**A Thesis on**

# DYNAMIC ANALYSIS OF FLAT SLAB AND GRID SLAB SYSTEM IN A MULTISTOREY BUILDING

**Submitted in Partial Fulfilment of the Requirements for the Degree of**

**MASTER OF TECHNOLOGY**

In

STRUCTURAL ENGINEERING

**by**


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# DECLARATION

I declare that the research thesis entitled "**Dynamic Analysis Of Flat Slab And Grid Slab System In A Multistorey Building"** is bonafide research work carried out by me, under the guidance of **Mr. Mohd Bilal Khan, Assistant Professor, Department of Civil Engineering, Integral University, Lucknow.** Further, I declare that this work has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not be submitted anywhere else.

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# CERTIFICATE

*Certified that the thesis entitled "***Dynamic Analysis Of Flat Slab And Grid Slab System In A Multistorey Building*"*** *is being submitted by* ***Mr. Suraj Kumar Ravi (Roll no. 1801431016)*** *in partial fulfilment of the requirement for the award of degree of Master of Technology (Structures) of Integral University, Lucknow is a record of candidate's own work carried out by him/her under my supervision and guidance.*

*The result presented in this thesis has not been submitted to any other university or institute for the award of any other degree or diploma.*

**Mr. Mohd Bilal Khan**
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# ACKNOWLEDGEMENT

All praises to *Almighty GOD* with whose grace I was able to complete this project successfully.

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Being the student of M. Tech Civil Engineering, I have chosen this project **"Dynamic Analysis of Flat Slab And Grid Slab System In A Multistorey Building"** which I believe will prove beneficial to me in my career and educational purpose.

I would also like to acknowledge my dear parents, who have given me the moral and monitory support every time and specially in formulating the project job.

SURAJ KUMAR RAVI

Place: Lucknow Date:

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# ABSTRACT


Civil Engineers are facing a great challenge in structural designing. The design must fulfil various parameters which include economical structure, durability and serviceability. But taking these points in mind it becomes very difficult for an Engineer to fulfil all these requirements at a time when a design is performed manually. This dissertation presents a research on digital tools used in civil engineering and comparing their results by taking in mind the requirements of the above points. In this research process a building is taken for analysis and design on well-known Software ETABS. Based on the results taken from the Software some comparison is done with manual analysis.

Nowadays every designing organisation is using these Software but there is a question mark to which software we must go for designing. The parent organisations which have developed these designing tools promote their Software by showing all the positive points. In addition to this they are trying to fill all the loop holes which they found in their products but it will never happen that another developing company will put the points in light what the negative points are there in existing products. They keep on improving to deliver their best. In this project work I will present the difference for future users to which tool you must go through to acquire your needs. I am not saying that some products are not ok at all. I have designed a residential building with proper loading which is being designed on both ETABS. Manual calculations make it crystal clear the difference between the Software.

The main purpose of this study is to show detailed difference between well-known simulation Software STAAD Pro and ETABS used by structural design engineers nowadays. This study is focussed on the advantages of digital tools in our life to make it easy and reliable for us to perform a difficult task. It is found that ETABS is good for building design and STAAD PRO on the whole deals with RCC Structures as well as Steel Structures but by survey I found STAAD Pro is mostly used to check analysis result. So, in this study I am going to check it out what is the reason, why Engineers are taking analysis result in case of RCC Design why not design result while using STTAD Pro.

# CHAPTER 1

# INTRODUCTION

## 1.1 GENERAL INTRODUCTION

An RCC framed structure is basically an assembly of slabs, beams, columns and foundation inter -connected to each other as a unit. The load transfer, in such a structure takes place from the slabs to the beams, from the beams to the columns and then to the lower columns and finally to the foundation which in turn transfers it to the soil. The floor area of a R.C.C framed structure building is 10 to 12 percent more than that of a load bearing walled building. Monolithic construction is possible with R.C.C framed structures and they can resist vibrations, earthquakes and shocks more effectively than load bearing walled buildings. Reinforced concrete is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength and ductility. The reinforcement is usually embedded passively in the concrete before the concrete sets.

The reinforcement needs to have the following properties at least for the strong and durable construction:

• High toleration of tensile strain.

• Good bond to the concrete, irrespective of pH, moisture, and similar factor.

•Thermal compatibility, not causing unacceptable stresses in response to changing temperatures.

Design needs to have good hand on numerical problem, to counter different challenges while getting twisted in a design. After complete knowledge of analysis and design one can design any structure but it is not possible for a single person to go through all fields. It is necessary to get a full knowledge in a particular field. Building analysis and design needs complete knowledge of IS Codes and numerical analysis. One must be well versed about loading which are considered in a building. Building can be of various types and can be residential, commercial, industrial and institutional. So, while performing a design we need to go through different design codes. Some of the codes are given below with their description of loading.

IS- 875 (Part 1) – Design Code for Dead Loads.

IS- 875 (Part 2) – Design Code for Live Loads.

IS- 875 (Part 3) – Wind Load Design Code.

IS- 1893 – Earthquake Design Code.

In addition to above codes we have other codes too to take proper loading and to follow the steps as per standard code recommendation. Engineers which are dealing with Analysis and Design of Structures are known as Structural Design Engineers. They are professional in design both by manual process and by software means. But there is a question that which method we must choose while designing nowadays. It is not as easy as it looks to design a problem it needs mathematical calculation and practice in that field. With this specialization one must have good hand on numerical calculation and must have good experience as well.

## 1.2 OBJECTIVE OF THE RESEARCH:

The main approach of this research is to test the basic assumptions that others in the field have used. It is quite possible for an assumption to become accepted fact simply because several authors have stated or cited the same idea, even though it has never been systematically tested or proven. I got the opportunity to find such an untested assumption and can think of a way to test it, then my work can be of great value to the field (provided it is well executed)

Technology is growing nowadays with an alarming rate. It is necessary for every individual to get know about latest technologies as they make life easier from time to time. Great scientist's and creative work force are involved in the process of making changes in technologies and to make complex things easy as much as possible.

With this research I will get to know about latest technologies and will compare some results how much difference is being acquired and how much accurate is the result given by technologies used in our field. The points which will be taken into consideration while going through the research are listed below:

- Modelling and analysis of G+14 R.C. framed structure by the use of ETABS and to detail the process using various design code algorithms for concrete member selection.
- To assign a suitable cross section which will resist load as well as fulfill some design requirements such as economy and serviceability.
- Comparison of results obtained in terms of storey drift, displacement, base shear, stresses and deflection in the portion of building with flat slab and the portion of building with grid slab and finally verifying the results.

### 1.2.1 LEARNING OUTCOME

With this research I am now familiar with various Software, which can be now added to my technical skills. Now onwards I can be able to perform various projects whether it may be building or any other structure. Things were very tough for me till date as I have solved various problems in my college level but while going through this, I found it don't need much efforts to design or analyse a structure. Models can be easily created using objects and can understand the concepts when editing and creating complex models.

You will be able to recognize story levels and be able to input building data in a logical and easy manner. You will be a productive, innovative, and communicative engineer, with an ability to work with people spanning different disciplines. You will create only one model of the floor systems and the vertical and lateral framing systems to be able to analyse and design the entire building due to the integrated system of ETABS. You can keep your design data and design intellectual property in graphics, tabular form or send it to a printer or export it to a database file or even save it as an ASCII file and manage them in a safe, centralized place. You can let your team collaborate with you at any stage of product development.

Many design companies use these Software for their project design purposes. So, this project mainly deals with the comparative analysis of the results obtained from the design of a multi storey building structure when designed using ETABS Software separately. For first case, structure is modelled using ETABS Software. The height of each storey is taken as 3m. Analysis and design of the structure is done and then the results generated by these Software are compared and a conclusion is drawn from them.

### 1.2.2 ESTABLISH RESEARCH PRIORITIES

The structure needs to be designed based on some priorities which can be achieved based on some facts and standard codes. The codes give us detailed knowledge about loading and some recommendations. The design performed which will not consider SI recommendation's will be considered dead end and will be not be considered as serviceable and durability. Some values are considered on the basis of different topography, site conditions and locations. Design codes are assigned according to the location. Every country has its own design codes. These codes are drafted based on knowledge collected from previous data.

This research considered all the values which must consider based on the functionality of the structure. The values are taken from design codes and then analysis is done. After completion of analysis design is prepared by making some assumptions. The assumptions which are made are mentioned below:

- Material is homogenous all over the member.
- All the structural elements are considered monolithic.
- Concrete will resist compression force and steel will resist tension.
- Force applied is less than the load resisted by member.

## 1.3 OVERVIEW OF METHODOLOGY

The research consists of various values which are considered to know the fact which I was searching for. The methodology must be well known and should be of practically applicable. So, in this research I found it suitable to select ETABS for my fact-finding process as they are widely used nowadays. Experts are available in case there is any need of assistance while having some technical issue. The brief history of these two Software is given below:

In structural design and analysis various types of software uses like: -

- STAAD PRO
- ETABS
- SAP
- SAFE
- ANSYS
- STAAD PRO FOUNDATION
- STAAD PRO RCDC

Many design alternatives run in parallel with the cloud services of STAAD PRO and view the results in clear side-by-side graphical comparisons. Design for high-seismic regions or everyday conditions, using Finite Element analysis. Optimize BIM concrete and steel workflows with full physical and surface integration.

### 1.3.1 UNIT SYSTEM:

The user is permitted to input data and request output in almost all commonly used engineering unit systems, including MKS, SI, and FPS. In the input file, the user can change units as many times as needed. Mixing and matching of units of length and force from different unit systems is also allowed. The unit of input angle (or rotation) is degrees. However, in the JOINT DISPLACEMENT output, the rotations are provided in radians. The program defines the units for all output clearly.

The Geometry of Structure and Coordinate Systems: "A structure is an assembly of individual components such as beams, columns, slabs, plates, etc. In ETABS frame elements and platform elements can be used to model structural components. Typically, structure geometry modeling consists of two steps: a. identification and description of joints and nodes.

Generally, the term MEMBER refers to frame elements and the term ELEMENT refers used to refer to plate / shell elements. MEMBER's connectivity may be provided by the MEMBER INCIDENCE command, while ELEMENT's connectivity may be provided by the ELEMENT INCIDENCE command. ETAB is one of the software discussed above in which we can find results whatever we need. We can make changes in the structure easily so that the project will meet needs according to objective of research.

### 1.3.2 OVERVIEW OF ETABS

The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object-based modelling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results. From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. The state-of-the-art SAP Fire 64-bit solver allows extremely large and complex models to be rapidly analysed and supports nonlinear modelling techniques such as construction sequencing and time effects (e.g., creep and shrinkage).

The structural analysis software plays an important role to carry out the seismic calculation for the infrastructures. In this modern period of time, where computer has reached every phase of life, using the traditional book system for analytical development of the students, which is no doubt necessary, is no longer sufficient. Moreover, construction and design has become so much competitive in this world that using computers became mandatory. In this chapter, an introduction to the structural analysis software ETABS has been presented.

This Research introduces you to ETABS Version 8. The step-by-step instructions guide to you through development of your first model. The intent is to demonstrate the fundamentals and to show how quickly and easily a model can be created using this program. ETABS is an extremely versatile and powerful program with many features and functions. This manual does not attempt to fully document all of those features and functions. Rather, we briefly show how to work with the program, providing some commentary along the way. To grasp the full value of ETABS, you should use this introductory manual in conjunction with the other ETABS documentation, such as the graphical user interface reference manual and the steel, concrete, shear wall, and composite floor design manuals. It is the first step in changing the way you work, for the better.

ETABS is a stand-alone finite-element-based structural analysis program with special purpose features for structural design and analysis of building systems. Embedded beneath the simple, intuitive user interface are very powerful numerical methods, design procedures and international design codes that allow you to be versatile and productive, whether you are designing a simple 2-dimensional frame or performing a dynamic base isolation analysis of a complex high-rise.

### 1.3.2.1 FUNDAMENTAL CONCEPTS

ETABS works off of an integrated database. The basic concept is that you create only one model consisting of the floor systems and the vertical and lateral framing systems to analyse and design the whole building. Everything you need is integrated into one versatile analysis and design system with one user interface. There are no external modules to maintain and no worries about data transfer between modules. The effects on one part of the structure from changes in another part are instantaneous and automatic.

ETABS is a refined and convenient special purpose analysis and design program developed especially for building systems. With its integrated system and the ability to handle the largest and most complex building model's configuration, it assures:

- Powerful CAD-like drawing tools in a graphical and object-based interface.
- Increased productivity of structural engineers in the building industry.
- Significant savings in time and efficiency over general purpose programs.

ETABS can help you convert your ideas into product designs quickly and effectively. It enhances your ability to learn the geometry of building systems. In ETABS, model creation and reporting of results are accomplished at the object level. It enables the designer to focus on macroscopic performance targets. ETABS is well equipped to handle simplified lateral procedures, Push-over analysis, Response Spectrum Analysis and Response History Analysis. The data output options are much more conducive to lateral design in special purpose software like ETABS. ETABS can also be utilized for handling large scale seismic projects including those that involve Non-Linear Modelling. It comes with libraries of various pre-built or pre-designed code-dependent formulations so that the user does not have to re-define basic parameters depending on the conditions.

