# Analysis Of High Rise Building Including Earthquake and Wind Loads

PROJECT REPORT

Under The Supervision of

*Mr. Chandra Pal Gautam*

*DEPARTMENT OF CIVILENGINEERING*

*JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY-WAKNAGHAT*

Submitted By:

Ishant Kukreja – 101681

# Certificate

This is to certify that project report entitled "**ANALYSIS OF HIGH RISE BUILDING** ", submitted by **ISHANT KUKREJA** in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

**Date:** **Supervisor's Name**

**Designation**

# Acknowledgement

*I take this opportunity to express my profound gratitude and deep regards to my guide Mr Chandrapal Gautam for his exemplary guidance, monitoring and constant encouragement throughout the course of this thesis. The blessing, help and guidance given by him time to time shall carry me a long way in the journey of life on which I am about to embark.*

*I also take this opportunity to express a deep sense of gratitude to Dr Ashok Kumar Gupta, Head of Department of Civil Engineering, JUIT Waknaghat for his cordial support, valuable information and guidance, which helped me in completing this task through various stages.*

# ABSTRACT

*The field of Analysis of High Rise Building encompasses the analysis of high rise building subjected to seismic loads and wind loads and its design. Our project comprises of designing and analysing a high rise building. Designing of the high rise building consist of designing of beams, columns, foundation, slab on Microsoft Excel and Staad Pro. Our project also deals with designing the building by considering wind and earthquake loads.*

# CONTENTS:

# INTRODUCTION.

High-rise buildings were made practicable by the use of steel structural frames and glass exterior sheathing. By the mid-20th century, such buildings had become a standard feature of the architectural landscape in most countries in the world.

The foundations of high-rise buildings must sometimes support very heavy gravity loads, and they usually consist of concrete piers, piles, or caissons that are sunk into the ground. Beds of solid rock are the most desirable base, but ways have been found to distribute loads evenly even on relatively soft ground. The most important factor in the design of high-rise buildings, however, is the building's need to withstand the lateral forces imposed by winds and potential earthquakes. Most high-rises have frames made of steel or steel and concrete. Their frames are constructed of columns (vertical-support members) and beams (horizontal-support members). Cross-bracing or shear walls may be used to provide a structural frame with greater lateral rigidity in order to withstand wind stresses. Even more stable frames use closely spaced columns at the building's perimeter, or they use the bundled-tube system, in which a number of framing tubes are bundled together to form exceptionally rigid columns

.

High-rise buildings are enclosed by curtain walls; these are non-load-bearing sheets of glass, masonry, stone, or metal that are affixed to the building's frame through a series of vertical and horizontal members called mullions and muntins.

The principal means of vertical transport in a high-rise is the elevator. It is moved by an electric motor that raises or lowers the cab in a vertical shaft by means of wire ropes. Each elevator cab is also engaged by vertical guide tracks and has a flexible electric cable connected to it that provides power forlighting, door operation, and signal transmission.

Because of their height and their large occupant populations, high-rises require the careful provision of life-safety systems. Fire-prevention standards should be strict, and provisions for adequate means of egress in case of fire, power failure, or other accident should be provided. Although originally designed for commercial purposes, many high-rises are now planned for multiple uses. The combination of office, residential, retail, and hotel space is common.

# EXAMPLES:

**PETRONAS TOWER ,KUALALUMPUR,MALAYSIA.**

**TAIPEI,TAIWAN.**

**BURJKHALIFA,DUBAI,**

**EMPIRE STATE BUILDING,USA**

# LITERATURE REVIEW:

Before starting the project we did a thorough research on the properties of Concrete, Beams, Slabs, Columns and Footing. We also did a thorough study about the effect of Wind and Earthquake loads on the high rise structures.

- **PROPERTIES OF CONCRETE:**

Concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension (often steel). The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion and as it matures concrete shrinks. All concrete structures will crack to some extent, due to shrinkage and tension. Concrete which is subjected to long-duration forces is prone to creep.

## a.) ELASTICITY:

The modulus of elasticity of concrete is a function of the modulus of elasticity of the aggregates and the cement matrix and their relative proportions. The modulus of elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. The elastic modulus of the hardened paste may be in the order of 10-30 GPa and aggregates about 45 to 85 GPa. The concrete composite is then in the range of 30 to 50 GPa.

## b.)EXPANSION AND SHRINKAGE:

Concrete has a very low coefficient of thermal expansion. However, if no provision is made for expansion, very large forces can be created, causing cracks in parts of the structure not capable of withstanding the force or the repeated cycles of expansion and contraction. The coefficient of thermal expansion of Portland cement concrete is 0.000008 to 0.000012 (per degree Celsius) (8 to 12 microstrains/°C)(8-12 1/MK).[5]

As concrete matures it continues to shrink, due to the ongoing reaction taking place in the material, although the rate of shrinkage falls relatively quickly and keeps reducing over time (for all practical purposes concrete is usually considered to not shrink due to hydration any further after 30 years). The relative shrinkage and expansion of concrete and brickwork require careful accommodation when the two forms of construction interface.

Because concrete is continuously shrinking for years after it is initially placed, it is generally accepted that under thermal loading it will never expand to its originally placed volume.

Due to its low thermal conductivity, a layer of concrete is frequently used for fireproofing of steel structures.

## c.)CREEP:

Creep is the permanent movement or deformation of a material in order to relieve stresses within the material. Concrete that is subjected to long-duration forces is prone to creep. Short-duration forces (such as wind or earthquakes) do not cause creep. Creep can sometimes reduce the amount of cracking that occurs in a concrete structure or element, but it also must be controlled. The amount of primary and secondary reinforcing in concrete structures contributes to a reduction in the amount of shrinkage, creep and cracking.

- Density : *2240 - 2400 kg/m$^3$ (140 - 150 lb/ft$^3$)*
- Compressive strength : *20 - 40 MPa (3000 - 6000 psi)*
- Flexural strength : *3 - 5 MPa (400 - 700 psi)*
- Tensile strength : *2 - 5 MPa (300 - 700 psi)*
- Modulus of elasticity : *14000 - 41000 MPa (2 - 6 x $10^6$ psi)*
- Permeability : *1 x $10^{-10}$ cm/sec*
- Coefficient of thermal expansion : *$10^{-5}$ $^oC^{-1}$ (5.5 x $10^{-6}$ $^oF^{-1}$)*
- Drying shrinkage : *4 - 8 x $10^{-4}$*
- Drying shrinkage of reinforced concrete : *2 - 3 x $10^{-4}$*

- Poisson's ratio : *0.20 - 0.21*
- Shear strength : *6 - 17 MPa*
- Specific heat capacity : *0.75 kJ/kg K (0.18 Btu/lb$_m$ $^o$F (kcal/kg $^o$C)).*

## ➢ PROPERTIES AND OF STRUCTURAL ELEMENTS:

### 1.) BEAMS:

A **beam** is a structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment.

Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

Generally beam are five types: that is given below:

1.simply supported beam

2.fixed beam

3.over hanging beam

4. continuous beam

5.cantilever beam

Beams are characterized by their profile (the shape of their cross-section), their length, and their material. In contemporary construction, beams are typically made of steel, reinforced concrete, wood, composites, or cased fluids (inflatable beams). One of the most common types of steel beam is the I-beam or wide-flange beam (also known as a "universal beam" or, for stouter sections, a "universal column"). This is commonly used in steel-frame buildings and bridges.[citation needed] Other common beam profiles are the C-channel, the hollow structural section beam, the pipe, and the angle.

Beams are also described by how they are supported. Supports restrict lateral and/or rotational movements so as to satisfy stability conditions as well as to limit the deformations to a certain allowance. A *simple beam* is supported by a pin support at one end and a roller support at the other end. A beam with a laterally and rotationally fixed support at one end with no support at the other end is called a *cantilever beam*. A beam simply supported at two points and having one end or both ends extended beyond the supports is called an *overhanging beam*.

## 2.) SLABS:

A **concrete slab** is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 100 and 500 millimetres thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving. In many domestic and industrial buildings a thick concrete slab, supported on foundations or directly on the subsoil, is used to construct the ground floor of a building. These can either be "ground-bearing" or "suspended" slabs. In high rise buildings and skyscrapers, thinner, pre-cast concrete slabs are slung between the steel frames to form the floors and ceilings on each level.

## 3. COLUMNS:

The design of rectangular RCC column for axial load and uniaxial bending is carried out using Pu-Mu Interaction Diagrams using SP 16. For axial compression and biaxial bending the procedure is to use the above mentioned Interaction diagrams to calculate limiting uniaxial bending moment( Muxl and Muyl) about each axes separately for given Pu and to satisfy inequality equation of IS-456 i.e. (Mux / Muxl) a + (Muy / Muyl) a < 1.

2. Design of Columns using 'SP 16' :
In SP 16, Pu-Mu interaction charts are presented for steel grade Fe 250,

Fe 415 and Fe500 for
d’/D = 0.05, 0.1, 0.15 and 0.2 . The reinforcement arrangement is idealized as :

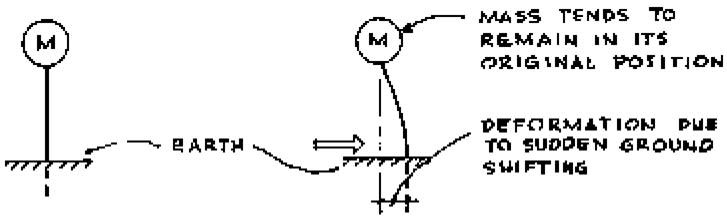
- 1. Reinforcement on two opposite faces : Chart No. 27 to 38
- 2. Reinforcement on all four faces equally distributed : Chart No. 39 to 50.

