7.214	-1.296	-0.131	6.566	154.160
C4	147.725	29863.467	23868.323	-2.184	-1.296	-0.131	1.988	149.582
D4	147.725	29863.467	23868.323	2.184	-1.296	-0.131	-1.988	145.606
E4	147.725	29863.467	23868.323	7.200	-1.296	-0.131	-6.553	141.041

Col. ID	P/A (kN/m^2)	I_{xx} (m^4)	I_{yy} (m^4)	X (m)	Y (m)	$M_{xx}\times Y/I_x$ (kN/m^2)	$M_{yy}\times X/I_{yy}$ (kN/m^2)	SOIL PRESSURE (kN/m^2)
F4	147.725	29863.467	23868.323	10.476	-1.296	-0.131	-9.535	138.059
A5	147.725	29863.467	23868.323	-10.490	5.182	0.523	9.548	157.796
B5	147.725	29863.467	23868.323	-7.214	5.182	0.523	6.566	154.814
C5	147.725	29863.467	23868.323	-2.184	5.182	0.523	1.988	150.236
D5	147.725	29863.467	23868.323	2.184	5.182	0.523	-1.988	146.260
E5	147.725	29863.467	23868.323	7.200	5.182	0.523	-6.553	141.695
F5	147.725	29863.467	23868.323	10.476	5.182	0.523	-9.535	138.713
A6	147.725	29863.467	23868.323	-10.490	8.535	0.862	9.548	158.134
B6	147.725	29863.467	23868.323	-7.214	8.535	0.862	6.566	155.153
C6	147.725	29863.467	23868.323	-2.184	8.535	0.862	1.988	150.574
D6	147.725	29863.467	23868.323	2.184	8.535	0.862	-1.988	146.599
E6	147.725	29863.467	23868.323	7.200	8.535	0.862	-6.553	142.033
F6	147.725	29863.467	23868.323	10.476	8.535	0.862	-9.535	139.052
A7	147.725	29863.467	23868.323	-10.490	11.81	1.192	9.548	158.465
B7	147.725	29863.467	23868.323	-7.214	11.81	1.192	6.566	155.483
C7	147.725	29863.467	23868.323	-2.184	11.81	1.192	1.988	150.905
D7	147.725	29863.467	23868.323	2.184	11.81	1.192	-1.988	146.929
E7	147.725	29863.467	23868.323	7.200	11.81	1.192	-6.553	142.364
F7	147.725	29863.467	23868.323	10.476	11.81	1.192	-9.535	139.382
CO. 1	147.725	29863.467	23868.323	-11.227	-12.56	-1.268	10.219	156.675
CO. 2	147.725	29863.467	23868.323	-11.227	12.56	1.268	10.219	159.211
CO. 3	147.725	29863.467	23868.323	11.227	12.56	1.268	-10.219	138.774
CO. 4	147.725	29863.467	23868.323	11.227	-12.56	-1.268	-10.219	136.238
							MAX.	159.211

*CO. = CORNER

Hence maximum downward stress (159.211 kN/m^2) is less than safe bearing capacity (187.5 kN/m^2) so **OK.**

In X-direction raft is divided in seven strips that is into seven equivalent beam, the beam with the respective soil pressure and moment are as follows.

Bending moment is obtained by coefficient (1/12) and ‘L’ as centre to centre distance, from **IS 456 Cl. 22.5.1**

$+M = -M = wl^2/12$

Beams	Width (m)	Length (m)	Coefficient	Soil Pressure	Equivalent Soil Pressure	Max. Moment kNm/m per strip
1—1	2.751	5.029	1/12	153.099	153.099	322.693
2—2	4.153	5.029	1/12	153.499	153.299	323.114
3—3	4.572	5.029	1/12	153.937	153.718	323.997
4—4	4.326	5.029	1/12	154.160	154.049	324.695
5—5	3.620	5.029	1/12	154.814	154.487	325.618
6—6	3.315	5.029	1/12	155.153	154.984	326.666
7—7	2.408	5.029	1/12	155.483	155.318	327.370
					MAX.	327.370

In the Y-direction the raft is divided into six strips i.e. into six equivalent beams.

Beams	Width (m)	Length (m)	Coefficient	Soil Pressure	Equivalent Soil Pressure	Max. Moment kNm/m per strip
A—A	2.408	4.801	1/12	157.142	157.142	301.788
B—B	4.153	4.801	1/12	154.160	155.651	298.925
C—C	4.697	4.801	1/12	149.582	151.871	291.665
D—D	4.676	4.801	1/12	145.606	147.594	283.451
E—E	4.153	4.801	1/12	141.041	143.324	275.250
F—F	2.408	4.801	1/12	138.059	139.550	268.003
					MAX.	301.788

Therefore, maximum moment is 327.370 kNm/m per strip.