### 1.3.2.2 FEATURES OF ETABS

It is more updated with latest version of ETABS of 2015. Hence revisions in Codal provisions and developments are incorporated every version. STAAD Pro on the other hand has its latest version in 2008.With that said, minor improvements are made every version. CSI, the company of ETABS is in close association & touch with NICEE, IIT Roorkee and other IITs. Hence field and lab observations are incorporated in ETABS. Design processor of ETABS is improved in every way possible, like in beams. (This was said by Prof Yogendra Singh, IIT Roorkee). So especially when Indian IS codes are used, enhanced efficiency is obtained.

STAAD Pro always gives higher demand for steel reinforcement. (Which sometimes is illogical and when checked manually proves to be excessive). This is why reputed structural consultants in Delhi, Blore, Mumbai moved to ETABS long ago, in addition to reasons mentioned above. eg. Vintech consultants, Delhi who designs many buildings of DLF, Jaypee used ETABS in its office. Also, they do this after proving the credibility of ETABS by manual calculations.

ETABS is used in structural design of Burj Khalifa, Taipei 101 and many other prominent high rises. Hence credibility. SOM, world's leading consultant who also design Burj Khalifa, China TV tower mostly uses ETABS. Also, most local Gulf/Middle east consultants use ETABS too. For Burj Khalifa, read paper by the designer William Baker, SOM- ETABS have robust feature of pushover/P-delta analysis and time history analysis. IIT Guwahati is providing PhD degrees basically on Pushover designs using ETABS. Hence the vastness of the software. Newer versions of ETABS has detailing provisions. E.g. as per SP 34. As we know detailing takes time and sucks. But ETABS does it post analysis and design and generates detailing drawings too. Awesome right! (Could be a bane to Draftsmen\U0001f62c) Once you correctly define materials in ETABS, things are taken care in the modelling process. Like ETABS automatically takes care of dead load. You have to assign dead loads manually in STAAD Pro. If you seriously want to be strong in your analytical skills, read the book written by the man behind ETABS- Ed Wilson "Three Dimensional Static and Dynamic Analysis of Structures" ETABS is basically product of University of California, Berkeley. Credibility. ETABS is good over STAAD Pro if u designing a reinforced concrete structure. The user interface is easy and the analysis values of RC structures are better and we get economical steel data from ETABS compared to that of STAAD pro.

STAAD Pro is good over ETABS for the analysis of steel structures frames as the codes and user ETABS and STAAD Pro both, I feel it's reliable for reinforced concrete design as it provides inbuilt options for optimization, seismic analysis parameter calculations like p∆ analysis, It Even has options for wind analysis with loaded codes and can consider gust loads. Few of the above options are not available with STAAD Pro.

# CHAPTER 2

## 2.1 LITERATURE REVIEW

Various literature has presented in the form of technical papers on grid slab. Various issues and points are covered in the review paper like seismic analysis of grid slab building as per seismic zones, storey displacement, storey drift and equivalent static and response spectrum method as per different IS-codes. Some of those are discussed below:

**Lalit Balhar et.al** (2019)**:** carried out the research on multi-storied RC slab buildings having flat slabs & conventional RC slabs with and without shear walls. All modelling is done in STAAD PRO software. For the analysis he was considering buildings of stories G+10. Building is subjected to gravity and dynamic loads and seismic zone V is selected. Analysis is done by time history analysis, response spectrum analysis, equivalent static analysis. From the analysis it has been observed that the lateral displacement is increasing from bottom level to top level and storey drift is minimum at bottom level and is increasing upto the middle stories and after that it will decreases upto top level of building for all types of models [1]

**Indrani V et. al** (2018)**:** It studies the Dynamic Analysis of Multistory RCC Building Frame with Grid Slab and Flat Slab. It is revealed from the study that base shear of grid slab building is more than the base shear of flat slab in building in both directions. Drift in grid slab building and flat slab building is within limit in both X and Y-directions. Axial force in intermediate columns of grid slab building is less as compared to flat slab building. Building drift in flat slab building is more as compared to grid slab building in each story and in both X and Y-directions. Axial force in end columns of flat slab building is less as compared to grid slab building [2]

**Ashwini Waghule et.al** (2018)**:** Reviewed on bubble deck slab and concluded that the usage is reduced by replacing the concrete by recycled plastic and reduces production of cement. Which will help in reduction of global $CO_2$ emissions. Hence this technology is environmentally green and sustainable. Reducing material consumption made it possible to make the construction time faster and reduces the overall cost of construction. By using this technology dead weight of slab is reduced up to 18%. Foundation sizes become smaller due to the reduced dead weight. The Bubble Deck configuration gives much improved shear capacity, flexural capacity and stiffness when the same amount of reinforcement and the concrete is used as in the solid slab. Waste plastic material is utilized in construction as it gives same strength or load carrying capacity as that of conventional slab. This type of slab is advantageously utilized for longer spans halls such as auditorium and theatre halls.[3]

**Mohd Aasim Ahmed** et.al (2018) Analysed that the Quantity of Concrete required for grid slab is more than conventional slab followed by flat slab for shorter spans. The Quantity of Steel required for grid slab is more than conventional slab followed by flat slab for shorter spans. As Span increases the Quantity of steel required for a slab system increases. The Maximum Joint Displacement (lateral sway) was found to be more for grid slab system followed by conventional slab system and least for flat slab system. The Maximum Joint Displacement (downward deflection) was found to be more for flat slab system followed by grid slab system and least for conventional slab system. The Maximum Storey Drift was found to be least for flat slab followed by conventional slab and more for grid slab system. The Maximum Column forces was found to be more for grid slab followed by conventional slab and least for flat slab system. The Maximum Column Moments was found to be more for grid slab followed by conventional slab and least for flat slab system.[4]

**S.V Mahamuni et.al** (2018) has done the analysis of the various methods by which grid floor system can be analysed. He has done the analysis of grid slab manually by using Plate theory, Rankine-Grashoff method, Stiffness method. Used various approaches for analyzing the grid slab system. For carrying out study, ratio of hall dimensions (L/B) from 1 to 1.5, halls having constant width 10.00m are considered. After applying the theoretical formulas, he observed that by using stiffness method, bending moment in x direction is increasing linearly by increasing L/B ratio. By using Rankine-Grashoff method it will give the lowest values of bending moment in x direction, which the lowest value among all the methods that is used in the analysis.[5]

**Sumit Sharma et.al** (2018) observed that thickness of the building having flat slab with shear wall changes with the storey height. Flat slab provides more flexibility to the building as compare to conventional slab. Flat slab also provides more stability and aesthetic view to the building. In case of industrial structures constructed in a square and rectangular layout the displacement is more in case of flat slab as compare to waffle system and displacement is increases with the increases in the height of the building.[6]

**R.S.More et.al** (2015) has done analytical study of different types of flat slab subjected to dynamic loading . Drift of flat plate is maximum than grid floor slab and flat slab. Grid slab has less drift compared to others. He gives the result that all slabs deflect within the limit when strata is of type one i.e. rock, or hard soil. There is definite correlation between increase in shear force and storey drift with change in soil condition for particular type of slab. [7]

**Ch. Rajkumar et.al** (2017) analysed a multistoried building and observed that the results are more conservative in Static analysis when compared with the dynamic analysis results in an uneconomical structure. Overall stiffness of the building increases therefore the sway problem in the structure reduces. As building is not regular the behaviour in x and y directions are not similar. For earthquake load the story drift values in x and y direction is higher than the wind load. For spectrum loads the storey shear is maximum in the top storey location. For top stories location the twisting moment increases from top to bottom stories. The story shear and twist increases from top to bottom storey for the bottom storey location and will be maximum for bottom storey. For force in z direction the support reaction values are maximum. [8]

**Anitha.K et.al** (2017) has done the analysis of grid slab and Observed the influence of various parameters on the economical spacing of the transverse beams in grid floor. The bending moment, the shear force and the mid span deflection developed in grid floor beams have been predicted by conventional and numerical methods and the results are compared. Area of steel required in the slab at a critical section for column are determined and also for the middle strips. Span to depth ratio 16 to 60 considered. The spacing of 0.5m to 2.0 m is used for transverse beams. the model is made by ANSYS 12.0 software. For the optimum performance of grid floors range of the magnitude of the various parameters to be considered in this paper.[9]

**Avinash Patel et.al** (2017) studied the behaviour of flat slab, grid slab and conventional slab separately. A comparative study was done to know which slab system is best**.** For this he performed the dynamic analysis of multi-storeyed building having flat slab, grid slab and conventional slab separately. In all the systems, the storey drift is within the permissible limits according to the IS:1893 (Part 1). Cost of grid slab system is more than the other slab systems. Storey drift in Flat Slabs are least than the other slab systems. The quantity of concrete and steel in case of Grid Slab system is huge when compared to Conventional Slabs or Flat Slabs. Flat Slabs resist the lateral loading most effectively than grid slab or conventional slab. [10]

**Sudhir Singh Bhaduria et.al** (2017) have studied the Comparative Analysis and Design of Conventional Slab System, Grid Slab System and Flat slab system. After the analysis, observed that the flat slab structure is more economical than the other slab systems. The quantity of steel and concrete required for grid slab system is maximum but for the flat slab system is minimum. In case of grid slab system maximum bending moment, maximum displacement and maximum force is found to be maximum. In flat slab system it is observed that the maximum bending moment, maximum displacement and maximum force is minimum in all the direction. [11]

**Harish M K.** et .al (2017) Analysed G+4 having Grid Slab in Building by Using Response Spectrum Method. The writer perform analysis for both seismic, gravity and wind force conditions according to the IS codes. The grid slab system is analyzed by using ETABS software. Because of the Box effect of modular type scheme, the overall stiffness of the building increasing due to this the sway problem in the structure is reduced. For irregular building the behavior is not similar in both directions x and y. For spectrum loads storey shear is maximum in the top stories location. For bottom storey, storey shear will be maximum. The storey shear increases from top storey to bottom storey for the bottom storey location. For earthquake load, storey drift values in x and y direction is higher than the wind load.[12]

**Mayuri S. Sethia et.al** (2017)**:** Compared to different types of Flat slab. Concrete and steel required is less in Flat with Drop panel. Drops are important criteria in increasing the shear strength of slab. For high rise structure, in order to increase rigidity of slab, column heads are incorporated. Drop panel increase negative moment capacity of slab. It stiffens the slab and therefore reduces deflection. Compared to different grids of grid Slab, Concrete and steel required is less in (1.5*2.0 m) grid panel. Rate of shuttering of grid slab is almost double the rate of Flat slab. Grid slab requires special or proprietary formwork, due to which flat slab with drop is preferred.[13]

**Avinash Patel et.al** (2017)**:** Analysed that in all the systems, the storey drift is within the permissible limits as per IS:1893 (Part 1). However grid floor system show better results when compared to other slab systems. When it is compared to Flat Slabs there is an increase of 163.57 % in the cost of Grid Slabs and increase of 45.97 % in the cost of Conventional slabs. This results in a reduction of 66.12 % in the amount of storey drift in Flat Slabs. There is a huge increase in the quantity of steel and concrete in Grid Slabs system when compared to Conventional Slabs or Flat Slabs.It is because of the increase in the number of beams in the Grid Slabs system. In Flat Slab system the lateral loading is most effectively resisted. Grid floor systems have longer service life. Due to the earthquake hazards flat slabs with shear walls are provided. Variation of cost is affected by the response reduction factor. Earthquake resisting techniques like base isolation, shear walls can be used to increase the effectiveness of the structure.[14]

**Uttam V Chothani et.al** (2016) Analysed that the flat slab with drop is the most economical from the economic point of view when it is compared to the rcc grid slab and flat slab without drop.

They considered the flat slab with drop and reinforced concrete flat slab, flat slab without drop. The thickness of reinforced concrete flat slab are 22% and 32% greater respectively and its cost are 25% and 27% greater respectively. The cost increases gradually if the panel sizes increases. The pure reinforced concrete flat slab structural system is more flexible for horizontal loads than the traditional RC frame structure which contributes to the increase of its exposure to seismic effects. Flat slab with drop is more economical than flat slab without drop and grid slab. Concluded that the Concrete required in grid slab is more as compared to flat slab without drop and flat slab with drop.[15]

**Chintha Santhosh** et.al (2016): Analysed a Multistory Building with Grid Slab by Using ETABS software. It is showed in the study that the maximum displacement is observed in flat slab with drop compare to grid slab without and with infills in both zones. Maximum Time period of grid slab is less in compare with flat slab without and with drop without and with infills structures in zone IV. Deflection is observed more in zone IV than zone III. Storey drift values of different types of buildings are within the permissible limit as per IS-1893-2002 code provision that is the 0.4% of height the floor. Structures having infills have less time period compare to structure without infills. Grid slab systems have maximum base shear in comparison with flat slab without and with drop in zone III and IV.[16]

**Salman I Khan et.al** (2015) analyse the seismic performance of multi-storied buildings having different floor heights and having different floor systems like Flat slabs, conventional solid slab-beam systems and Grid slabs. The storey drift in building with flat slab construction was significantly more as compared to conventional RCC building. The axial force in the intermediate columns are more in case of flat slabs than grid slabs. Buildings having the flat slab system are weaker in shear as compared to those with conventional or even grid slab systems. As a result, additional moments were developed. Therefore, the columns of such buildings should be designed by considering additional moments caused by the drift. The base shear of a multi-storey structure with grid slab is more as compared to flat slab.[17]

**Mohana H.S** et.al (2015) studied the Comparative Study of Conventional Slab and Flat Slab Structure Using ETABS for the Different Earthquake Zones of India . In this paper he observed that the storey shear of flat slab is 5% more than that of conventional grid-slab structure. The axial forces on flats slab building is nearly 6% more than conventional building. The difference in storey displacement of conventional building and flat building are about 4mm in each floor. Storey shear intensities, displacement, axial force are the parameters that increases with the increase of seismic level.[18]

**Amit A. Sathawane et.al** (2012) Analysed that the drops are important criteria in increasing the shear strength of the slab and increase resistance to punching failure at the junction of concrete slab and column. By introduction of heads in slab, rigidity of slab increases. Steel required in Flat slab without Drop is more as compared to Flat slab with Drop and Grid slab. Concrete required in Grid slab system is more when it is compared to the Flat slab with Drop and Flat slab without Drop. Flat slab with drop is more economical than flat slab without drop and grid slab. Rate of flat slab system with drop was found to be more economical than the flat slab without drop and grid slab [19]

**R.Arvind et.al :** This paper deals with voided slabs using U-boot beton technology made by recycled polypropylene, the technology is designs for lightweight slabs in RCC. It is solution to build slabs of large spans with more bearing capacity. U-Boot its lightweight, stability, modularity, can be used to make structures without mechanical helps of equipment and it’s also foundation rafters can be created with a low amount of concrete with big thickness. By using U-boot beton, it is easy to build raft foundations with a low quantity of concrete. It is used in high rise buildings to reduce the weight of the structure. It reduces the construction time and also requires less labours. It has high fire resistance and it’s economical. Higher number of floors can be built. The u- boot beton is so economical, efficient, Fire resistance, and Eco friendly. Thus, the result gives a clear view of u-boot beton that is very useful for construction purpose.[20]

# CHAPTER 3
# APPROACH AND METHODOLOGY

## 3.1 STRUCTURAL DESIGNING

Structural engineers have proper technical knowledge for structural detailing and their analysis. So, they are more experienced to design structures. The structural designing procedures carried out by the structural engineers include **calculating the loads and the stresses acting on the building, analysis results for the applied loading, design of sections of structures to sustain the loads**, so that the structure designed will withstand the loads predicted safely.