## ➢ EARTHQUAKE LOADS:

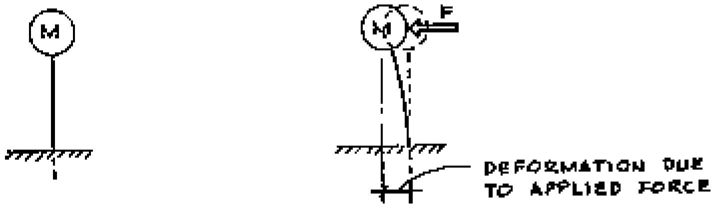
Earthquake loads are another lateral live load. They are very complex, uncertain, and potentially more damaging than wind loads. It is quite fortunate that they do not occur frequently. The earthquake creates ground movements that can be categorized as a "shake," "rattle," and a "roll." Every structure in an earthquake zone must be able to withstand all three of these loadings of different intensities. Although the ground under a structure may shift in any direction, only the horizontal components of this movement are usually considered critical in a structural analysis. It is assumed that a load-bearing structure which supports properly calculated design loads for vertical dead and live loads are adequate for the vertical component of the earthquake. The "static equivalent load" method is used to design most small and moderate-sized buildings.

The lateral load resisting systems for earthquake loads are similar to those for wind loads. Both are designed as if they are horizontally applied to the structural system. The wind load is considered to be more of a constant force while the earthquake load is almost instantaneous. The wind load is an external force, the magnitude of which depends upon the height of the building, the velocity of the wind and the amount of surface area that the wind "attacks." The magnitude earthquake load depends up the mass of the structure, the stiffness of the structural system and the acceleration of the surface of the earch. It can be seen that the application of these two types of loads is very different.

This movie is a representation of the movement of a free standing water tower in an earthquake. It can be seen that the as the ground moves, the initial tendency is for the water tower to remain in place. The shifting of the ground is so rapid that the tower cannot "keep up."




After a moment, the tower moves to catch up with the movement of the ground. The movement is actually an acceleration. From Newtonian Physics, it is know that an applied force=mass x acceleration. Thus, the force which is applied to the water tower depends upon the mass of the tower and the acceleration of the earth's surface.




The force in this last diagram may be thought of as the "equivalent static load" for which the structure would be designed. This idealized situation demonstrates a concept; it requires modification for actual buildings. These modifications account for building location, importance, soil type, and type of construction. This movement can also be seen in the following movie of lateral earth movement. Note how the mass slowly reacts to the movement of the earth. Eventually, the bending strength of the stem of the tower would be exceeded and it will fail

## ➢ **WIND LOADS:**

The most common lateral load is a wind load. The Eiffel Tower is one example of a building which has a structure that was designed to resist a high wind load. Wind against a building builds up a positive pressure on the windward side and a negative pressure (or suction) on the leeward side. Depending upon the shape of the structure it may also cause a negative pressure on the side walls or even the roof. The pressure on the walls and roof is not uniform, but varies across the surface. Winds can apply loads to structures from unexpected directions. Thus, a designer must be well aware of the dangers implied by this lateral load. The magnitude of the pressure that acts upon the surfaces is proportional to the square of the wind speed.

Wind loads vary around the world. Meteorological data collected by national weather services are one of the most reliable sources of wind data. Factors that effect the wind load include the geographic location, elevation, degree of exposure, relationship to nearby structures, building height and size, direction of prevailing winds, velocity of prevailing winds and positive or negative pressures due to architectural design features (atriums, entrances, or other openings). All of these factors are taken into account when the lateral loads on the facades are calculated. It is often necessary to examine more than one wind load case.

For this course, it will be assumed that wind loads, as well as the pressure they develop upon wall and roof elements, are static and uniform. They actually not only pound a structure with a constantly oscillating force, but also increase as a building increases in height. The loading of a tower can be very roughly approximated by an evenly distributed load. It is a vertical cantilever. The applet below allows you to investigate the variables which influence the structural behavior of a tall, thin tower. It does not represent actual methods of calculating the total wind force on a tall building. It is intended to demonstrate the interaction between the variables of the equations which govern the structural behavior.

# USAGE OF THIS TOPIC IN OUR CAREERS:

This topic which is design and analysis of high rise buildings helps in expanding our knowledge in the field of design and analysis. With incomes growing and large numbers of people moving to urban areas, the demand for housing is on the upswing. Due to high construction costs and non-availability of land at preferred locations, people opt for apartments. Today's upwardly mobile live and work in high-rise buildings with terraces and balconies overlooking the cityscape.

The Indian economy has opened up and brought new business opportunities that have changed urban dynamics. With growing incomes, priority for comfort and convenience, and an increasing demand for lifestyle homes, it's boom time for real estate folks. According to a Techno park study the Indian luxury market is about $ 444 million with a huge potential in the coming years. With this kind of money, there is more scope for high-rise apartments with all the amenities one could dream of.

Moreover, designing the high rise structure for wind and earthquake loads help us gaining thorough knowledge regarding these loads as consideration of these loads is a must while designing a high rise structure in a earthquake prone area.

Due to the above reasons we feel that gaining knowledge in the field of high rise buildings will be beneficial for us to grow as civil engineers and will only help in widening our knowledge in this fast growing field of civil engineering.

# WORK TILL DATE:

In our project so far we have completed the following objectives as follows:

**a.) <u>Reviewing papers on high rise buildings</u>:** We have gained substantial knowledge regarding the designing and analysis of high rise buildings by reviewing research papers by.

**b.) <u>Designed the layout of the building:</u>** We designed the layout and the elevation of our 20 storey high rise building on AUTOCAD by taking reference from various layout plans of various previous high rise buildings.

**<u>c.) Designing of structural elements:</u>**

We designed various structural elements such as:

i) We designed singly and doubly reinforced beam using limit state method.

ii) We designed uniaxial and biaxial columns using limit state method.

iii) We designed two way slab using Limit state method.

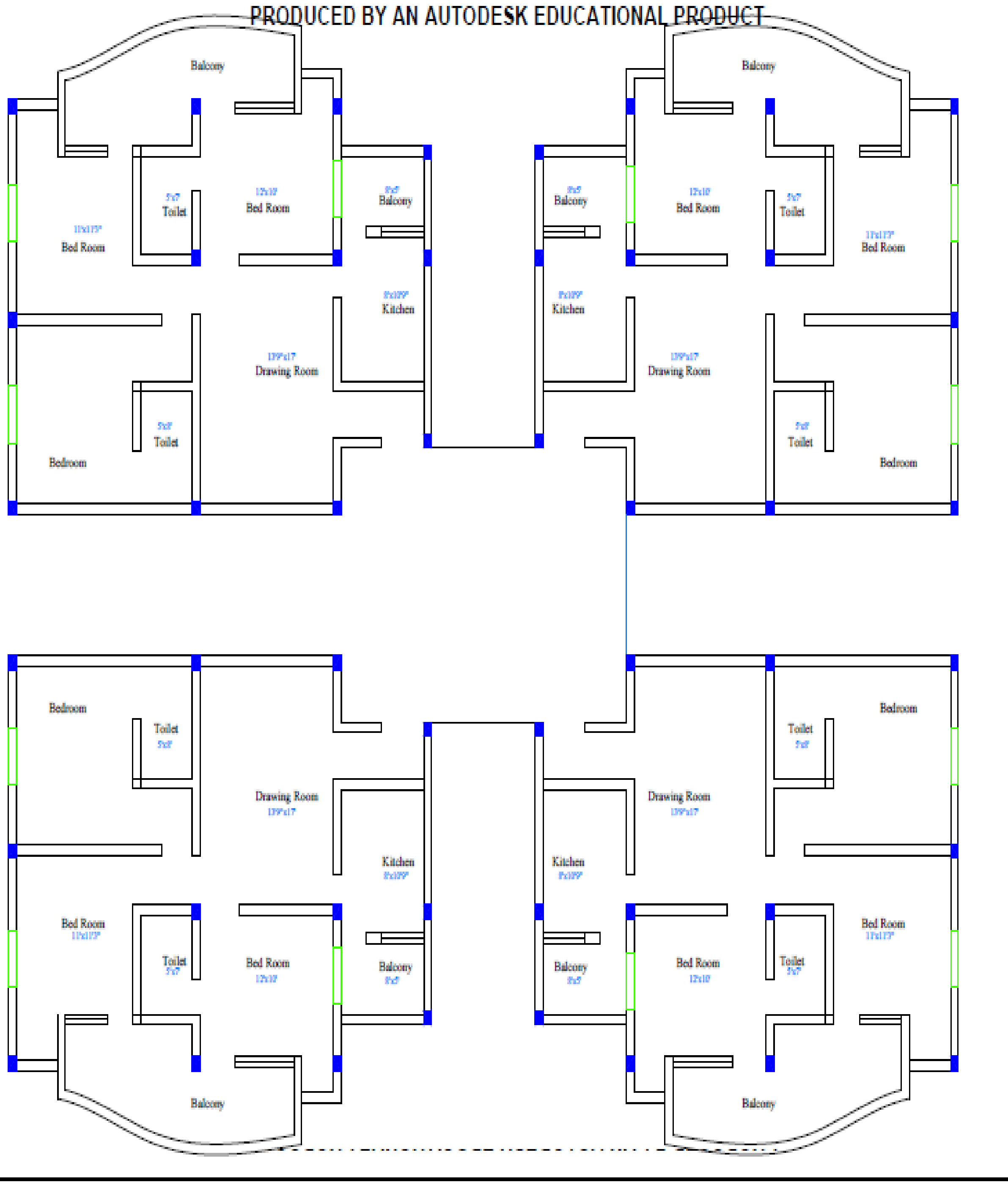
iv) We designed square footing .