Calculation of Depth of Foundation:

i. **Calculation of Depth from Moment Criterion (IS 456 : 2000, ANNEX G 1.1):**

$$d = \sqrt{\frac{M_u}{Q \times b}}$$

Where, $Q = 0.36 \times f_{ck} \times \frac{x_{u,l}}{d} \times (1 - 0.416 \times \frac{x_{u,l}}{d})$

Here,

f_{ck} = 25 MPa

For Fe500 grade of steel, $\frac{x_{u,l}}{d} = 0.48$ **(IS 456: 2000, Cl. 38.1)**

$\therefore Q = 3.457$ and $M_u = 327.370\times10^6$ N-m

And d = 307.730 mm

ii. Calculation of Depth from Two Way Shear:

Depth of raft will govern by two-way shear at one of the exterior column. In case, location of critical shear is not obvious it may be necessary to check all locations. When shear reinforcement is not provided, the calculated shear stress at critical section shall not exceed $K_s\times\tau_c$. i.e. $\tau_v \leq K_s\times\tau_c$. **(IS 456 : 2000, Cl. 31.6.3.1)**

Where,

$K_s = (0.5 + \beta_c)$ but not greater than 1, β_c being the ration of short side to long side of the column/capital; and

$\tau_c = 0.25\sqrt{f_{ck}}$ in limit state method of design and $0.16\sqrt{f_{ck}}$ in working stress method of design.

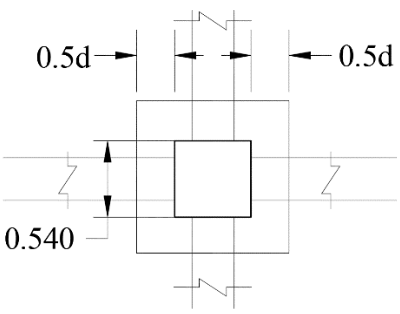
Here, $\beta_c = 1$

$K_s = 1+0.5 = 1.5 > 1$

Hence, $K_s = 1$

Shear strength of concrete (τ_c) = $0.25\times\sqrt{25}$ = 1.25 N/mm^2

For Column D3



Column Load = 2703.346 kN

Perimeter (p_o) = 4 (d + 540)

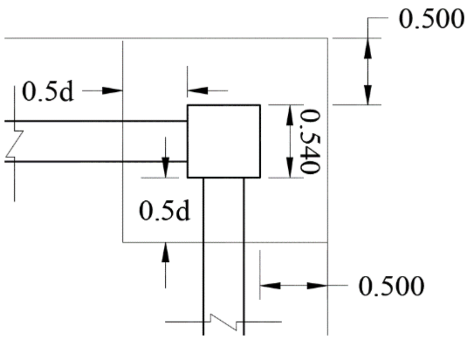
The nominal shear stress in flat slabs shall be taken as $V/(p_o \times d)$ where V is the shear force due to design, p_0 is the periphery of the critical section and d is the effective depth of the slab. **(IS 456 : 2000, Cl. 31.6.2.1)**

$$\tau_v = \frac{V_u}{p_o \times d} = \frac{2703.346 \times 10^3}{4(d + 540) \times d}$$

$$Or, 1.25 = \frac{2703.346 \times 10^3}{4(d + 540) \times d}$$

Hence d = 513.31 mm

For side column F7



Column Load = 1630.701 kN

Perimeter $p_o = 2\times(0.5d + 540 + 500) = 2\times(d + 2080)$

$$\tau_v = \frac{V_u}{p_o \times d} = \frac{1630.701 \times 10^3}{2(d + 2080) \times d}$$

$$Or, 1.25 = \frac{1630.701 \times 10^3}{2(d + 2080) \times d}$$

Hence d = 276.768 mm

Hence, Depth is governed by two-way shear.

Adopt effective Depth (d) = 600 mm

Diameter of steel used (Ø) = 28 mm

Adopt Clear cover of 50 mm **(IS456: 2000, Cl. 26.4.2.2)**

Overall Depth = 600 + (28/2) + 50 = 664 mm

<u>Adopt Overall Depth (D) = 700 mm</u>

<u>Effective depth adopted = 700 – 50 – (28/2) = 636 mm</u>

In shorter Direction

We have from **(IS 456 : 2000, Annex G 1.1)**

BM = $0.87 \times f_y \times A_{st} \times (d - \frac{f_y \times A_{st}}{f_{ck} \times b})$

Or, $301.788 \times 10^6 = 0.87 \times 500 \times A_{st} \times (636 - \frac{500 \times A_{st}}{25 \times 1000})$

Solving we get,

$A_{st} = 1131.055\ mm^2$

The mild steel reinforcement in either direction in slab shall not be less than 0.15% of the total cross-sectional area. However this value can be reduced to 0.12% when high strength deformed bar or welded wire fabric are used. **(IS 456 : 2000, Cl. 26.5.2.1)**