The structural engineers are also involved in the **selection of materials** best suited for the structure. This will hence ask for good knowledge about the different materials that are used in the construction at the current condition like their economic factors, strength factors and durability factors.

The quality factors of different building materials can be analysed by a structural engineer to finalize their suitability in the design of the beams, columns or the foundations.

Another skill of a structural designer is the **analysis of structures**. This is presently carried out by the software like ETABS, STAAD PRO, SAP etc. As years pass new software are being developed for the analysis of structures at different conditions of loads like wind, earthquake etc.

Most of the structural engineers have to study and work with this software with a knowledge of both the technical details and the programming details. In some organizations, the analysis is carried out by a programmer who may not have the civil engineering graduation but is assisted by a structural engineer.

Whatever be the mode of analysis done, the structural engineer must have the ability to understand and **interpret the results from the software** to know the validity of the values provided as output. Some organization won't completely rely on the computer results, they conduct a separate man-made calculation for assurance.

Even though structural engineers are the ones that bring and develop the design ideas and detail, he can only see it happen on the site only if the structure is constructed as desired. For this interpretation and ideas have to conveyed with the other members of the projects.

The structural engineer has to make coordination and consult other members like the site engineers, other design engineers, geotechnical engineers, landscape architects, architects, project managers etc. Proper knowledge helps in spreading correct information among the group avoiding confusion and errors.

## 3.2 WORKING TIME AND LOCATION OF A STRUCTURAL ENGINEER

When looking into the working time and the place spent by the structural engineers, most of the highly involved structural engineers will be working in office as well as on the construction sites.

They can work by splitting the time between both the contexts. The locations of work vary based on the working environments. Rural or metropolitan areas have different working schedules and environment.

The structural engineers may have to work for long hours sometimes similar to site engineers, which mainly depend on the size of the project and the size of the organization. If the structure of the organization is well defined and large, it will have sufficient members for the design team, planning team, execution team with a group of professionals, skilled as well as semi-skilled employees and workers. This will reduce some burden on the structural engineer.

## 3.3 ROLES AND RESPONSIBILITIES OF STRUCTURAL DESIGN ENGINEERS IN CONSTRUCTION

A strong knowledge of physics, creative problem solving and three-dimensional conceptual skill must be gained by a structural engineer. Other than these, the roles and the responsibilities of the structural engineer includes:

- Structural Designing
- Site and Work Investigations
- Communication

Adequate Training is required for a Structural Engineer to make him technically sound so that he can solve complex problems, find solutions of various problems and can make efforts to rectify errors as much as possible. The structural model is composed of framed structure, with beams and columns being monolithically considered.

## 3.4 DESCRIPTION OF MODEL TYPE

The model consists of RCC frame with concrete as a base material. This project mainly consists of **Grid Slab and Flat slab** in building at each level. Flat slab is being used at front portion of building to make beamless area for aesthetic purpose whereas inner side of building is having grid slab to resist loads easily and to increase rigidity of the structure. This consideration of both flat slab and grid slab helps us to minimize use of closely spaced columns. The various parameters taken for analysis and design process are mentioned below:

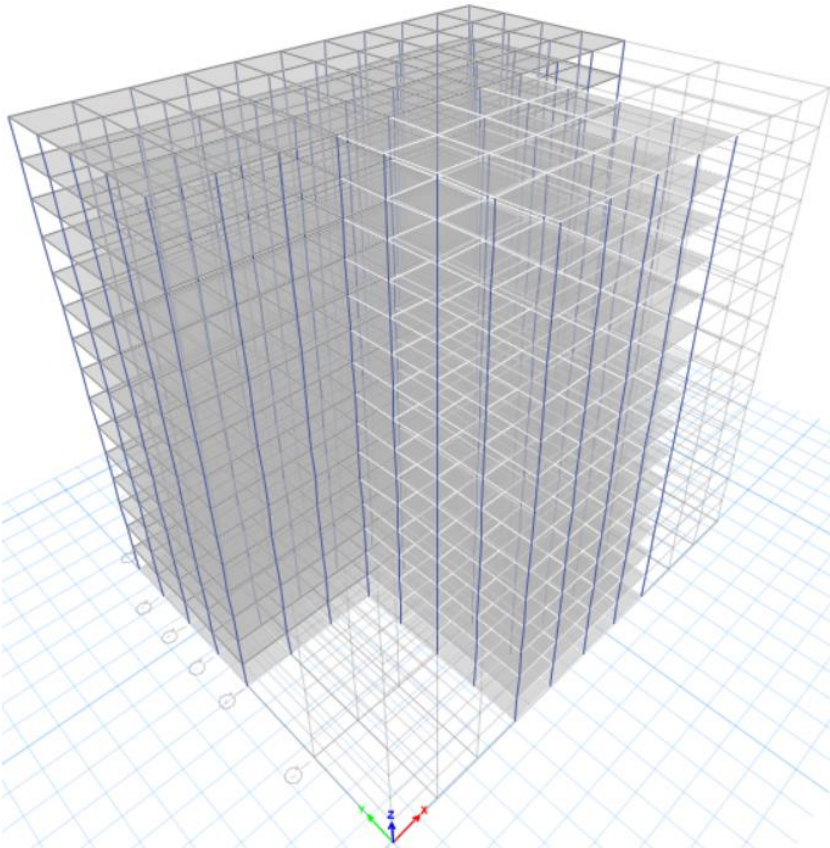


**Fig3.1: Isometric view of structure.**

No of Floors = G+14

Height of each Floor = 3m

Beam Size = 300 mm X 250 mm

Column Size's taken = 500mm X 400mm, 350mmX300mm, 450mmX350mm

and 550mmX500mm.

Flat Slab Thickness = 150 mm

Grid Slab Thickness (Waffle Slab) = 450 (Overall)

Live load on each floor = 3 $KN/M^2$

Load due to Floor Finish = 0.75 KN/M$^2$

Type of Soil = Medium

Zone = III

Grade of Concrete used = M25

Grade of Steel = Fe-415

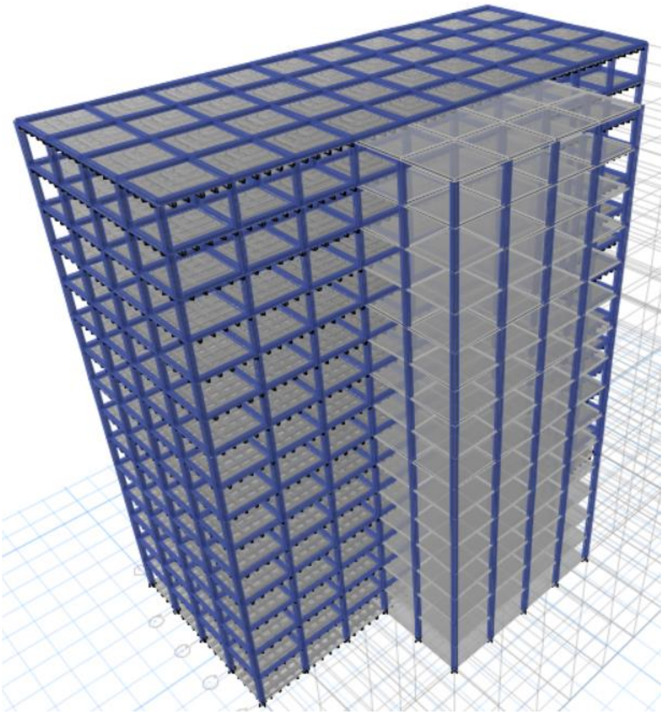


**Fig 3.2: 3D Rendered view of building.**

The structure composes of both flat and grid slabs. Above diagram makes it clear by showing rendered view of structure. When slabs are used without beams, they are called flat slabs. That means load coming on slab is resisted by slabs itself but not transferred to beams. In case of flat slab load is directly transferred from slab to columns. In this configuration of slabs, load is not distributed in one way or two way phenomenon. Drop panels were used to prevent the structure from punching failure.

The Plan decided to complete this research was of greater importance. So, accordingly I chose a Plan which can fulfil all the requirement's in the whole analysis process. The Plan taken for modelling of a building is shown below:

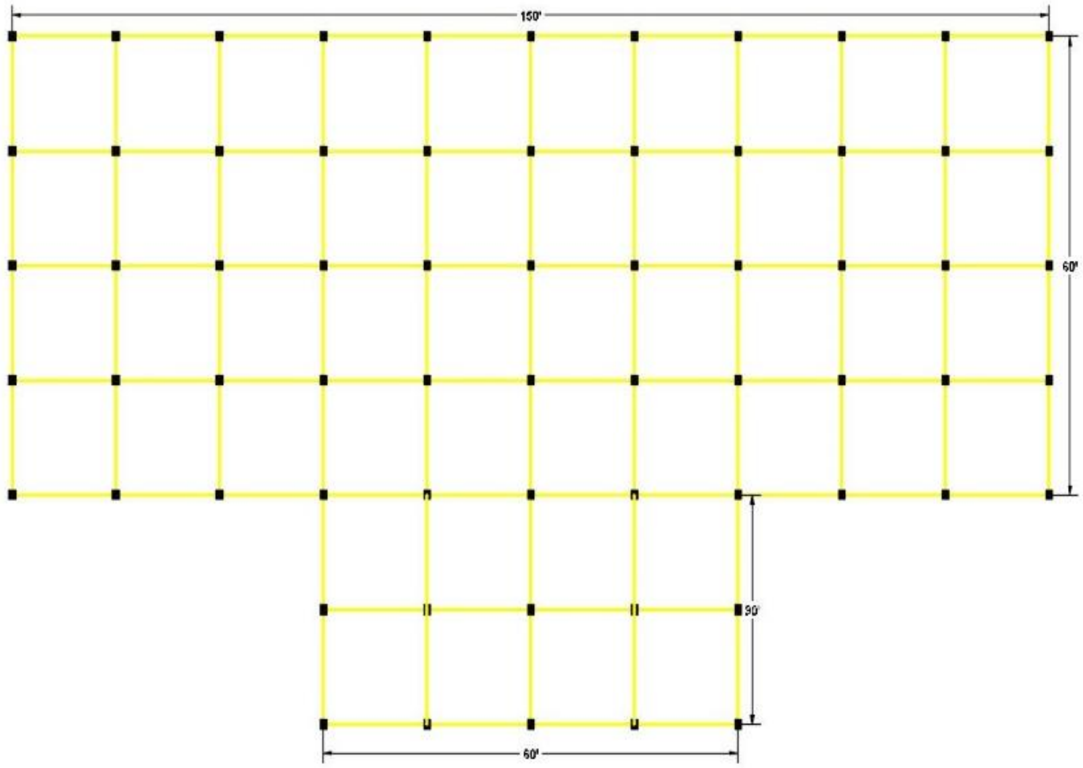



**Fig 3.3: AutoCAD file showing PLAN of Structure.**

## 3.5 LOADING

Consideration of loading is the main aspect which must be taken very carefully as the Analysis and Design Process is based on loading conditions. The various codes to finalize the magnitude of loading are mentioned below:

IS-875 (Part 1) ________ Design Code for Dead Loads.

IS-875 (Part 2) ________ Design Code for Live Loads.

IS-875 (Part 3) ________ Wind Load Design Code.

IS-456 :2000 _________ Concrete Design Code.

IS -800: 2007 __________ Steel Design Code.

IS-10262: 2009 ________ Mix Design Code.

IS-1893: 2002 _________ Earthquake Design Code.