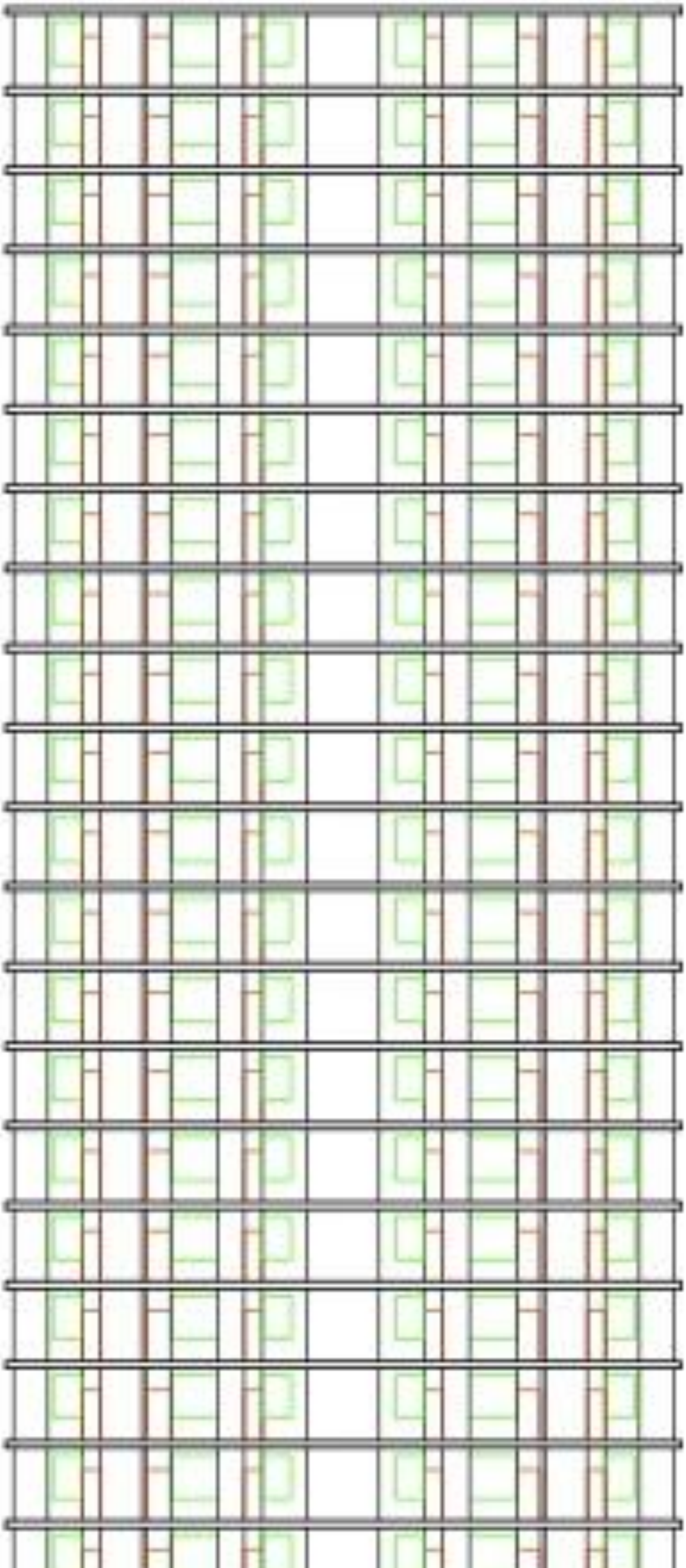
All of the above mentioned designing has been done using Microsoft Excel .

**<u>d.)Detailing of structural elements:</u>** After designing the structural elements we made detailing of each element Thoroughly by the values obtained on Microsoft Excel.

(note: We referred IS :875 and IS:456 for loads and RCC structures.)

# LAYOUT AND ELEVATION:





# DESIGN OF STRUCTURAL ELEMENTS:

## a.) Design of beams:

| | |
|---|---|
| SPAN(L ,m) | 6 |
| BREADTH(MM),b | 300 |
| DEPTH(MM),D | 500 |
| COVER(MM) | 40 |
| EFFECTIVE DEPTH (MM).d | 460 |
| Fck(mpa) | 20 |
| Fy(mpa) | 415 |
| DEAD LOAD(KN/m) | 3.75 |
| LIVE LOAD(KN/m2) | 2 |
| TOTAL LOAD | 5.75 |
| FACTORED LOAD | 8.625 |
| MAX.BENDING MOMENT,Mu(KNm) | 38.8125 |
| | |
| RESISTING MOMENT,Mr(KNm) | 175.2048 |
| FACTORED MOMENT,Mu(KNm) | 300 |
| | |
| | Mu>Mr therefore design the beam as doubly r/f beam. |
| Mu1=Mr | |
| | |
| Xulim(mm) | 220.8 |
| Ast1 | 1319.127751 |
| | |
| | |
| d'(mm) | 40 |
| Mu2(KNm) | 124.7952 |
| | |
| From fig 2 Esc = 0.0028 | |
| | |
| Fsc from fig 1(graph)= 0.85Fy | |
| Fsc | 352.75 |
| | |

## b.)DESIGN OF SLABS:

# Loads on slab

| | | |
|---|---|---|
| Density of Concrete | 25 | KN/m3 |
| Live load | 2 | |
| R | 3.45 | |
| fy | 415 | |
| fck | 25 | |

)

| Resistance Factor(lim) | | | |
|---|---|---|---|
| fck | fy=250 | fy=415 | fy=500 |
| 20 | 2.98 | 3.76 | 2.66 |
| 25 | 3.73 | 3.45 | 3.33 |
| 30 | 4.47 | 4.14 | 3.99 |

# DESIGN OF TWO-WAY SLAB

| | | | | | | |
|---|---|---|---|---|---|---|
| Ly | 6000 | mm | | | | |
| Lx | 4000 | mm | | | | |
| Shorter Span to Depth Ratio(Cl 24.1 note 2) | 30 | | | | | |
| Depth | 140 | mm | | | | |
| Effective Cover(Cl 26.4.2, Table 16) | 20 | mm | | | | |
| Total depth (D) | 160 | | | | | |
| **Factored loads** | | | | | | |
| Dead Load of Slab | 4 | kn/m | | | | |
| Load of floor finish | 1 | kn/m | | | | |
| Live Load | 5 | kn/m | | | | |
| Total load | 10 | kn/m | | | | |
| **Factored Load** | **15** | kn/m | | | | |
| **MAXIMUM Bending Moments** | | | | | | |
| | | **Short Span** | | **Long Span** | | |
| | coeff | Moment(kn-m) | coeff | Moment(kn-m) | | |
| Negative Moment At continuous edge(Annex D, D-2.1) | 0.075 | 18 | 0.047 | 11.28 | | |
| Positive Moment At continuous edge(Annex D, D-2.1) | 0.056 | 13.44 | 0.035 | 13.44 | | |
| MAXIMUM Positive Bending Moment | 13.44 | | | | | |
| MAXIMMUM Negative bending Moment | 18 | | | | | |
| **MAXIMUM Bending Moments** | **18** | | | | | |
| Check for depth | 72.23151 | mm | OK | | | |
| **Check for Shear Force** | | | | | | |

| | positive | negative |
|---|---|---|
| a | 0.000119 | 0.000119 |
| b | -1 | -1 |
| c | 265.8912 | 356.1042 |
| | | |
| x+ | 8158.887 | 8061.173 |
| x- | 274.8482 | 372.5622 |

## Check for Shear Force

| | | | |
|---|---|---|---|
| Shear Force | 30 | kn | |
| τv(Cl. 40.1) | 0.214286 | kn/mm2 | |
| τc(Table 19) | 0.364 | kn/mm2 | OK |
| **Positive Steel Area(Annex G, G-1.1(b))** | **274.8482** | **mm2** | OK |
| **Negative Steel Area** | **372.5622** | **mm2** | OK |
| Minimum Reinforcement Required | 192 | mm2 | |

## TORSION

| | | |
|---|---|---|
| Distance from the centre of support upto which torsion | 800 | mm |
| Ast of Torsional Steel | 206.1362 | mm2 |

| | | |
|---|---|---|
| Density of Concrete | 25 | KN/m3 |
| Live load | 2 | |
| R | 3.45 | |
| fy | 415 | |
| fck | 25 | |

)

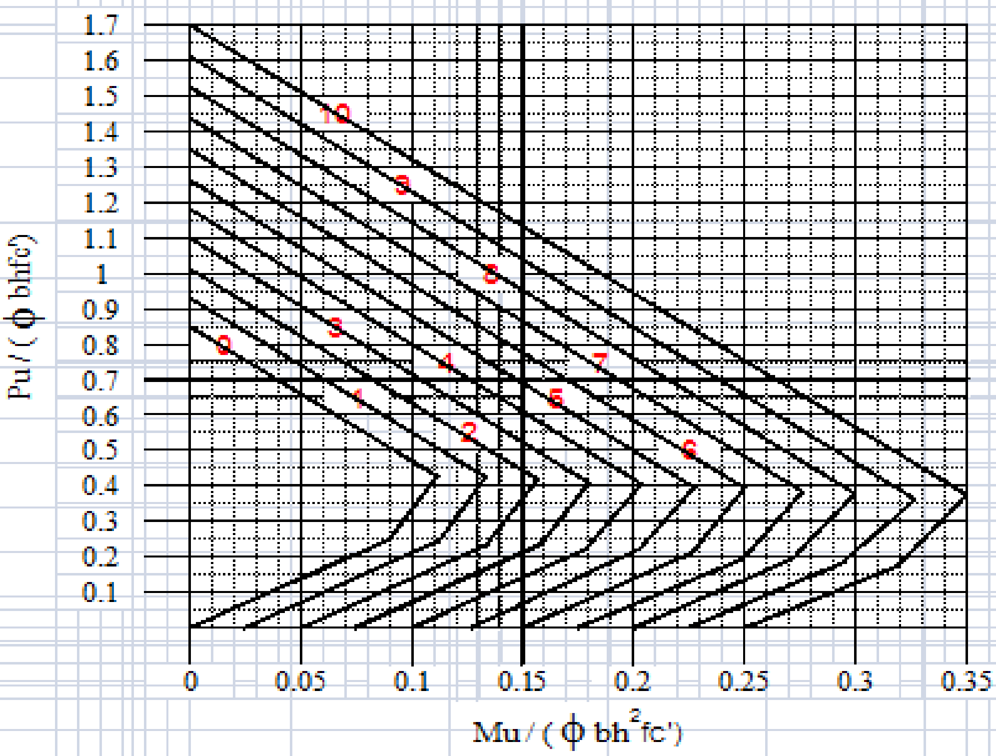
| Resistance Factor(lim) | | | |
|---|---|---|---|
| fck | fy=250 | fy=415 | fy=500 |
| 20 | 2.98 | 3.76 | 2.66 |
| 25 | 3.73 | 3.45 | 3.33 |
| 30 | 4.47 | 4.14 | 3.99 |