Minimum reinforcement in slab = 0.12%×1000×700 = 840mm^2

i.e. $A_{st}^{required} > A_{st}^{Min.}$ **OK.**

Using 16 mm Ø bars,

Spacing of Bar (S_v) = $\frac{A_b}{A_{st}} \times 1000 = \frac{201.062}{1131.055} \times 1000 = 177.765\ mm$

Hence, <u>Provide 16 mm Ø Bars @ 140 mm C/C in Shorter direction.</u>

Therefore, $A_{st}^{Provided}$ = (201.062/140)×1000 = 1436.157 mm^2

In Longer Direction:

Adopt effective depth = 700 – 50 – (28/2) – 16 = 620 mm

Reinforcement in longer direction is given by:

BM = $0.87 \times f_y \times A_{st} \times (d - \frac{f_y \times A_{st}}{f_{ck} \times b})$

Or, $327.370 \times 10^6 = 0.87 \times 500 \times A_{st} \times (620 - \frac{500 \times A_{st}}{25 \times 1000})$

Solving we get $A_{st} = 1265.491\ mm^2$

Minimum reinforcement in slab = 0.12%×700×1000 = 840 mm^2

i.e. $A_{st}^{required} > A_{st}^{Min.}$ **OK.**

Using 16 mm Ø bars,

Spacing of Bar (S_v) = $\frac{A_b}{A_{st}} \times 1000 = \frac{201.062}{1265.491} \times 1000 = 158.881\ mm$

Hence, Provide 16 mm Ø @ 140 mm C/C in Longer direction.

Therefore, $A_{st}^{Provided}$ = (201.062/140)×1000 = 1436.157 mm^2

Check for Development Length:

Bond Stress $(\tau_{bd}) = 1.4\ N/mm^2$, For M25 Concrete. This value can be increased by 60% for Tor Steel. **(IS 456 : 2000, Cl. 26.2.1.1)**

The development length (L_d) is given by **(IS 456 : 2000, Cl. 26.2.1)**

$$L_d = \frac{\emptyset \times \sigma_s}{4 \times \tau_{bd}} = \frac{\emptyset \times 0.87 \times 500}{4 \times 1.6 \times 1.4} = 48.548\emptyset$$

L_d = 48.54×16 = 776.640 mm

$L_d \leq\ 1.3 \times \frac{M_1}{V} + l_o$ **(IS 456 : 2000, Cl. 26.2.1)**

l_o = Effective depth or 12$\emptyset$, Whichever is greater.

$L_d \leq\ 1.3 \times \frac{330.479 \times 10^6}{2703.346 \times 1000} + 636 = 794.923\ mm$ **OK.**

Load Transfer from Column to footing:

Nominal bearing stress in column concrete (σ_{br}) = P_u/A_c

= (4055.019×1000)/(540×540) = 13.906 N/mm^2

Allowable bearing stress = 0.45×f_{ck} = 0.45×25 = 11.25 N/mm^2 **(IS 456: 2000, Cl. 34.4)**

When the permissible bearing stress on the concrete in the supporting or supported member would be exceeded, reinforcement shall be provided for developing the excess force by dowels. **(IS 456: 2000, Cl. 34.4.1)**

Dowel of at least 0.5% of the cross-sectional area of the supported column and a minimum of four bars shall be provided. Diameter of the Dowels shall not exceed the diameter of column bar by more than 3 mm. **(IS 456 : 2000, Cl. 34.4.1)**

Area of Dowels Bar = 0.5%×540×540 = 1458 mm^2

Provide 28 mm Ø as Dowel bar.

Development length for dowel bar = $\frac{\emptyset \times \sigma_s}{4 \times \tau_{bd}} = \frac{28 \times 0.87 \times 500}{4 \times 1.6 \times 1.4} = 1359.375\ mm$

Available vertical length for anchorage = 1450 – 50 – (28/2) -16 = 1370 mm > 1359.375 mm

Use 4 – 28 mm Ø Bars as Dowel Bar, then $A_s^{Provided}$ = 4×PI×14^2 = 24630.008 mm^2 > 1458 mm^2

7. DRAWINGS

8. Conclusion

The fact that Nepal lies in a hotspot for tectonic activities is a big factor to be accounted for in the design of any structure that aims to be safe, durable and serviceable. In this regard, the details of the structure we have designed for use as a residential apartment building, to the best of our team's knowledge, incorporate the required precautionary measures that allow it to overcome the perils that come with being situated in an earthquake prone zone along with the regular gravity loads that are expected in such a structure. Hence, we as the students of Civil Engineering hope that this project meets the expectations of our respected supervisor and the rest of our teachers to whom we owe the sum total of our knowledge in this subject.

9. References

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