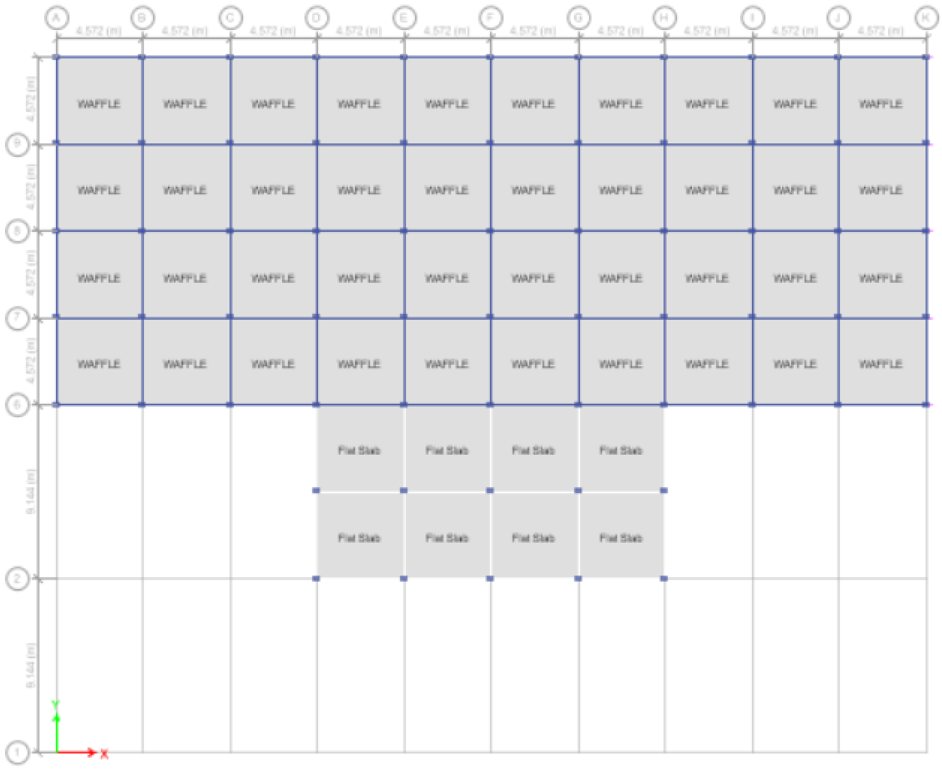


**Fig 3.4: Plan of Structure**

Above figure shows the plan view of structure labelled with waffle slab and flat slab.

Loads are the main parameters which we must consider while designing to make the final project such that it can resist all loading. The loads variety according to the function of the structure. The residential buildings are considered in general structures whereas institutional or commercial buildings are considered in important structures. The load distribution is same in case of residential and commercial structures as the building blocks are of same properties and mechanism but there is variation in amount of material used only. The loads are distributed from slab to beams. The slabs may distribute load in two ways that is either by one-way distribution or two-way distribution.

In case of one-way distribution, the load is transferred to longer span beams and shorter span beams experience minimum loading which is neglected in calculation process. A slab is said to be One-way slab when the ratio of longer span to shorter span is greater than 2 whereas a slab is said to be Two-Way when the ratio of longer span to shorter span is less or equal to 2.

After the transfer of loads from slab to adjacent beams, the load is transferred to columns and then finally to foundation.

# CHAPTER 4

# ANALYSIS AND DESIGN RESULT FROM ETABS.

## 4.1 STRUCTURE DATA

This chapter provides model geometry information, including items such as story levels, point coordinates, and element connectivity.

### 4.1.1 Story Data

**Table 4.1 - Story Data**

| Name | Height Mm | Elevation mm | Master Story | Similar To | Splice Story |
|---|---|---|---|---|---|
| Story15 | 3000 | 45000 | Yes | None | No |
| Story14 | 3000 | 42000 | No | Story15 | No |
| Story13 | 3000 | 39000 | No | Story15 | No |
| Story12 | 3000 | 36000 | No | Story15 | No |
| Story11 | 3000 | 33000 | No | Story15 | No |
| Story10 | 3000 | 30000 | No | Story15 | No |
| Story9 | 3000 | 27000 | No | Story15 | No |
| Story8 | 3000 | 24000 | No | Story15 | No |
| Story7 | 3000 | 21000 | No | Story15 | No |
| Story6 | 3000 | 18000 | No | Story15 | No |
| Story5 | 3000 | 15000 | No | Story15 | No |
| Story4 | 3000 | 12000 | No | Story15 | No |
| Story3 | 3000 | 9000 | No | Story15 | No |
| Story2 | 3000 | 6000 | No | Story15 | No |
| Story1 | 3000 | 3000 | No | Story15 | No |
| Base | 0 | 0 | No | None | No |

### 4.1.2 Loads

This chapter provides loading information as applied to the model.

#### 4.1.2.1 Load Patterns

**Table 4.2 - Load Patterns**

| Name | Type | Self Weight Multiplier | Auto Load |
|---|---|---|---|
| Dead | Dead | 1 | |
| Live | Live | 0 | |

| Name | Type | Self Weight Multiplier | Auto Load |
|---|---|---|---|
| Masonry | Superimposed Dead | 0 | |
| Ex | Seismic | 0 | IS1893 2002 |
| Ey | Seismic | 0 | IS1893 2002 |

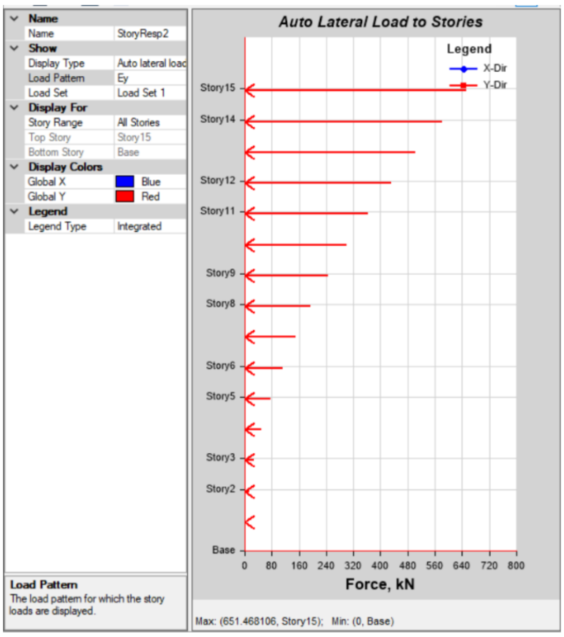



Fig 4.1(a): Earthquake loading along-X

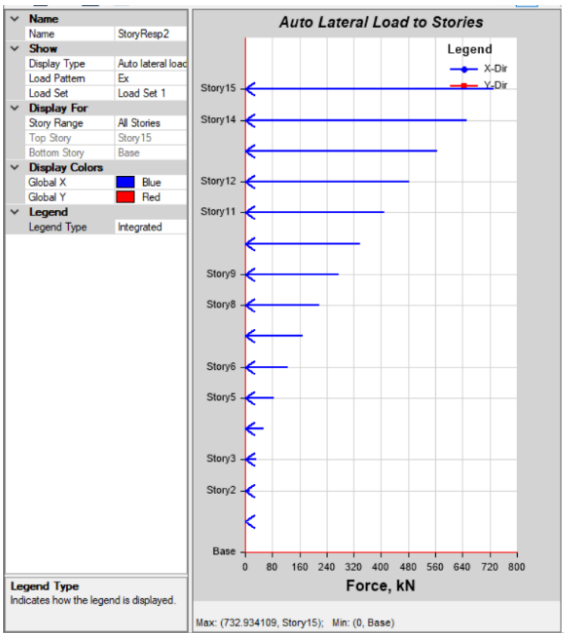



Fig 4.1(b): Earthquake loading along-Y

The lateral loads considered for this structure in shown by two graphs above. Intensity of earthquake depends on the zone in which building is located. The consideration of earthquake zone for this building is zone III and location for the construction site is Lucknow UP, India. Earthquake loading is the main cause of building failure in earthquake prone areas. So, to make building earthquake resistant we consider earthquake loading while analysing a structure. Dynamic analysis is the main consideration if building is of 5 or more than 5 stories.

### 4.1.3 Functions

#### 4.1.3.1 Response Spectrum Functions

**Table 4.3 - Response Spectrum Function - IS 1893:2002**

| Name | Period sec | Acceleration | Damping | Z | Soil Type |
|---|---|---|---|---|---|
| Responce Spectrum | 0 | 0.36 | 5 | 0.36 | III |
| Responce Spectrum | 0.1 | 0.9 | | | |

| Name | Period sec | Acceleration | Damping | Z | Soil Type |
|---|---|---|---|---|---|
| Responce Spectrum | 0.67 | 0.9 | | | |
| Responce Spectrum | 0.8 | 0.7515 | | | |
| Responce Spectrum | 1 | 0.6012 | | | |
| Responce Spectrum | 1.2 | 0.501 | | | |
| Responce Spectrum | 1.4 | 0.429429 | | | |
| Responce Spectrum | 1.6 | 0.37575 | | | |
| Responce Spectrum | 1.8 | 0.334 | | | |
| Responce Spectrum | 2 | 0.3006 | | | |
| Responce Spectrum | 2.5 | 0.24048 | | | |
| Responce Spectrum | 3 | 0.2004 | | | |
| Responce Spectrum | 3.5 | 0.171771 | | | |
| Responce Spectrum | 4 | 0.1503 | | | |
| Responce Spectrum | 4.5 | 0.1503 | | | |
| Responce Spectrum | 5 | 0.1503 | | | |
| Responce Spectrum | 5.5 | 0.1503 | | | |
| Responce Spectrum | 6 | 0.1503 | | | |
| Responce Spectrum | 6.5 | 0.1503 | | | |
| Responce Spectrum | 7 | 0.1503 | | | |
| Responce Spectrum | 7.5 | 0.1503 | | | |
| Responce Spectrum | 8 | 0.1503 | | | |
| Responce Spectrum | 8.5 | 0.1503 | | | |
| Responce Spectrum | 9 | 0.1503 | | | |

| Name | Period sec | Acceleration | Damping | Z | Soil Type |
|---|---|---|---|---|---|
| Responce Spectrum | 9.5 | 0.1503 | | | |
| Responce Spectrum | 10 | 0.1503 | | | |

### 4.1.2.3 Load Cases

**Table 4.4 - Load Cases - Summary**

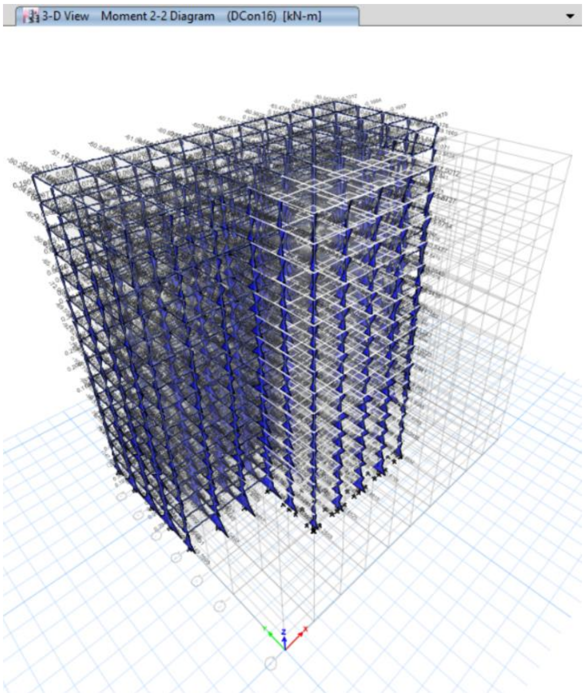
| Name | Type |
|---|---|
| Dead | Linear Static |
| Live | Linear Static |
| RS | Response Spectrum |
| Masonry | Linear Static |
| Ex | Linear Static |
| Ey | Linear Static |

## 4.2 ANALYSIS RESULT

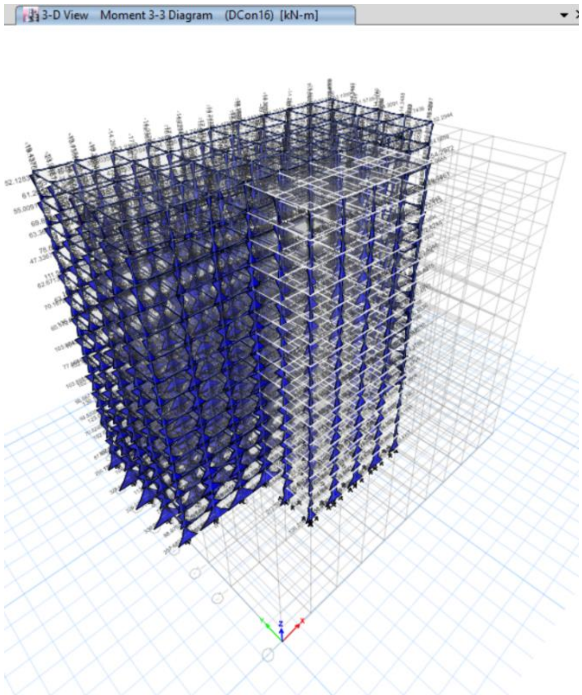
### 4.2.1 Bending Moment

Two figures shown below gives the bending moment of whole structure along two axes. Bending moment gives the idea about how much reinforcement is required for a section to resist external loading. Below shown diagrams are the calculation of bending moment on design combination 16. Bending moment goes on increasing as we move from top to bottom. This makes it clear that area of reinforcement requirement for below members will be more as compared to top members.

It is also found that bending moment will be greater at grid slabs and lesser at flat slabs as there are no beams. So, in this case reinforcement provided will be greater in the region of grid slabs as compared to flat slabs.