## c.) Design Of Columns:

## Design of column

| | | | | |
|---|---|---|---|---|
| Factored load (Pu kn) | 3000 | | fck (Mpa) | 20 |
| Size of column | 500*500 | | fy (Mpa) | 415 |
| length | 500 | | | |
| breadth | 500 | | | |
| Pu=.4fckAc+.67fyAst | | Ac=area of concrete | | |
| | | Ast=area of steel | | |
| Ac=(500*500-Ast) | | | | |
| Ast (mm2) | 3703.018 | | | |
| check for min. steel (mm2) | 2000 | | | |
| Here Ast>Astmin. | | | | |
| hence ok | | | | |
| provide 25mm dia bars | | | | |
| d (mm) | 25 | | | |
| no of bars | 7.595934 | | | |
| | 8 | | | |
| **Total no. of bars to be provided** | 8 | | | |

| | | |
|---|---|---|
| **Total no. of bars to be provided** | 8 | |
| ***Lateral Ties*** | | |
| d' (mm) | 6 | Using 6mm dia bars |
| ***Spacing of lateral ties*** | | |
| Least of the following | | |
| According to IS Code | | |
| Least Lateral Dimension (s) | 500 | |
| spacing (s) | 400 | |
| spacing (s) | 288 | |
| ***Using 6mm dia bars at 280mm C/C*** | | |



# DETAILING OF STRUCTURAL ELEMENTS:

**a.) Detailing of slabs:**

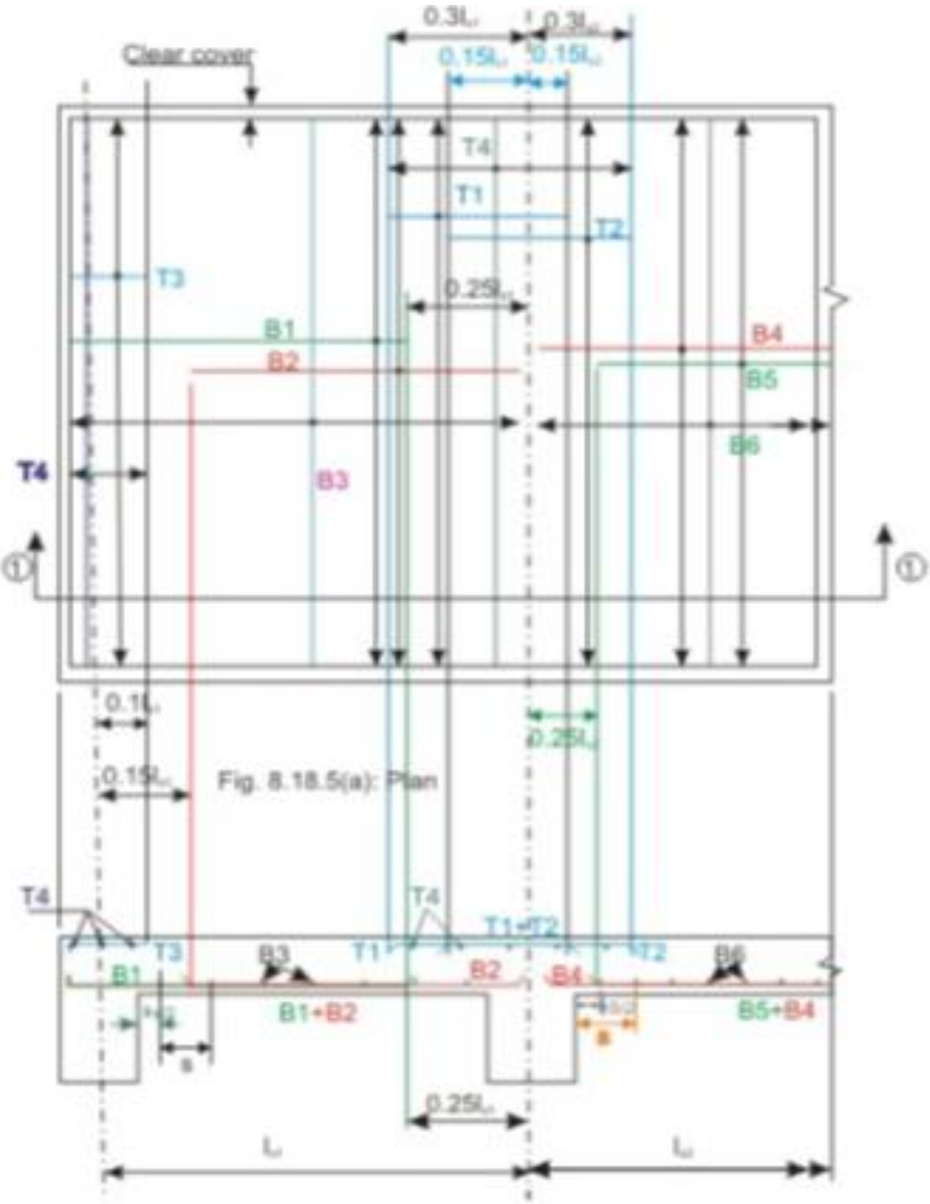
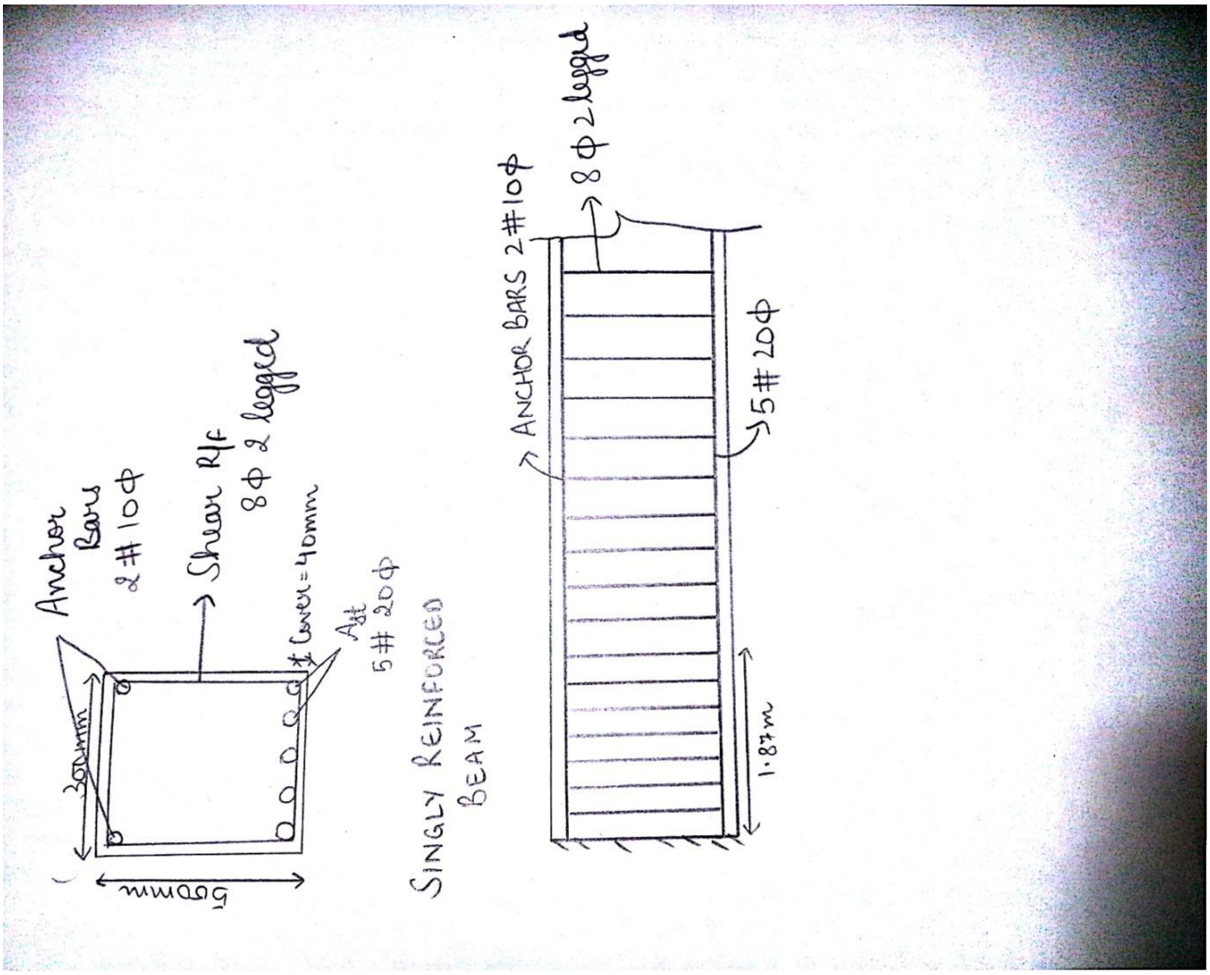
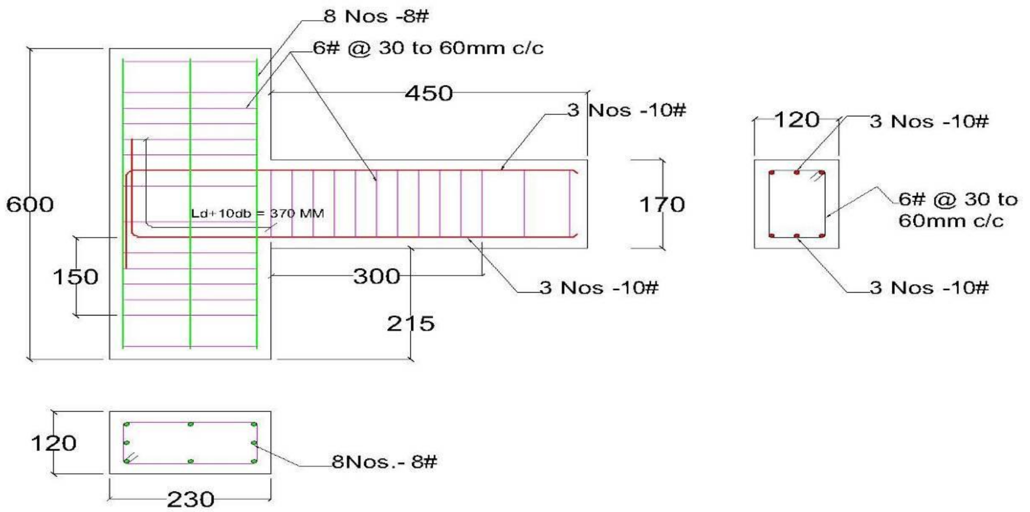



Fig. 8.18.5(a): Plan

## b.) Detailing of Beams:




## c.) Detailing of Columns:



# FUTURE PROSPECTS:

The future prospects of our projects are as follows:

Till now we have designed the high rise building by considering the limit state method for the design of structural elements such as beams, slabs, columns and footings. While designing these elements we used Microsoft Excel and various IS CODES for precision and accuracy.

After the above mentioned objective our next step in this project is to consider wind and earthquake loads combined with other loads such as dead load, live load and other such loads.

After considering all the loads on RCC high rise building our next step is to widen our knowledge in the field of steel design. In the next semester we are going to design a hybrid high rise building of 20 storey. This hybrid structure will have the following features.

1.) First 10 storey will be RCC structure.

2.) next 10 storeys will be steel structures.

Thus in the next phase of our project we are going to design steel connections between beams ,and columns.

All the designing will be done STAAD PRO in the next semester and after designing cost estimation of all the three structures steel, RCC and hybrid structure will be done and the economy of all the three structures will be compared.

# Staad Design

STAAD or (STAAD.Pro) is a structural analysis and design computer program originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineer International was bought by Bentley Systems.

An older version called Staad-III for windows is used by Iowa State University for educational purposes for civil and structural engineers.

The commercial version STAAD.Pro is one of the most widely used structural analysis and design software. It supports several steel, concrete and timber design codes.

It can make use of various forms of analysis from the traditional 1st order static analysis, 2nd order p-delta analysis, geometric non linear analysis or a buckling analysis. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.

STAAD Pro is the structural engineering professional's choice for steel, concrete, timber, aluminium, and cold-formed steel design of virtually any structure including culverts, petrochemical plants, tunnels, bridges, piles, and much more through its flexible modelling environment, advanced features, and fluent data collaboration.

The students did a literature survey, problem definition and did a complete structural analysis and design of the four story residential building in reinforced concrete. Theyfollowed the Indian code BIS 456 – 1978 and used ACI-1999 and wind/earthquake loads by using Canadian Code 1995, and ANSI standards 1995 for checking. The analysis and design of slabs, beams, girders, columns and footings were completed using theory from Reinforced Concrete Design and Structural Analysis by STAAD-III software, which uses finite elements. Design for slabs, beams , columns and footings were carried out using the software RC Design Suite. Drawings were done using Auto-CAD.

# DESIGN SPECIFICATIONS

The three dimensional view of the building is shown in Fig.1 and the plan view is given in Fig.2. The geometrical properties of the structure included a maximum length spanning 48.27 meters, and a maximum width of 31.60 meters. The building comprised of 2.9 meter floors and spanned 11.6 meters above grade. A wall beam was provided 0.75 meters below grade to support the earth pressure against supporting columns above the footings of the structure. At the roof level, a mechanical room was provided for the elevator of the complex. ( 1metre = 3.281 feet ) Each typical floor consisted of 8 apartments. The slab of the bath room was depressed approximately 0.6 meters and was accounted for in the beam design around the toilet rooms. A balcony was attached to each apartment, and the loading was accounted for in the floor beam design. The Indian code BIS 456- 1978 was used using the concrete mix with 15 MPa and 415 MPa reinforcing steel. The surrounding conditions indicated a low – seismic, and a strong soil layer boundary with a strength of 150 KN/sq.m. As indicated, the height to width ratio of the structure did not exceed 2, therefore a wind analysis was not required according to the Indian Code. Due to the monsoon season, the Indian Code included a specific loading for the roof of the structure

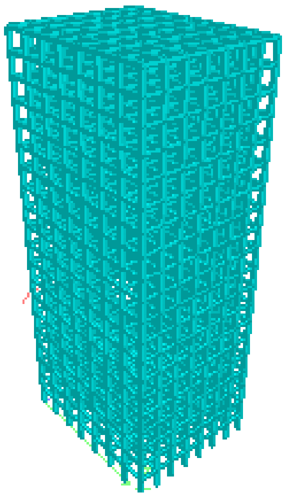


Fig 1

# ASSUMPTIONS MADE

1. Only centre line dimensions are taken

2. The base joints are assumed to be hinged and assumed to be at a depth of 3.35 m below ground level.

3. Half of the structure is considered because of symmetry and on the symmetric axis suitable boundary conditions are applied

4. Even though the beam behaviour is like a T beam over a certain length of span, moment of inertia is calculated based on the rectangular beam. This is on the conservative side.

5. The following three loading conditions are considered a) dead load b) live load c) 1.5 dead load + 1.5 live load. Since the design is carried out using limit state design load factor of 1.5 is used.

6. The live load on the slab is assumed as 3 kN/sq.m and the self – weight of slab + floor finish (assuming 120 mm thick ) is taken as 4 kN/sq.m and the total load on the slab is taken as 7 kN/sq.m for all floors except roof for which 10kN/sq.m is considered. Based on slab load and 45 degrees distribution the loads for beams for all floors are considered.

7. In addition, the wall load assuming the self-weight of masonry as 20 kN/cu.m is taken as 13.34 kN/m for full brick wall and 6.67 kN/m for half brick wall.

8. The slab is assumed to be 120mm thick , floor and roof beams are assumed as 230 x 450 mm or 230 x 400 mm as the case may be and the concrete columns are assumed to be 230x380 and some columns are assumed to be 230 x 450 . The columns in the lift portion are assumed to be 230 x 230

9. The safe bearing capacity of the soil is taken as 150 kN/sq.m

# ANALYSIS BY STAAD-III

Staad-III is a finite element analysis and design software system and was developed by Research Engineers Inc. In addition to the analysis and design complete graphical interface is included in this package. The following are the main options available from the concurrent Graphics environment.

STAAD-III - Analysis and Design

STAAD-III – Graphical Input Generator

STAAD-POST – Graphical post processing

STAAD-INTDES – Interactive Design of structural components

This package can perform static analysis, second order stability analysis and dynamic analysis. It uses 2 or 3 dimensional frame elements, grid elements, and continuum elements and spring elements. Extensive design capabilities are available in STAAD III/ISDS for steel, concrete, timber and pre-stressed sections. Interactive design consists of design for footing, slab and retaining walls. One can also get deformed shape, bending and shear and axial forces diagrams. Displacements are also checked for ACI, Canadian and Indian Standards.

SIX STEPS IN THE ANALYSIS

The following six steps are used in the Finite element analysis of any structure.

1. Idealize the structure into a number of elements

2. Develop the element stiffness matrix using constitutive law.

3. Assemble the element stiffness to form global stiffness matrix using compatibility and equilibrium.

4. Apply necessary boundary conditions

5. Solve the equations [K]{r}={R} where [K] is the structural stiffness matrix, {r} – generalized displacements and {R} – generalized forces.

6. Knowing the displacements solve for elemental stresses.

The multi story-building complex included a 3 dimensional mesh arrangement consisting of 2212 nodes with total of 6 degrees of freedom at each node. This model required a total of 13272 equilibrium equations to be solved in the form of a matrix system, ad in order to compute bending moments and displacements. Fortunately, the building contains a symmetry line, which permitted the analysis of half of the structure , therefore reducing the mesh arrangement to 1106 nodes and the number of equations was reduced to a total of 6636 equations which were solved using STAAD-III. The renumbering of nodes is automatically done so as to reduce the bandwidth. Reducing the number of equations and reducing the bandwidth of the matrix system to be solved, which alternatively required less time from cpu point of view.

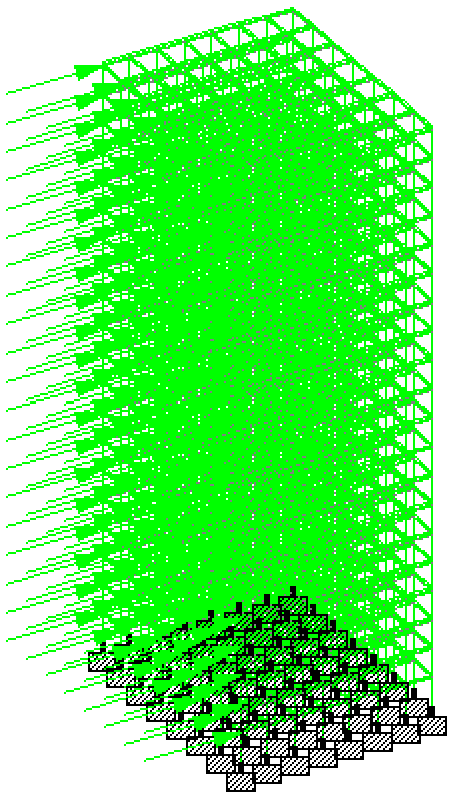


Fig 2

# RC-DESIGN SUITE

RC –Design suite is a reinforced concrete design program that has numerous applications for the design of concrete structures. It contains modules for the design of beams, columns , footings and slabs. For this project the students utilized this program only for the design of floor slab and combined footings. This program will also be used in the partial design of the raft footing. Design of beams and columns are carried out in STAAD- III package itself. A clear cover of 20 mm is adopted for the slab. For each column load the individual footing is designed. However, many of these individual footings overlapped each other and had to be redesigned as combined footings. RC Design – suite provided an effective way of designing these combined footings through its footing design module. The footing design module of the program provides the footing length, effective depth and reinforcement requirements. The raft footing was designed in the area under the lift duct of the building. Some criteria dictated that the support to the elevator shaft should be watertight. RC-Design Suite was used to engineer the design of the raft. Four column loads of 562 kN, 425 kN, 832 kN and 498 kN are being transmitted to the four corners of the raft of the lift well. The design of the raft footing was modelled adopting an inverted slab-beam-column approach. To prevent deterioration in the footing, associated with the position of the water table, it was decided that a raft footing would be beneficiary since its depth would be considerably less than a conventional shallow or combined – footing. The thickness of the raft was 0.6 m.