**(a) Along 2-2 axes**




**(b) Along 3-3 axes.**

**Fig 4.2: Bending Moment Diagram.**

## 4.2.2 Shear Force Diagram:

This force is the algebraic sum of vertical forces at a section. Shear force at a section gives idea about the provision of shear reinforcement to prevent cracking.

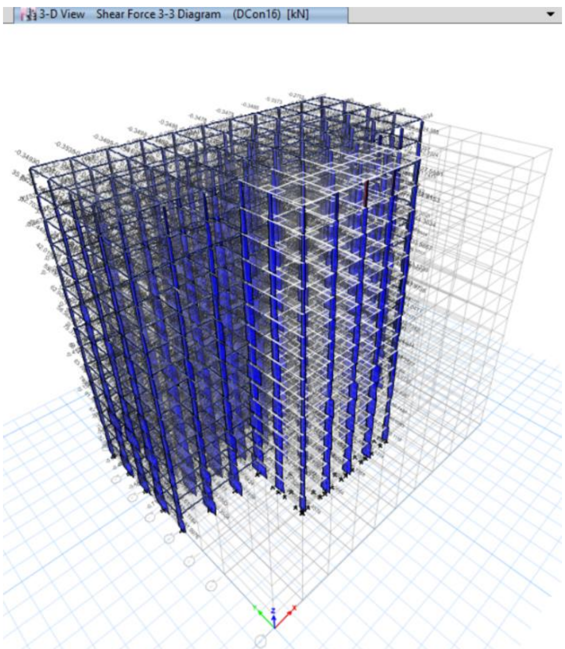



**Fig 4.3: Shear Force on 3-3 axis.**

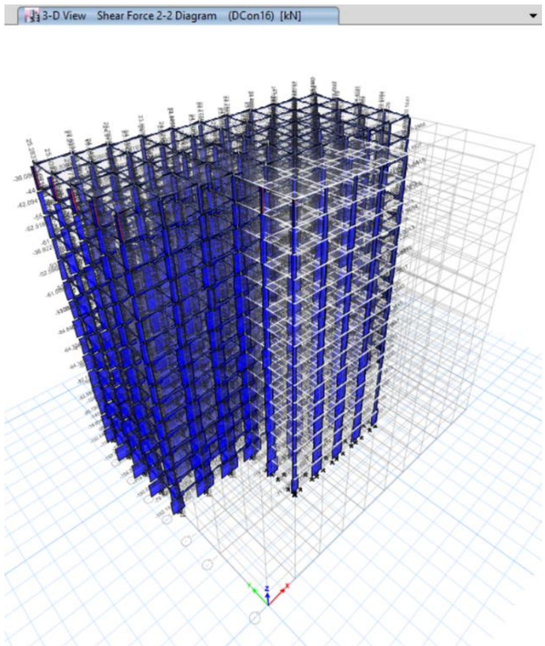



**Fig 4.4: Shear Force on 2-2 axis**

### 4.2.3 Displacement

Displacement is due to external loads, in this project maximum displacement takes place in the area where there are flat slabs. Some pictorial representation showing displacement due to dead load in slabs are shown below:

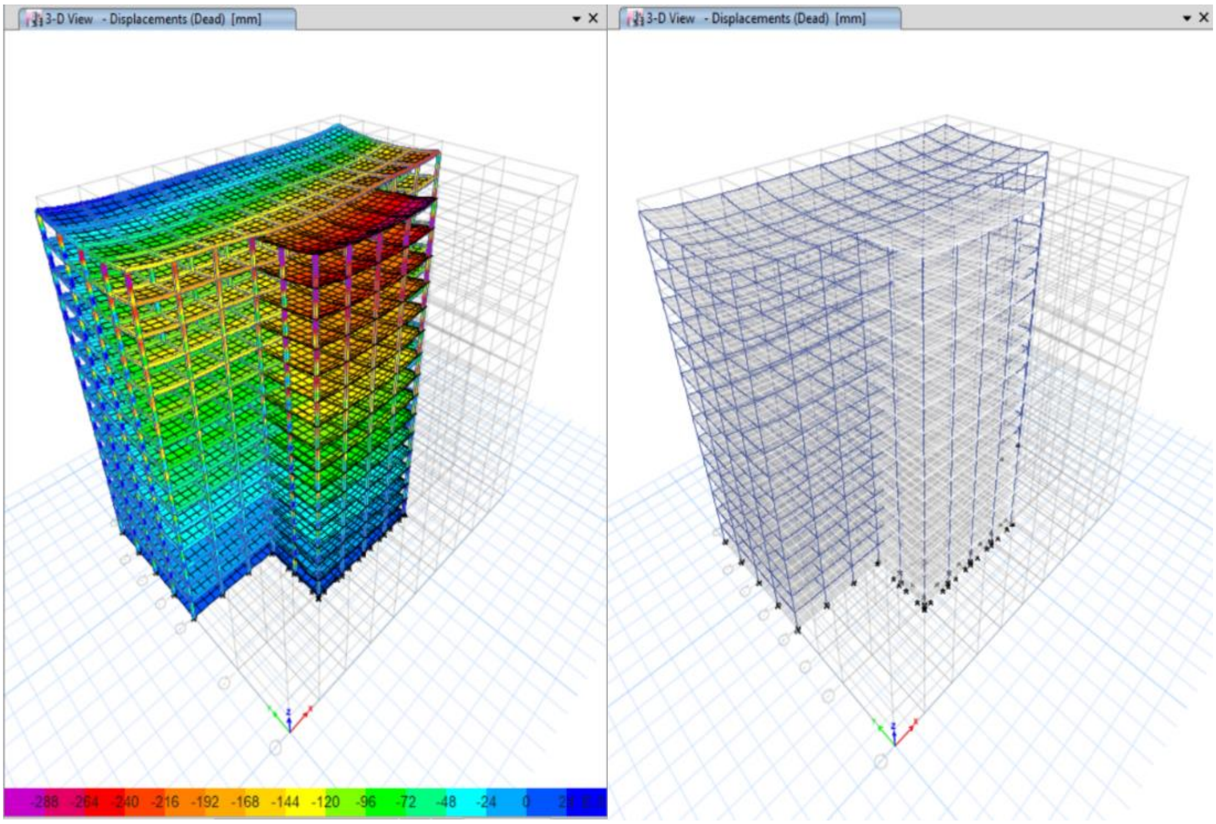



**Fig 4.5: Deformation in Building**

It is found that max displacement in slabs reach up to $240X10^{-3}$ mm shown in red zone. It can be clearly depicted that flat slabs experience maximum displacement as compared to grid slabs.

### 4.2.4: Stress in slab


**Fig 4.6: Comparison in stress between in the area of flat and waffle slab.**

Some green spots can be seen near columns showing less stress in slabs near columns. Stress analysis in slabs was broadly checked to know the different nature of flat and grid slabs. Above pictures show stress at top storey.

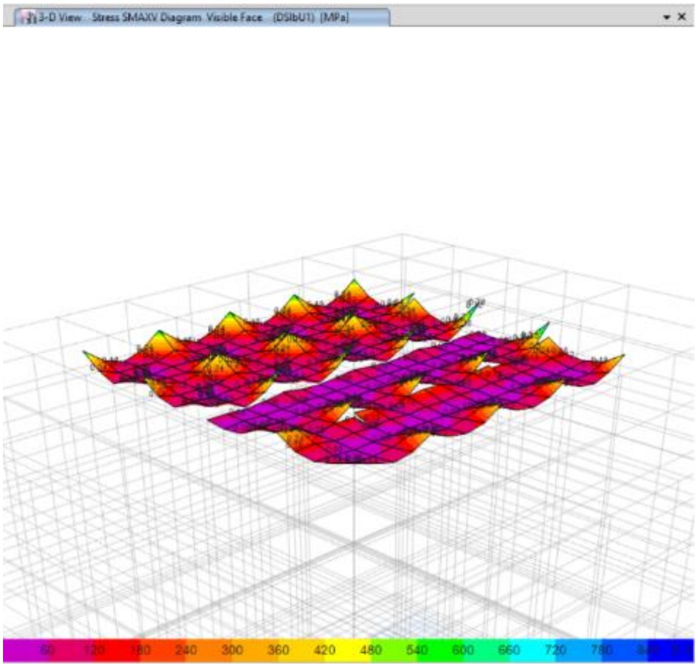


**Fig 4.7 Stress Diagram**

Picture showing Stress levels in each zone of slab. Slabs are shown apart to make it clear. This is the stress diagram of visible face.

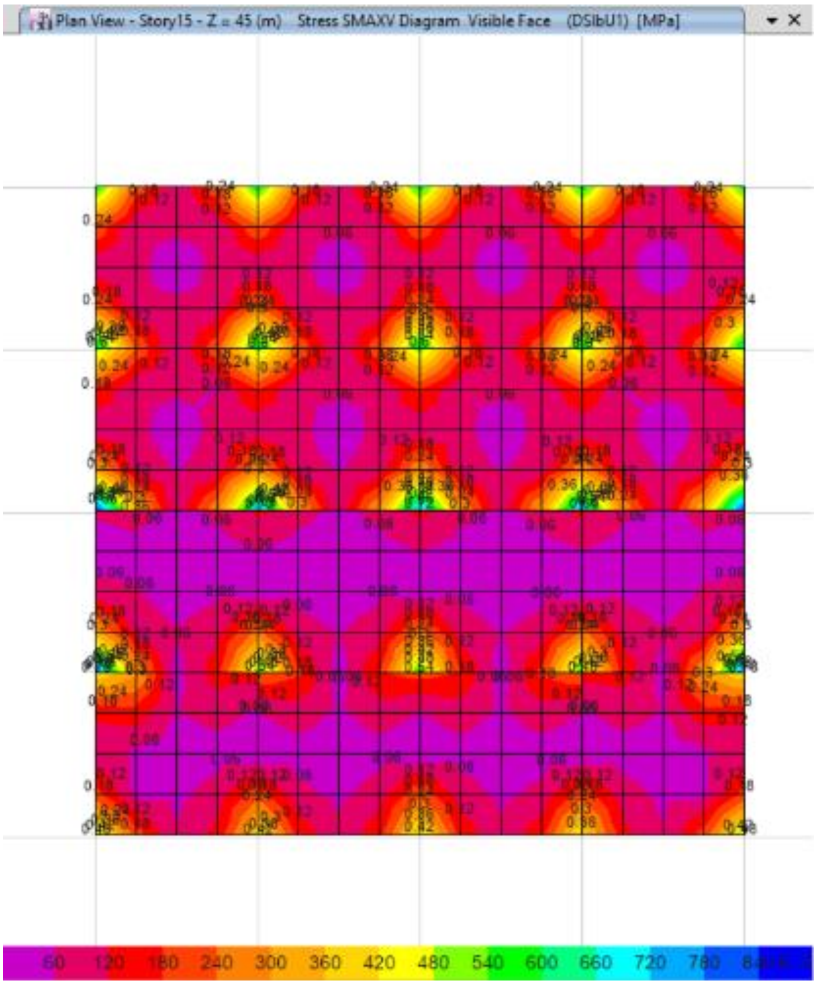



**Fig 4.8 : Stress in Flat Slab and Grid Slab.**

Above picture shows that magnitude of stress is less in grid slabs as compared to flat slabs. Above panels are waffle slabs and below panels are showing flat slabs. It can be seen that purple color is spread more in the area of flat slabs. As per scale shown below picture purple color shows region with greater stress whereas blue color shows less stress. Here it is clear that stress will be maximum at mid span of slab. Slab portion near columns experience less stress shown by yellow color. Above portion in slab shows color between red and orange while as bottom portion shows maximum area with purple color. But stress at column looks same in both the cases.

## 4.2.5: Storey Displacement

Displacement is calculated for each member of building including beams, columns and slabs. The results are taken to know effect at each load combination. It is necessary to check storey displacement to know if it found under limit. Below graph shows the storey displacement. Here maximum displacement occurs on top storey with magnitude of less than $13.5X10^{-3}$mm and displacement on base is zero. Red line shows displacement along

Y-axes whereas blue line shows displacement along x-axes. As there is large span along X-axis that is why stiffness of building is greater in this direction. And it clear that displacement along Y direction will be maximum because of small span.

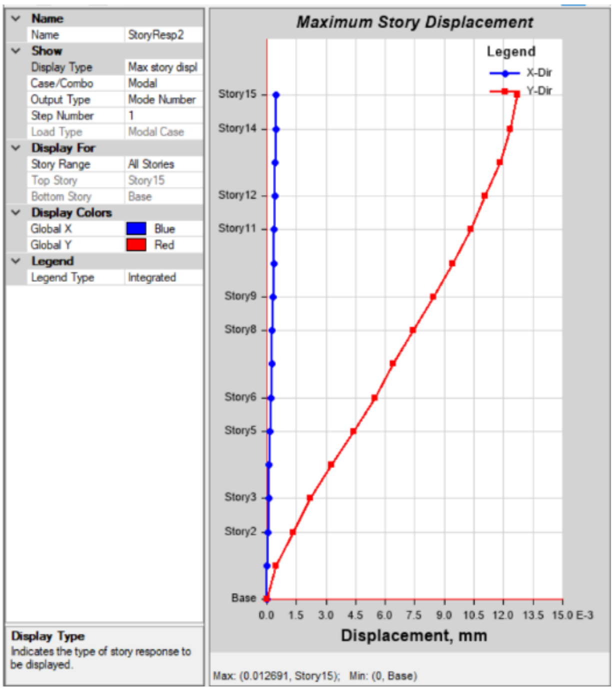



**Fig 4.9 : Storey Displacement.**

## 4.2.6 Story Response - Maximum Story Displacement

This is story response output for a specified range of stories and a selected load case or load combination.