# Loads on the Structure

***Dead load:*** Loads cause stresses, deformations, and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled. Dead loads are static forces that are relatively constant for an extended time.

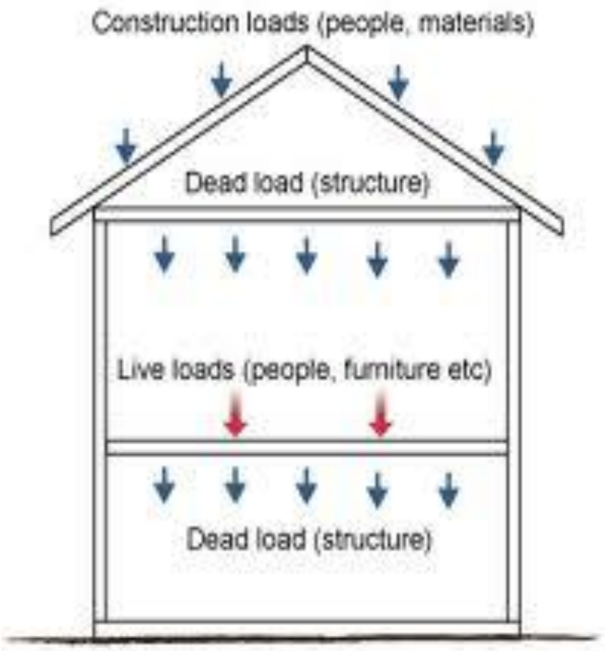



Fig 3

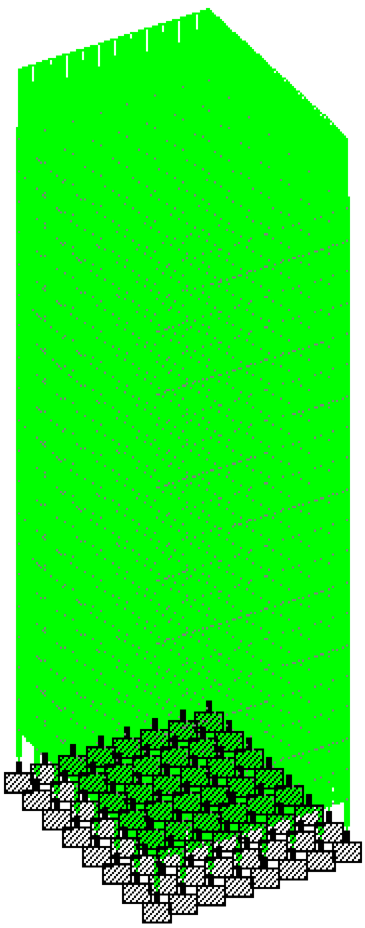
***Live load:*** Live loads, or imposed loads, are temporary, of short duration, or a moving load. These dynamic loads may involve considerations such as impact, momentum, vibration, slosh dynamics of fluids and material fatigue. Live loads, sometimes also referred to as probabilistic loads, include all the forces that are variable within the object's normal operation cycle not including construction or environmental loads.

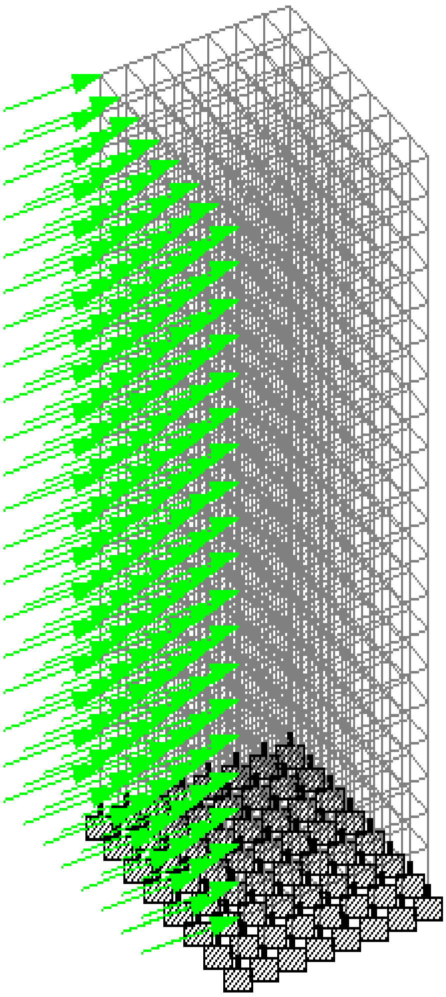
Roof and floor live loads are produced during maintenance by workers, equipment and materials, and during the life of the structure by movable objects, such as planters and people.

Bridge live loads are produced by vehicles traveling over the deck of the bridge.

Various live loads:

- Wind load
- Earthquake load
- Snow load
- Temperature load





# Staad Results

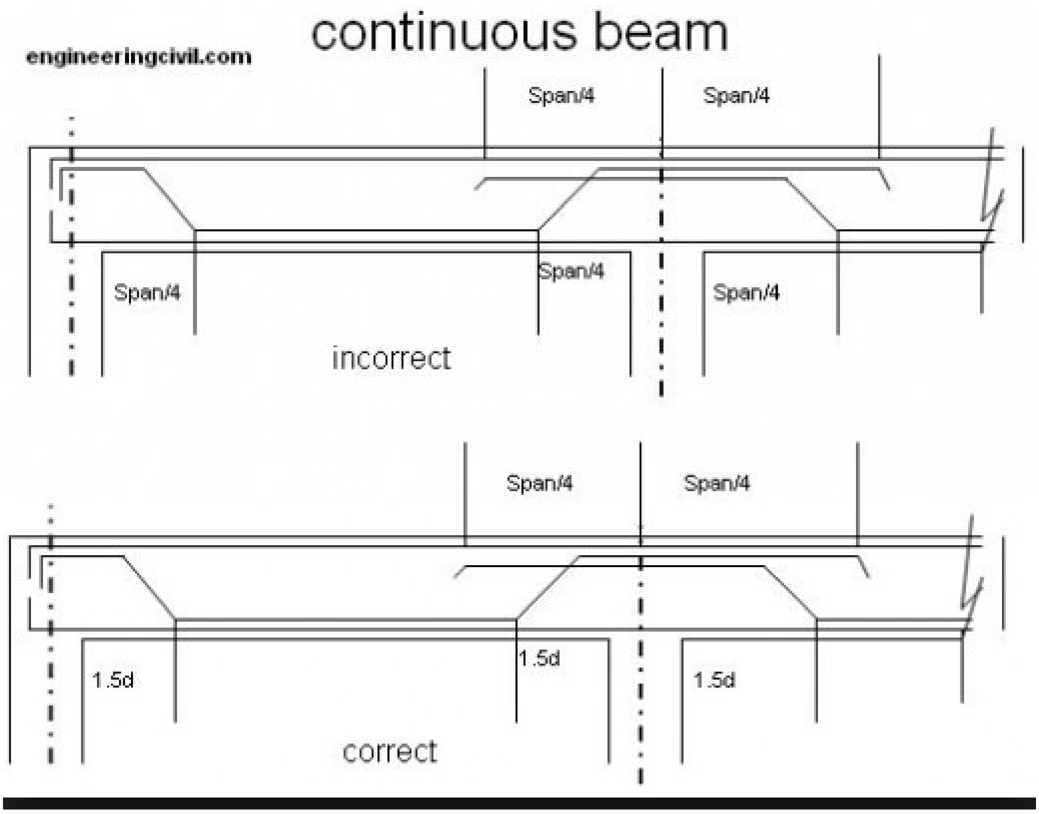
***Beams***: A beam is a structural element that is capable of withstanding load primarily by resisting bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment.

In this structure I have used fixed continuous doubly reinforced beam.

Size of beam: 300*500

M25 grade of concrete

Fe415 grade of steel



# Reinforcement details

## Main reinforcement:

B E A M  N O.  3  D E S I G N  R E S U L T S

M25 Fe415 (Main) Fe415 (Sec.)

LENGTH: 2857.1 mm SIZE: 300.0 mm X 500.0 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

| SECTION | 0.0 mm | 714.3 mm | 1428.6 mm | 2142.9 mm | 2857.1 mm |
|---|---|---|---|---|---|
| TOP REINF. | 279.58 (Sq. mm) | 0.00 (Sq. mm) | 279.58 (Sq. mm) | 279.58 (Sq. mm) | 279.58 (Sq. mm) |
| BOTTOM REINF. | 279.58 (Sq. mm) | 279.58 (Sq. mm) | 279.58 (Sq. mm) | 279.58 (Sq. mm) | 0.00 (Sq. mm) |

***Fig 1***

SUMMARY OF PROVIDED REINF. AREA

| SECTION | 0.0 mm | 714.3 mm | 1428.6 mm | 2142.9 mm | 2857.1 mm |
|---|---|---|---|---|---|
| TOP REINF. | 4-10í 1 layer(s) | 4-10í 1 layer(s) | 2-10í 1 layer(s) | 4-10í 1 layer(s) | 4-10í 1 layer(s) |
| BOTTOM REINF. | 4-10í 1 layer(s) | 4-10í 1 layer(s) | 4-10í 1 layer(s) | 4-10í 1 layer(s) | 4-10í 1 layer(s) |
| SHEAR REINF. | 2 legged 8í @ 150 mm c/c | 2 legged 8í @ 150 mm c/c | 2 legged 8í @ 150 mm c/c | 2 legged 8í @ 150 mm c/c | 2 legged 8í @ 150 mm c/c |

***Fig 2***

Fig 1 shows required reinforcement details and fig 2 shows provided reinforcement.

***Shear Reinforcement:***

```
SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT   700.0 mm AWAY FROM START SUPPORT
  VY =     3.72 MX =     0.22 LD=    6
  Provide 2 Legged  8í  @ 150 mm c/c

SHEAR DESIGN RESULTS AT   700.0 mm AWAY FROM END SUPPORT
  VY =    -4.35 MX =     0.22 LD=    6
  Provide 2 Legged  8í  @ 150 mm c/c

=============================================================================
```

***Fig 3***

Fig 3 shows shear reinforcement details

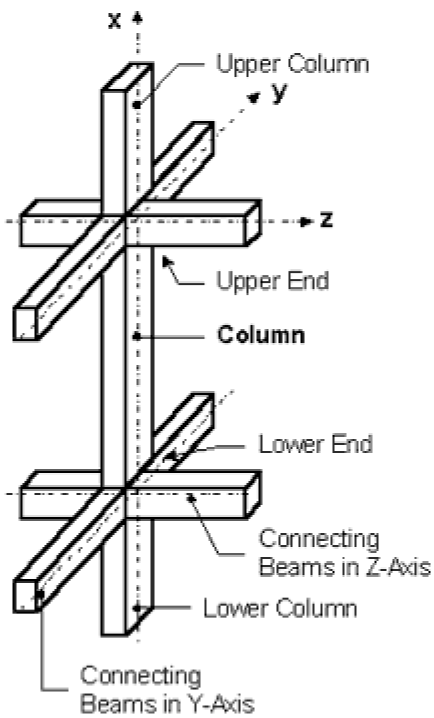
***Column:*** Column or pillar in architecture and structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member. The term column applies especially to a large round support with a capital and base and made of stone, or appearing to be so.

In this structure I have used two types of columns i.e

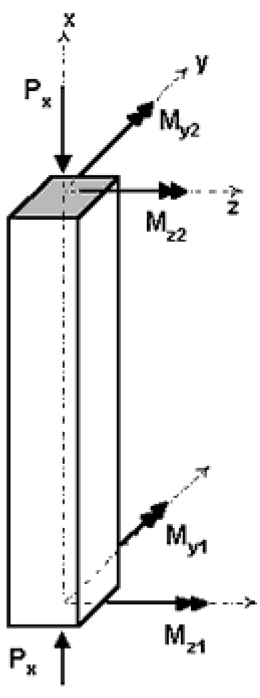
Uniaxial column: The column having axial load acted in such a way that, It is eccentric about one axis of the plane column then it is called uniaxial column.

Biaxial column: .If the load is eccentric about both the axes in the plane of column then it is called biaxial column.

Size of Column:300*500




a) Basic Model




a) Column Loads

# Reinforcement details

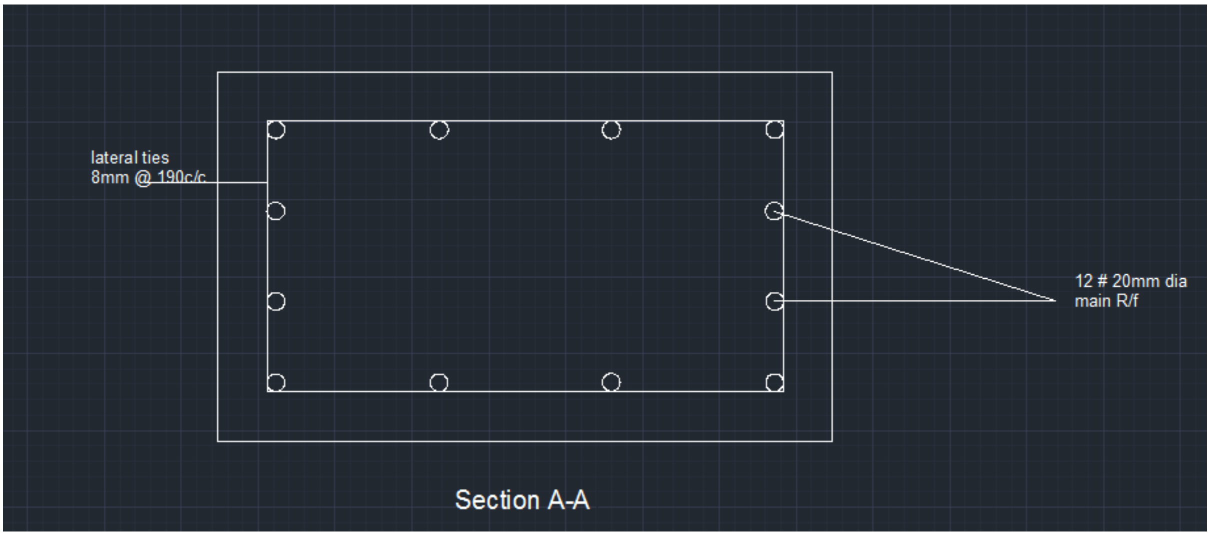
## Main reinforcement:

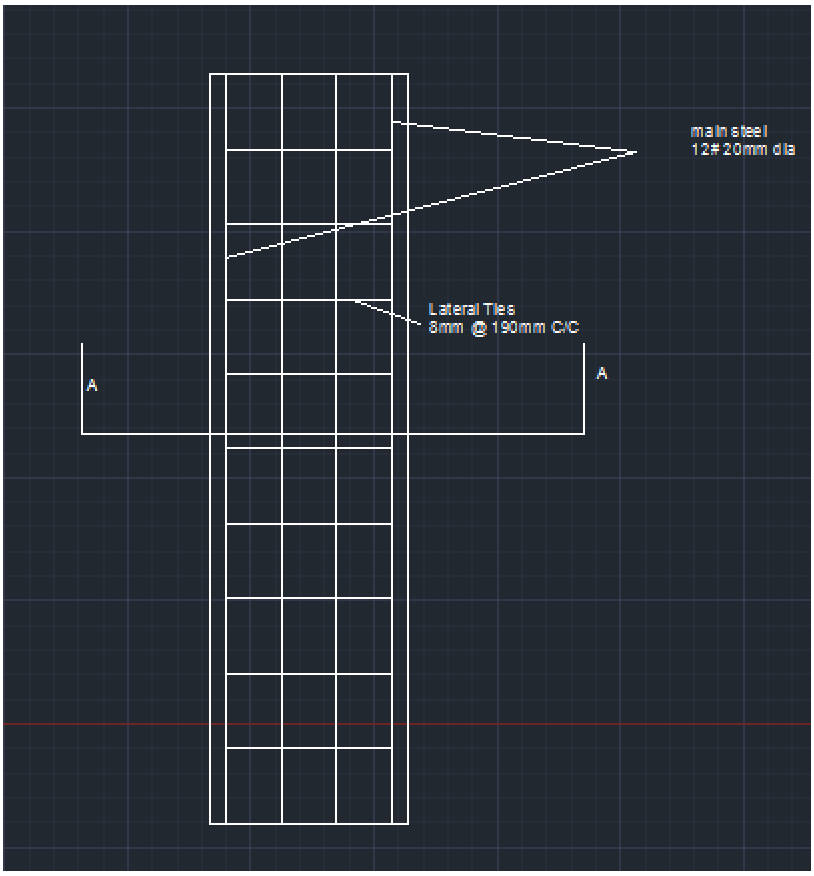
```
            C O L U M N   N O.   449  D E S I G N   R E S U L T S

      M25                   Fe415 (Main)              Fe415 (Sec.)

 LENGTH:  3000.0 mm   CROSS SECTION:  500.0 mm X  500.0 mm  COVER: 40.0 mm

 ** GUIDING LOAD CASE:    1 END JOINT:   177  SHORT COLUMN


 REQD. STEEL AREA   :     2000.00 Sq.mm.
 REQD. CONCRETE AREA:   248000.00 Sq.mm.
 MAIN REINFORCEMENT : Provide  20 - 12 dia. (0.90%,   2261.95 Sq.mm.)
                      (Equally distributed)
 TIE REINFORCEMENT  : Provide  8 mm dia. rectangular ties @ 190 mm c/c

 SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)
 ----------------------------------------------------------
 Puz :   3412.50   Muz1 :    135.62   Muy1 :    135.62

 INTERACTION RATIO: 0.04 (as per Cl. 39.6, IS456:2000)

 SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)
 ----------------------------------------------------------
 WORST LOAD CASE:     6
 END JOINT:   177 Puz :   3106.32   Muz :      0.00   Muy :      0.00   IR: 0.19
 ============================================================================
```

***Fig 4***

Fig 4 shows reinforcement details of a uniaxial column.

## ***Column detailing:***



**<u>Slab:</u>** A concrete slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 4 and 20 inches (100 and 500 millimetres) thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving.

***<u>One way slab:</u>*** One way slab is supported on two opposite side only thus structural action is only at one direction. Total load is carried in the direction perpendicular to the supporting beam.


***<u>Two way slab:</u>*** Two way slabs are the slabs that are supported on four sides and the ratio of longer span (l) to shorter span (b) is less than 2. In two way slabs, load will be carried in both the directions.