**Input Data**

| | | | |
|---|---|---|---|
| Name | StoryResp1 | | |
| Display Type | Max story displ | Story Range | All Stories |
| Modal Case | Modal | Top Story | Story15 |
| Mode Number | 1 | Bottom Story | Base |

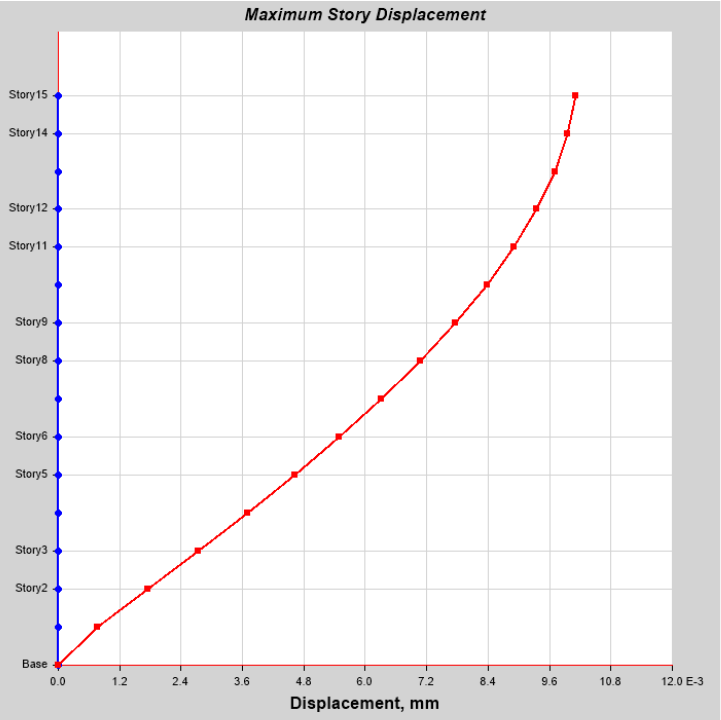



**Fig 4.10: Storey Displacement (Response Spectrum)**

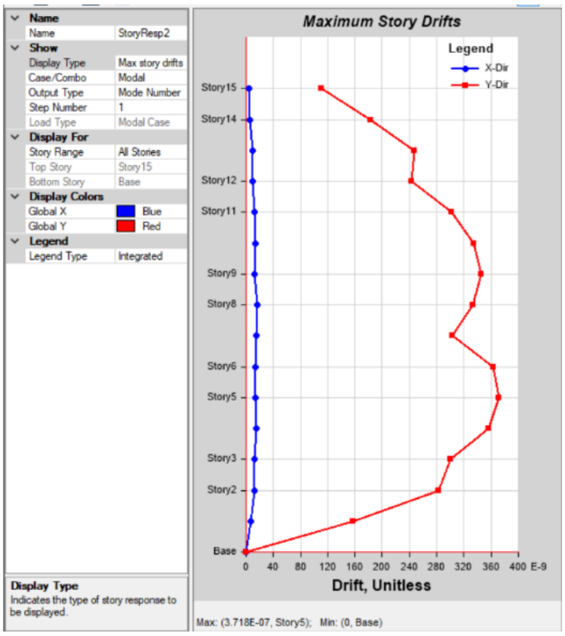
**Tabulated Plot Coordinates**

**Table 4.5 : Story Response Values**

| Story | Elevation | Location | X-Dir | Y-Dir |
|---|---|---|---|---|
| | m | | mm | mm |
| Story15 | 45 | Top | 2.65E-07 | 0.01 |
| Story14 | 42 | Top | 4.657E-07 | 0.01 |
| Story13 | 39 | Top | 3.924E-07 | 0.01 |
| Story12 | 36 | Top | 3.824E-07 | 0.009 |
| Story11 | 33 | Top | 3.716E-07 | 0.009 |
| Story10 | 30 | Top | 3.588E-07 | 0.008 |
| Story9 | 27 | Top | 3.444E-07 | 0.008 |
| Story8 | 24 | Top | 3.285E-07 | 0.007 |
| Story7 | 21 | Top | 3.112E-07 | 0.006 |
| Story6 | 18 | Top | 2.926E-07 | 0.005 |
| Story5 | 15 | Top | 2.728E-07 | 0.005 |
| Story4 | 12 | Top | 2.532E-07 | 0.004 |
| Story3 | 9 | Top | 2.25E-07 | 0.003 |
| Story2 | 6 | Top | 2.893E-07 | 0.002 |
| Story1 | 3 | Top | 2.083E-06 | 0.001 |
| Base | 0 | Top | 0 | 0 |

### 4.2.7 Storey drift:

The resultant drift in two adjacent storey define storey drift. Below graph makes it clear to know the condition of the building for storey drift due to external loading.



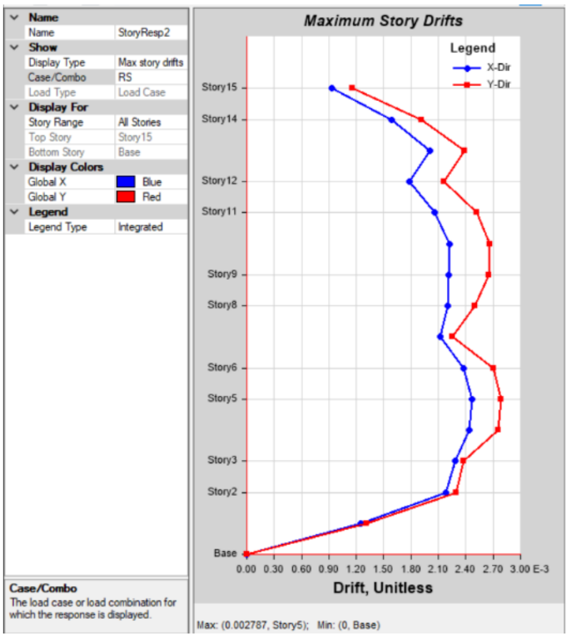



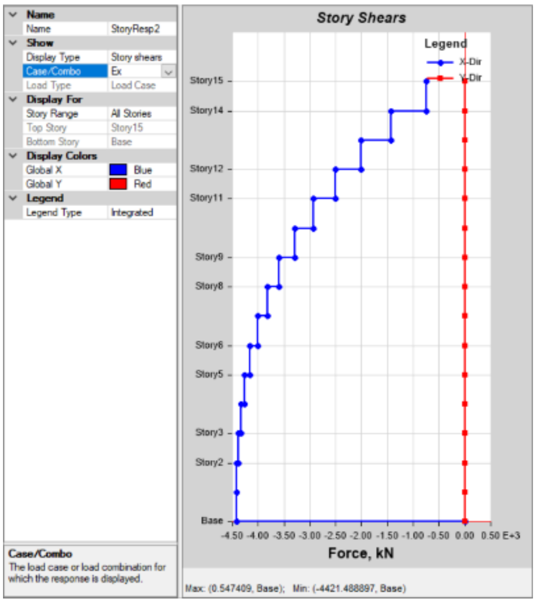

**Fig 4.11: Maximum Storey Drift** .

**Fig 4.12: Storey drift due to Response Spectrum**

It is found that Storey drift along X-axis is minimum as compared to Y -axis because displacement along y axis is greater than the displacement along x-axis. It mainly depends on orientation of building. If building is symmetrical along both the axes then there will be same drift along both the axes.

### 4.2.8: Storey Shear

Shear is the resultant force at a point. Below graph shows along X axes and Y axes. Graph “A” shows Shear due to earthquake along X axes. This graph makes it clear that shear due to earthquake along x-axes will be maximum as loading will be in that direction and shear will be zero along y direction in this case as shown clearly in graph. In addition to this it can be found that shear will be maximum always at base as magnitude of earthquake increases from top to bottom. It will be minimum at top of structure.



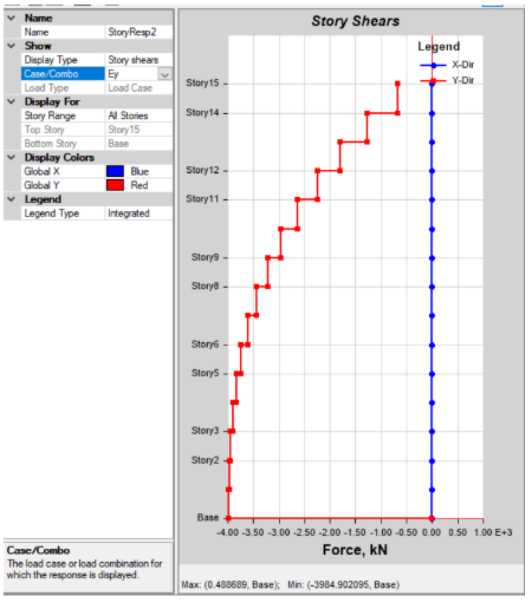




**Fig 4.13(A): Storey Shear due to EQ-X** **Fig 4.13(B): Storey Shear due to EQ-Y**

Similarly red line in figure "B " shows shear on consecutive storey's due to earthquake loading along Y-axis.

## 4.2.9 Storey Stiffness

This is the reaction of storeys towards force being exerted on it. Storey stiffness defines the amount of force that will lead to failure along and the resistance of storey to counter act that critical load.The values of story stiffness are tabulated below.

**Table 4.6 - Story Stiffness**

| Story | Load Case | Shear X kN | Drift X mm | Stiffness X kN/m | Shear Y kN | Drift Y mm | Stiffness Y kN/m |
|---|---|---|---|---|---|---|---|
| Story15 | RS | 1004.0369 | 1.391 | 721882.369 | 947.9339 | 1.742 | 544208.824 |
| Story14 | RS | 1844.3391 | 2.378 | 775453.725 | 1719.6557 | 2.866 | 599929.85 |
| Story13 | RS | 2460.4419 | 3.016 | 815749.595 | 2263.0174 | 3.581 | 631996.223 |
| Story12 | RS | 2930.011 | 2.675 | 1095415.317 | 2672.1854 | 3.242 | 824277.67 |
| Story11 | RS | 3350.2201 | 3.091 | 1083902.259 | 3044.0616 | 3.783 | 804669.895 |
| Story10 | RS | 3707.4804 | 3.326 | 1114596.972 | 3360.5014 | 3.997 | 840762.293 |
| Story9 | RS | 4024.0344 | 3.319 | 1212488.714 | 3641.5952 | 3.984 | 914132.324 |

| Story | Load Case | Shear X kN | Drift X mm | Stiffness X kN/m | Shear Y kN | Drift Y mm | Stiffness Y kN/m |
|---|---|---|---|---|---|---|---|
| Story8 | RS | 4332.7138 | 3.31 | 1308982.417 | 3917.5974 | 3.752 | 1044004.385 |
| Story7 | RS | 4641.682 | 3.189 | 1455746.398 | 4195.4063 | 3.371 | 1244486.782 |
| Story6 | RS | 4945.3359 | 3.556 | 1390720.606 | 4470.6671 | 4.052 | 1103201.92 |
| Story5 | RS | 5239.1512 | 3.694 | 1418400.221 | 4732.1099 | 4.181 | 1131839.193 |
| Story4 | RS | 5548.8036 | 3.664 | 1514311.94 | 5016.8718 | 4.133 | 1214000.8 |
| Story3 | RS | 5861.3737 | 3.434 | 1706963.141 | 5314.2148 | 3.566 | 1490248.406 |
| Story2 | RS | 6115.5485 | 3.273 | 1868583.876 | 5562.435 | 3.447 | 1613519.961 |
| Story1 | RS | 6229.1227 | 3.699 | 1683823.041 | 5674.747 | 3.895 | 1456903.314 |
| Story15 | Ex | 750.1542 | 1.127 | 665411.107 | 0.0338 | 0.071 | 0 |
| Story14 | Ex | 1422.3534 | 1.938 | 733841.142 | 0.0705 | 0.147 | 0 |
| Story13 | Ex | 2005.1942 | 2.563 | 782225.607 | 0.1083 | 0.179 | 0 |
| Story12 | Ex | 2508.1534 | 2.374 | 1056634.269 | 0.1471 | 0.235 | 0 |
| Story11 | Ex | 2936.3259 | 2.799 | 1049236.276 | 0.1862 | 0.225 | 0 |
| Story10 | Ex | 3293.4478 | 3.045 | 1081559.315 | 0.2259 | 0.272 | 0 |
| Story9 | Ex | 3587.4915 | 3.023 | 1186607.886 | 0.2652 | 0.158 | 0 |
| Story8 | Ex | 3825.2535 | 2.867 | 1334464.23 | 0.3045 | 0.043 | 0 |
| Story7 | Ex | 4013.537 | 2.757 | 1455740.149 | 0.345 | 0.116 | 0 |
| Story6 | Ex | 4156.7912 | 3.077 | 1350816.423 | 0.3862 | 0.185 | 0 |
| Story5 | Ex | 4260.565 | 3.092 | 1378005.021 | 0.4267 | 0.21 | 0 |
| Story4 | Ex | 4332.6516 | 2.936 | 1475835.252 | 0.4644 | 0.128 | 0 |
| Story3 | Ex | 4379.648 | 2.488 | 1759977.368 | 0.4982 | 0.01 | 0 |
| Story2 | Ex | 4407.8467 | 2.359 | 1868481.027 | 0.5288 | 0.066 | 0 |

| Story | Load Case | Shear X kN | Drift X mm | Stiffness X kN/m | Shear Y kN | Drift Y mm | Stiffness Y kN/m |
|---|---|---|---|---|---|---|---|
| Story1 | Ex | 4421.4889 | 2.633 | 1678947.961 | 0.5474 | 0.046 | 0 |
| Story15 | Ey | 0.031 | 0.005 | 0 | 671.0183 | 1.356 | 494706.036 |
| Story14 | Ey | 0.064 | 0.007 | 0 | 1272.9651 | 2.22 | 573323.326 |
| Story13 | Ey | 0.0973 | 0.017 | 0 | 1795.5261 | 2.914 | 616266.249 |
| Story12 | Ey | 0.1309 | 0.016 | 0 | 2247.074 | 2.739 | 820475.447 |
| Story11 | Ey | 0.1644 | 0.026 | 0 | 2632.1143 | 3.268 | 805510.02 |
| Story10 | Ey | 0.199 | 0.024 | 0 | 2953.8462 | 3.5 | 844029.564 |
| Story9 | Ey | 0.2337 | 0.024 | 0 | 3219.3066 | 3.51 | 917100.677 |
| Story8 | Ey | 0.2683 | 0.071 | 0 | 3434.4789 | 3.278 | 1047654.619 |
| Story7 | Ey | 0.3052 | 0.048 | 0 | 3605.5769 | 2.893 | 1246482.437 |
| Story6 | Ey | 0.3425 | 0.022 | 0 | 3736.7427 | 3.395 | 1100712.246 |
| Story5 | Ey | 0.3788 | 0.023 | 0 | 3832.4851 | 3.386 | 1131821.805 |
| Story4 | Ey | 0.4129 | 0.042 | 0 | 3899.6672 | 3.246 | 1201513.41 |
| Story3 | Ey | 0.4441 | 0.026 | 0 | 3943.9524 | 2.65 | 1488117.225 |
| Story2 | Ey | 0.4718 | 0.024 | 0 | 3971.2203 | 2.466 | 1610494.436 |
| Story1 | Ey | 0.4887 | 0.02 | 0 | 3984.9021 | 2.756 | 1446160.333 |

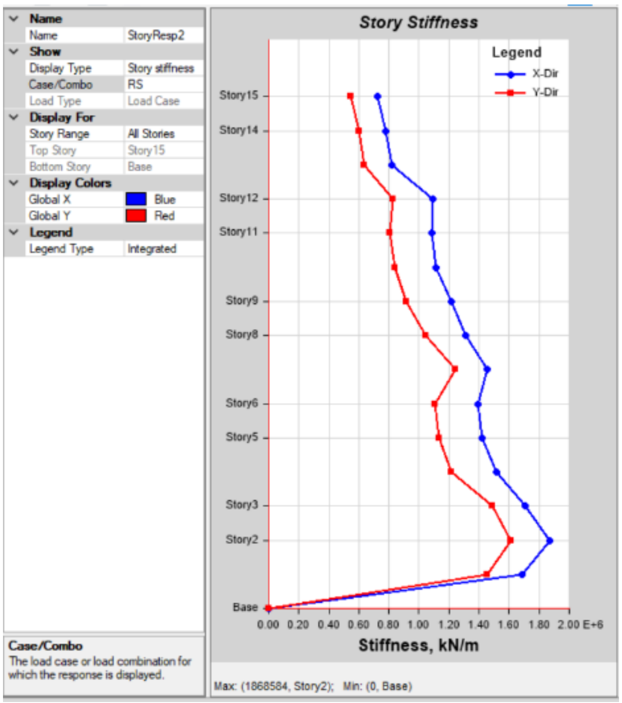



**Fig 4.14:Storey Stiffness by Response Spectrum.**

It can be interpreted from above graph that story stiffness values are minimum along Y direction whereas it is found maximum in X direction. This is the configuration of building, longer span shows greater value for stiffness whereas shorter span shows minimum magnitude for stiffness. The above graph depicts values on Response spectrum.

### 4.2.10 Story Overturning Moment:

When the building is subjected to earthquake forces then there leads to shear at base and overturning moment which is due to inertia of building. These are considered for design of building with eathquake loading. It is found from graph below that overturning moment is maximum at base and goes on decreasing when we move upwards. Similarly shear is also found maximum at base and minimum at top.

**Table 4.7 - Base Reactions**

| Load Case/Combo | FX kN | FY kN | FZ kN | MX kN-m | MY kN-m | MZ kN-m | X m | Y m | Z m |
|---|---|---|---|---|---|---|---|---|---|
| Dead | 0 | 0 | 119123.6812 | 3028737.4458 | -2721819 | -2.046E-06 | 0 | 0 | 0 |
| Live | 0 | 0 | 48652.4391 | 1216512.5711 | -1111755 | 0 | 0 | 0 | 0 |
| RS Max | 5933.645 | 5354.6095 | 0 | 143804.3093 | 161641.6492 | 194604.3748 | 0 | 0 | 0 |

| Load Case/Combo | FX kN | FY kN | FZ kN | MX kN-m | MY kN-m | MZ kN-m | X m | Y m | Z m |
|---|---|---|---|---|---|---|---|---|---|
| Masonry | 0 | 0 | 41902.38 | 1149466.0882 | -957888.4068 | -3.819E-06 | 0 | 0 | 0 |
| Ex | -4160.32 | 0 | 0 | 3.843E-06 | -144314.118 | 107766.5797 | 0 | 0 | 0 |
| Ey | 0 | -3697.8983 | 0 | 128273.5301 | 0 | -84514.0094 | 0 | 0 | 0 |
| DSlbU16 Max | 8900.4675 | 8031.9142 | 107211.3131 | 2941570.1652 | -2207174 | 291906.5621 | 0 | 0 | 0 |
| DSlbU16 Min | -8900.4675 | -8031.9142 | 107211.313 | 2510157.2372 | -2692099 | -291906.5621 | 0 | 0 | 0 |
| DCon16 Max | 8900.4675 | 8031.9142 | 241539.0918 | 6483011.7649 | -5277098 | 291906.5621 | 0 | 0 | 0 |
| DCon16 Min | -8900.4675 | -8031.9142 | 241539.0917 | 6051598.8369 | -5762023 | -291906.5622 | 0 | 0 | 0 |

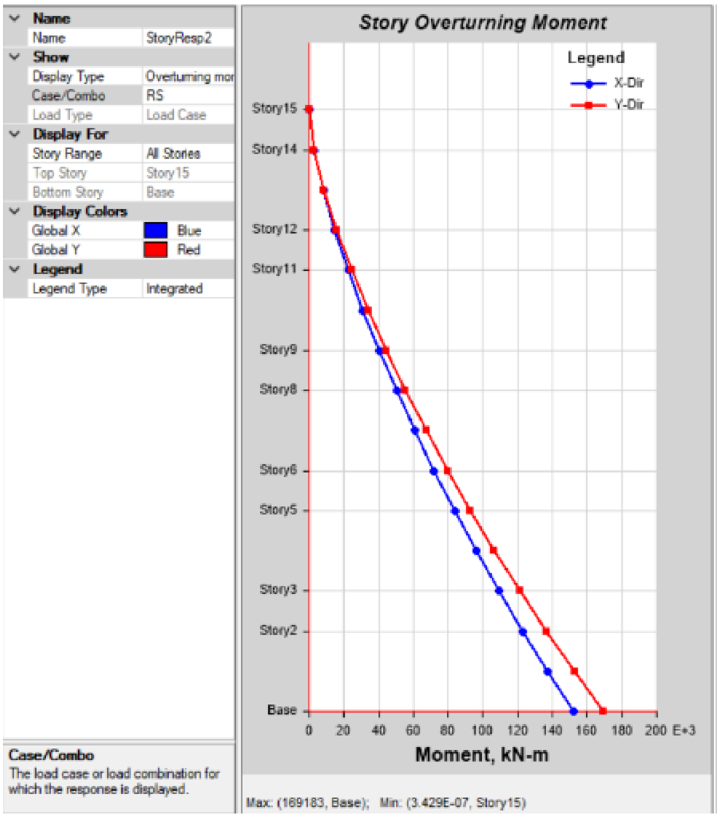
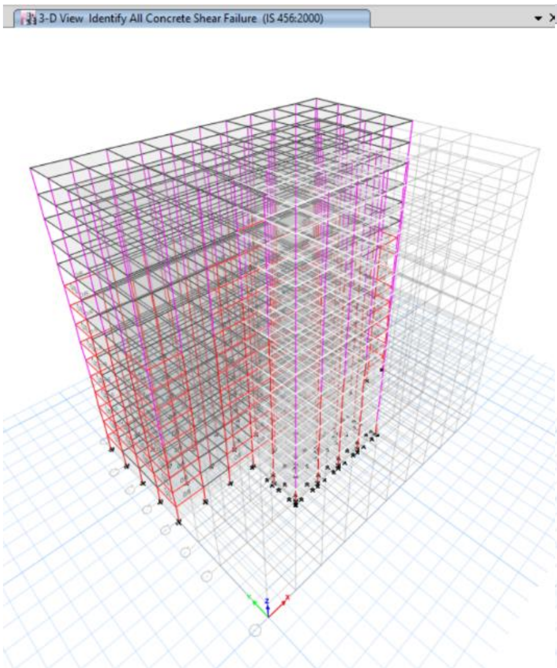



**Fig 4.15: Story Overturning Moment.**

## 4.3 DESIGN RESULTS

Design results are taken after completion of analysis process. Analysis gives idea of reaction of building members towards applied load and gives the values at different sections. Design inturn is the selection of member sections to resist load coming on it and the amount of reinforcement needed to counteract bending moment and shear force generated at a section. The main aim of all the process of loading and analysis is done to get an idea about selection of cross section and amount of reinforcement provided.

To get sections and reinforcement data is the final stage of design of a structure so that drawings can be created which is then implemented for construction.In this project there were some iterations to get best cross section for beams and columns so that they can resist loading without failure. It can be seen from pictures that there are some red lines which shows failed members. We know that as we go from top to bottom the section of columns goes on increasing because axial forces on columns increase as we go downwards. Similarly section of beams are found larger in interior beams as compared to outer beams.



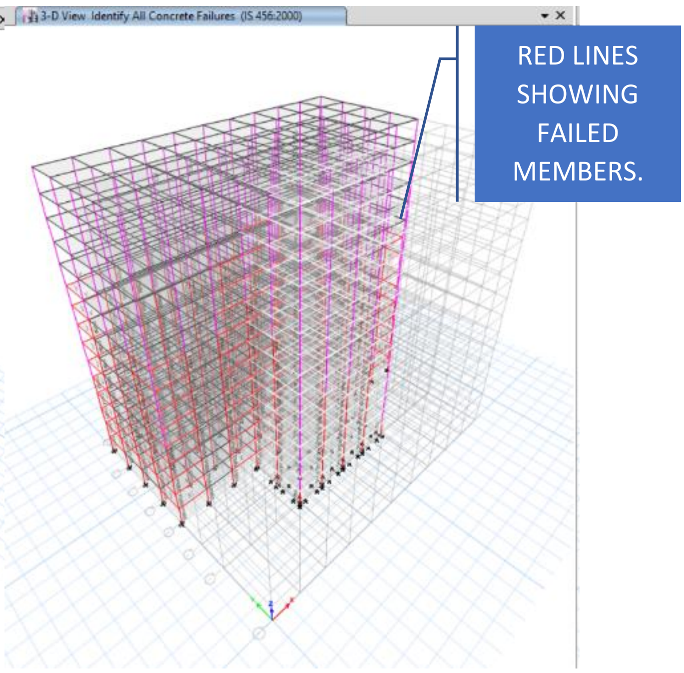
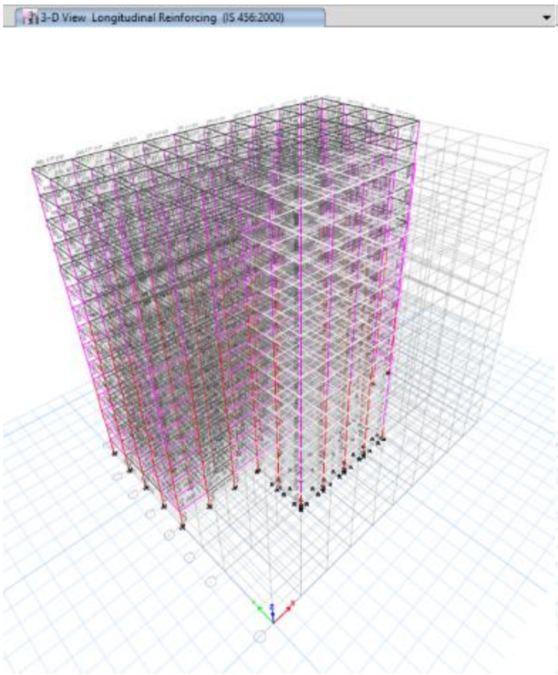