# Reinforcement details:

# Slab Details:

```
ELEMENT DESIGN SUMMARY
----------------------

ELEMENT     LONG. REINF      MOM-X /LOAD    TRANS. REINF      MOM-Y /LOAD
             (SQ.MM/ME)     (KN-M/M)        (SQ.MM/ME)      (KN-M/M)

 3521 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3522 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3523 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3524 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3525 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3526 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3527 TOP :       156.         0.00 /    0         156.          0.00 /    0
     BOTT:       156.         0.00 /    6         156.          0.00 /    6

 3528 TOP :       156.         0.00 /    0         156.          0.00 /    0
```

| | | | | | | |
|---|---|---|---|---|---|---|
| 3529 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3530 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3531 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3532 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3533 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3534 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3535 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |
| 3536 TOP : | 156. | 0.00 / | 0 | 156. | 0.00 / | 0 |
| BOTT: | 156. | 0.00 / | 6 | 156. | 0.00 / | 6 |

## ***Deatailing of Slab:***

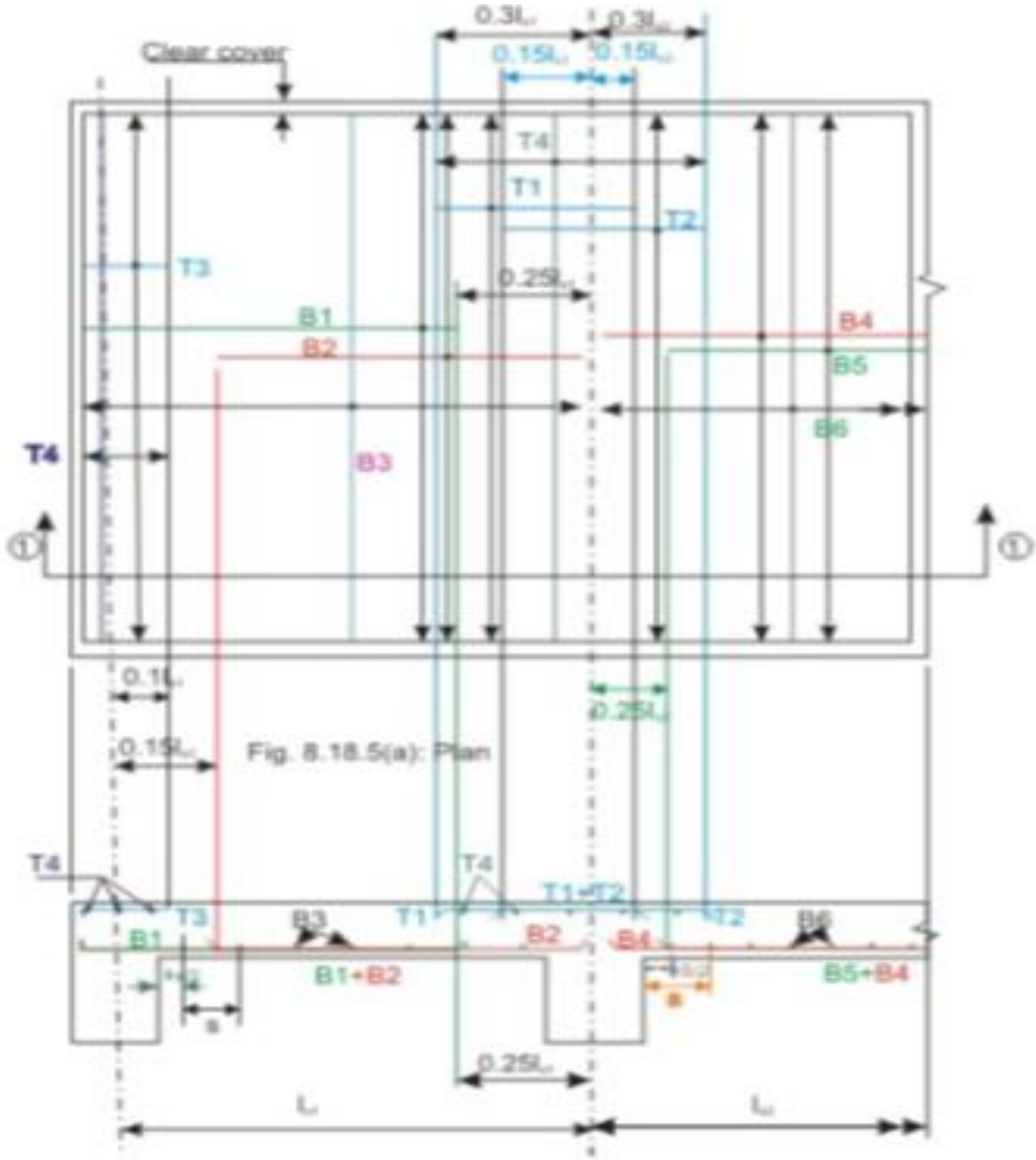



Fig. 8.18.5(a): Plan

# Cost Estimation

| | Length(m) | Breadth(m) | Height(m) | Number | Volume(m3) | Raw m rate | Labour Rate | Amount |
|---|---|---|---|---|---|---|---|---|
| Excavation | | | | | | | | |
| (i) Footing | 5.25 | 5.25 | 2 | 32 | 1764 | | 200 | 352800 |
| (ii) Boundary Wall | 110 | 0.5 | 1 | 1 | 55 | | 150 | 8250 |
| | | | | | | | | |
| Concrete | | | | | | | | |
| (i) Footing | 2.5 | 2.5 | 0.7 | sn | 140 | 3000 | 445 | 420000 |
| (ii) Column | 13.5 | 0.5 | 0.5 | 32 | 108 | 3000 | 720 | 401760 |
| (iii) Beam | 10 | 0.25 | 0.5 | 144 | 180 | 3000 | 564 | 641520 |
| (iv) Slab | 30 | 30 | 0.25 | 6 | 1350 | 3000 | 564 | 4811400 |
| | | | | | | | | |

| Steel | | Area(m2) | | | | Weight of steel | | |
|---|---|---|---|---|---|---|---|---|
| (i) Footing | | | | | | (Tonne) | | |
| (a) main | 4.4 | 0.0023 | | 32 | 0.32384 | 3.12 | 42000 | 131040 |
| (b) Sec | 4.4 | 0.0021 | | 32 | 0.29568 | 2.83 | 42000 | 118860 |
| (ii) Column | | | | | | | | |
| (a) 2rd floor | 4 | 0.002 | | 32 | 0.256 | 1.99 | 42000 | 83580 |
| (b) 1st floor | 4 | 0.002 | | 32 | 0.256 | 1.99 | 42000 | 83580 |
| (c) Ground F | 4 | 0.0054 | | 32 | 0.6912 | 5.4 | 42000 | 226800 |
| (d) below G. L. | 2.5 | 0.0084 | | 32 | 0.672 | 5.24 | 42000 | 220080 |
| (e) Secn. r/f | 2 | 0.0007 | | 96 | 0.1344 | 1.1 | 42000 | 46200 |
| (iii) Beam | | | | | | | | |
| (a) main | 10.5 | 0.0054 | | 144 | 8.1648 | 55.88 | 42000 | 2346960 |
| (b)shear | 1.5 | 0.0033 | | 144 | 0.7128 | 5.46 | 42000 | 229320 |
| (iv) slab | | | | | | | | |
| (a) main r/f | 10.5 | 0.00156 | | 54 | 0.88452 | 7.2 | 42000 | 302400 |
| (b) sec r/f | 10.5 | 0.00156 | | 54 | 0.88452 | 7.2 | 42000 | 302400 |
| | | | | | | | | |
| | | | | | | | ***TOTAL*** | 10726950 |

# Results

According to my project i.e analysis and design of high rise building I have learned a lot of things. I have used both Microsoft excel and Staad pro for designing the structure.

The results are summarised as follows:

## ***Beam Design:***

| | **Excel Design** | **Staad Design** |
|---|---|---|
| Main R/F Top | 2# 10 ¢ | 4# 8 ¢ |
| Bottom | 5# 10 ¢ | 4# 10 ¢ |
| Shear R/F | 8¢ @ 150mm C/C | 8¢ @ 150mm C/C |
| | | |

## ***Column Design:***

| | **Excel design** | **Staad Design** |
|---|---|---|
| Main R/F | 8# 25¢ | 12# 20 ¢ |
| Lateral ties | 6mm@ 150c/c | 8mm @190c/c |
| | | |

## ***Slab Design:***

| | **Excel design** | **Staad design** |
|---|---|---|
| Transverse R/F | 208mm2 | 156mm2 |
| Longitudnal R/F | 190mm2 | 156mm |
| Shear R/f | safe | safe |
| Torsional Steel | 206.13mm2 | 126mm2 |

***The approximate cost of one floor of the structure comes out to be Rs5768900.***

# Conclusion

This topic which is analysis and design of high rise buildings will help in expanding our knowledge in the field of design and analysis. With incomes growing and large numbers of people moving to urban areas, the demand for housing is on the upswing. Due to high construction costs and non-availability of land at preferred locations, people opt for apartments. Today's upwardly mobile live and work in high-rise buildings with terraces and balconies overlooking the cityscape.

The Indian economy has opened up and brought new business opportunities that have changed urban dynamics. With growing incomes, priority for comfort and convenience, and an increasing demand for lifestyle homes, it's boom time for real estate folks. According to a Techno park study the Indian luxury market is about $ 444 million with a huge potential in the coming years. With this kind of money, there is more scope for high-rise apartments with all the amenities one could dream of.

# Refrences

***Research papers:***


- **International Journal of High-Rise Buildings by *Naoki NIWA***

- **Council on Tall Buildings and Urban habitat consists of**

  - Architectural Planning & Design
  - Construction Technology
  - Energy Savings
  - MEP
  - Structural Engineering
  - Sustainability

By:

- Prof. Sang Dae Kim, Korea University
- Prof. Shinsuke Kato, University of Tokyo
- Prof. Guo-Qiang Li, Tongji University, China
- Prof. William Bahnfleth, The Pennsylvania State University

- **Low Energy High Rise Building Research Study by Ms Sue Salmon – Project Director LEHR Project**

- **Effects of High Rise Building Complex on the Wind Flow Patterns on Surrounding Urban Pockets by Dr. Alka Bharat, Ar. Seemi Ahmed**


***Books refered:***


***Wright and MacGregor's*** Reinforced Concrete

Structural analysis by Hibbeler

Design Of R.C.C. Structural Elements by SS Bhavikatti