**Fig 4.16: First Iteration.**

**Fig 4.17: Second Iteration**



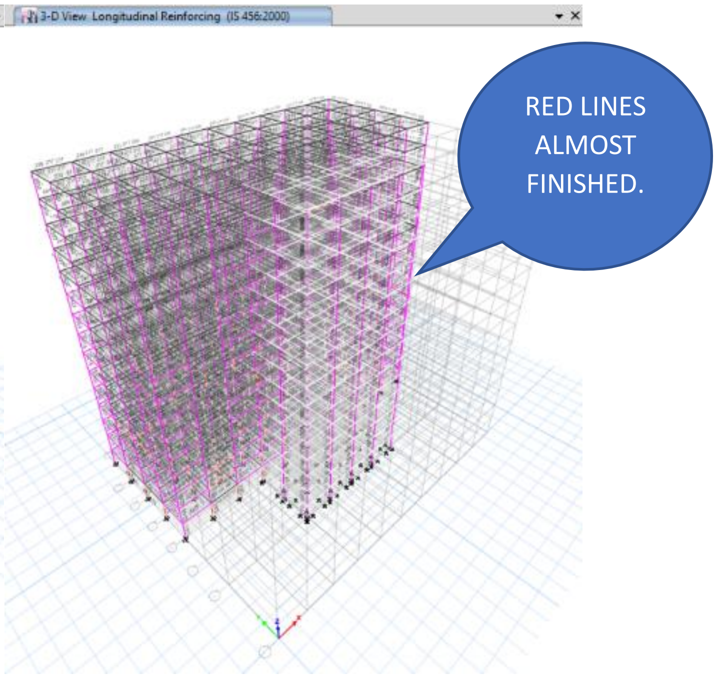




**Fig 4.18: Third Iteration.** **Fig 4.19: Fourth Iteration.**

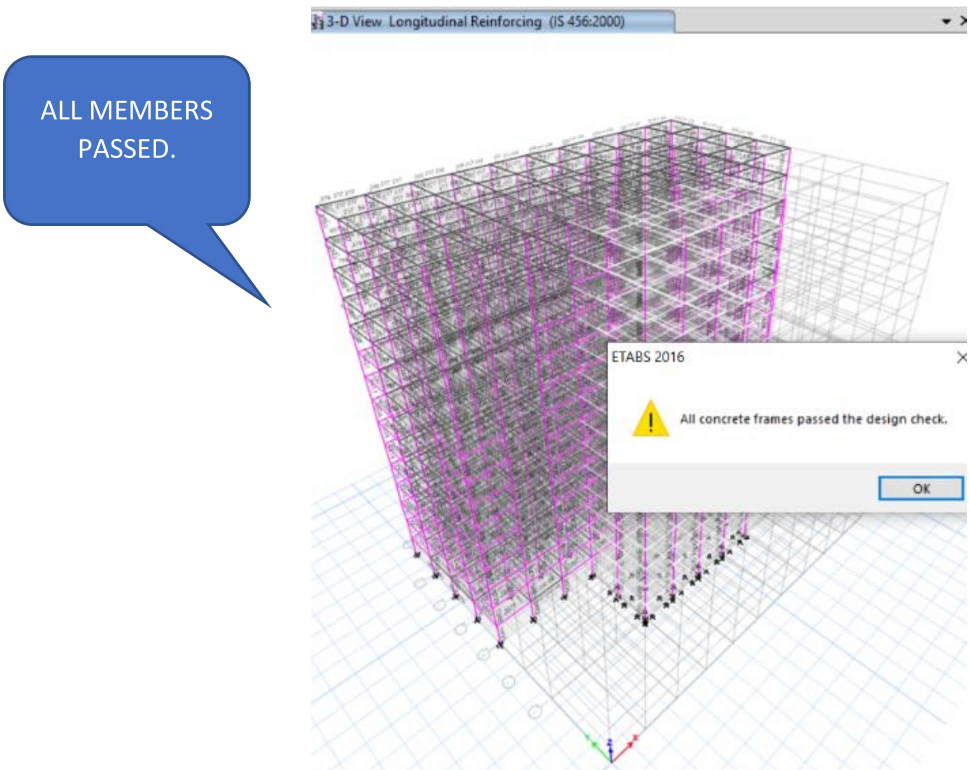



**Fig 4.20: Final Iteration**

In first iteration it can be seen that there are number of red lines showing failed members and we have red lines at bottom sides as top members are passing for assigned cross section. After changing cross section for failed members in second iteration some members get passed but all members do not take this section as final cross section. It is observed from these iterations that we keep on passing members whether it may be beams or columns. In case of beams outer beams are passing first and then interior beams because practically load is found maximum on interior beams that is why they need bigger cross section as compared to outer beams.

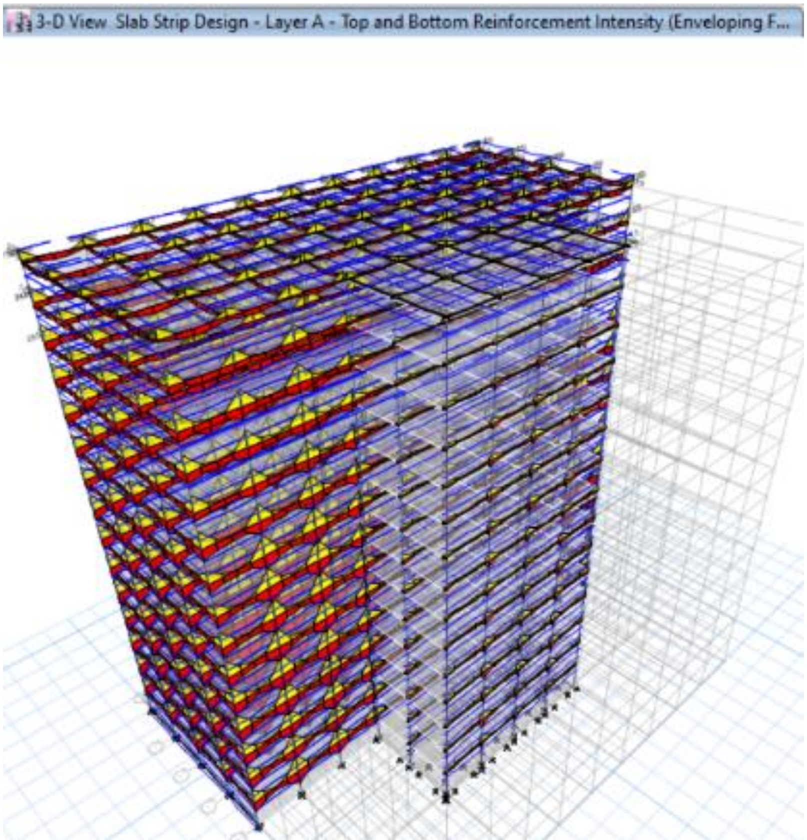



**Fig 4.21: Reinforcement data in beams and columns.**

In case of columns top columns pass for design and then bottom columns. This process of changing cross section after back to back analysis help us to know the minimum cross section which we can provide and this helps to make economical cross section. In final stage a message prompt that "All concrete frames passed the design check". Area of reinforcement in case of slabs for top floor only was taken from four strips of grid slab and four strips of flat slab to make comparison of change in area of reinforcement for both the cases. Following is the diagrammatic representation showing area of reinforcement.

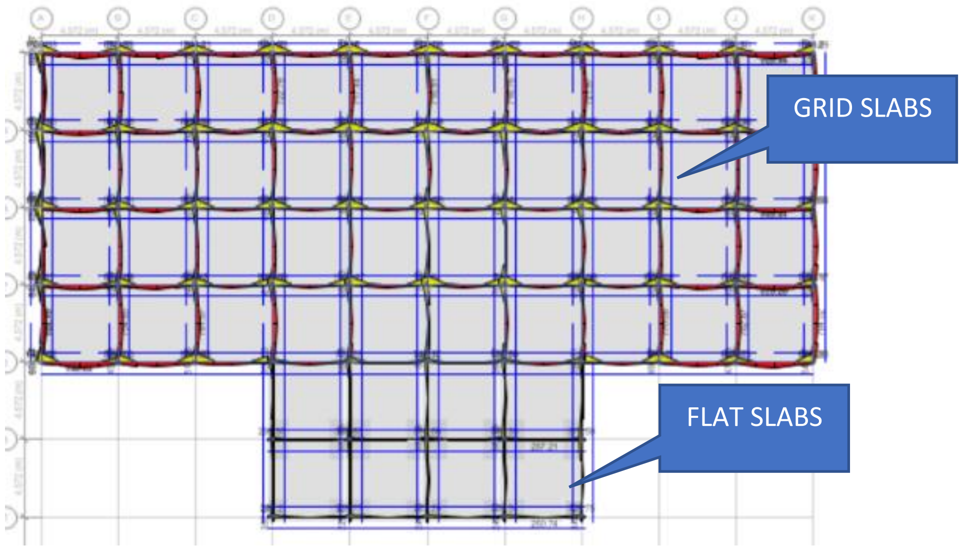



**Fig 4.22: Diagrammatic representation of Reinforcement in Top Slab.**

**Table 4.8 : Area of Reinforcement at mid span of slab.**

| | | | |
|---|---|---|---|
| 0<br>535.4mm$^2$ | 0<br>524.48mm$^2$ | 0<br>523.22mm$^2$ | 0<br>529.95mm$^2$ |
| 0<br>499.56mm$^2$ | 6.73mm$^2$<br>498.22mm$^2$ | 6.54mm$^2$<br>506.25mm$^2$ | 0<br>539.9mm$^2$ |
| 0<br>403.23mm$^2$ | 0<br>348.12mm$^2$ | 0<br>352.8mm$^2$ | 0<br>412.95mm$^2$ |
| 0<br>257.35mm$^2$ | 0<br>163.18mm$^2$ | 0<br>162.94mm$^2$ | 0<br>258.37mm$^2$ |

GRID SLAB

FLAT SLAB

Above table shows reinforcement consisting of data from four panels of flat slab and four panels of grid slab. Reinforcement data is taken at mid span of edges of each panel to make comparison with flat and Grid slab on the basis of reinforcement. It can be clearly figured out that area of reinforcement needed for Grid slabs is more than Flat slabs.

# CHAPTER 5

# CONCLUSION

Although the approaches to check various results of different slabs in a single building is different but main focus is same, which is to check the effectiveness on their structural point of view. Static and dynamic analysis is being carried out to know the collective reaction of slab and beams to external loading. Economical section is being checked by many researches at different load conditions. Storey drift is minimized by provision of grid slabs. By going through all these papers, I came to know if we consider economical point of view then grid slab is not necessary. But if we are designing an important structure where there is need of large spaces Grid slabs plays a vital role at that place. Some structural Engineers recommend to provide floating columns in parking lots, open spaces etc but in return that needs extra reinforcement for nearby beams and columns which bypass the loading which is transferred by that column.

To know the inter-relation between grid slab and flat slab and their dependency on adjacent beams and to check the effect on reinforcement, section detailing. By going through some of the researches done previously I came to conclusion by this research that:

1. Flat slab makes it best for design purpose instead of grid slab if we take economic point of view.
2. Reinforcement provided for flat slabs is minimum as compared to grid slabs.
3. Grid slabs help to minimize provision of number of columns as they are rigid and can be used for longer spans. But flat slabs cannot resist that much amount of load as they are not supported by beams.
4. Stress is found to be maximum on flat slab as compared to grid slab. So, chances of cracks will be more in flat slabs.
5. As found in analysis result stress is minimum at column joints in both the cases but in case of flat slab drop panels are used to minimize stress on columns. Drop panels transfer loading uniformly from all sides.
6. Deflection is always found more in case of flat slabs as they are not supported by beams whereas grid slabs show good resistance for deflection.
7. By this research work I came to conclusion that if it is any important building like public building then it is necessary to use grid slabs to make frame as rigid as possible. On the other hand, it will cost more but will be durable and safe as

compared to flat slabs. Flat slabs are mostly used in the cases where we prioritize aesthetic look of building and where we want to provide any different architectural look in building.

Designing the building with Flat Slab and Grid slab for long span building on ETABS, it is clear that ETAB gives best result for reinforcement data. This is the main reason which I found while going through this research. Secondly ETABS gives the reinforcement detailing with drawing in the form of distinct tables,

In case of ETABS failed members can be checked simply after design step. “Check failed members” in design section directly select those members and Design Engineer can change the section of those members by taking them in “view selected objects only”. And then section is changed to those members to make them pass for the given loading. ETABS consists of multiple steps to complete a design by assigning each parameter of design that is why results were taken by use of this software.

# CHAPTER 6

# FUTURE WORK PROCESS

Using ETABS, the research of review document and journal discovered the different outcome and conclusion on the grounds of these results and the further work is evaluation of multi-storey construction (G+14) such as strengthening, shear force, bending moment etc. This research will help to select technology accordingly if project type is known to get better results. In next research processes this research can be used to know the best point of application of each technology to make some adjustments in case of slabs to get best results. This process does not end here it is a vast field there is lot of research to know about strengthening process of structures by these results. Future projects can be analysed by using other materials on both slabs to get economical design and can be made various changes. This was for the purpose of education but this definitely gives us the practical idea of use of different slabs at various conditions.

Some researchers are still going there on types of slabs to be provided at different instances. This research will help other researchers to get idea and to put fore front its results and then elaborate it with other techniques. There might be some flaws in this research which can be fulfilled onwards by engineers going for higher studies.

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# LIST OF PUBLICATIONS

1. Suraj Kumar Ravi , Mr. Mohd Bilal Khan., "Comparative Dynamic Analysis Of Flat Slab And Grid Slab System" SCIENCE AND ENGINEERING JOURNAL(SAEJ), ISSN No: 0103-944X, UGC Approved, GOOGLE SCHOLAR and SCOPUS INDEXED Journal. Published in - Volume 15 | Issue 7 | August 2020
   Link: http:// saejournal.com/volume-24-issue-8

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Published a paper entitled

"Comparative Dynamic Analysis of Flat Slab and Grid Slab System"

PAPER ID: SAE/0820-54

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