# SEISMIC ASSESSMENT OF STRUCTURES USING P-DELTA EFFECT

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY

IN

**STRUCTURAL ENGINEERING**

SUBMITTED BY

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I, MANISH CHAKRAWARTY, Roll No. 2K20/STE/13, student of M.Tech (Structural Engineering), hereby declare that the project Dissertation titled "SEISMIC ASSESSMENT OF STRUCTURES USING P-DELTA EFFECT", is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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## CERTIFICATE

I hereby certify that the Project Dissertation titled "SEISMIC ASSESSMENT OF STRUCTURES USING P-DELTA EFFECT" which is submitted by Manish Chakrawarty, Roll No. 2K20/STE/13, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge and based on declaration of student, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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# ABSTRACT

Earthquake is the most catastrophic and erratic natural occurrence which causes huge devastation to human lives as well as structures. Earthquake forces produced during earthquake advances to severely damage the structural elements and sometimes even their failure. Also, urbanization is growing rapidly, existing land for building is becoming less and costlier. So, popularity of Tall Buildings is increasing. Based on guidelines of IS:16700-2017, the P-Delta analysis must be used when analyzing tall buildings, which is also an iterative type of method. When a member is loaded axially and a lateral force act on it but it remains in place then moment is only produced by this lateral load, but when the member gets deflected by Δ, with initial moment still acting on it, a secondary moment starts acting on it due to this deflection which is called as P-Delta effect. In most of the structures with elements which are applied with axial load, the non-linear effect which is called as P-Delta occurs. More the height of building, more is lateral seismic load. With increase in height of the structure P-Delta effect becomes very significant. In this work we have taken 3 RC building models of residential complex of East Delhi which comprise of G+4, G+10, and G+22 storeys. All three models have same dimensions of beams and columns and slabs. The work is done in two phases. In one phase analysis is done excluding P-Delta effect, while in second part P-Delta effect is considered. We have reported the storey displacement and storey drift of all 3 models in both the cases. Results show significant difference in storey displacement and storey drift with and without P-delta effect. For future considerations, a correlation analysis is done and correlation factors are determined.

***Keywords:*** *Seismic Analysis, P-Delta Analysis, IS 16700:2017, Correlation Factor*

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# Chapter I

# INTRODUCTION

According to the United Nations Office for Disaster Risk Reduction (UNISDR), a disaster may be described as "a serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope with using its own resources". But, after the enhancement in science and technology, forecast of different types of calamities has become possible and outcome of these disasters can be greatly lowered by providing appropriate and intime warnings and cautions. From the year 1950 to 2011, it has been perceived that the events of the various calamities has been increasing.

The figure 1.1 represents rise in different kinds natural disasters around the globe from 1980 to 2019.

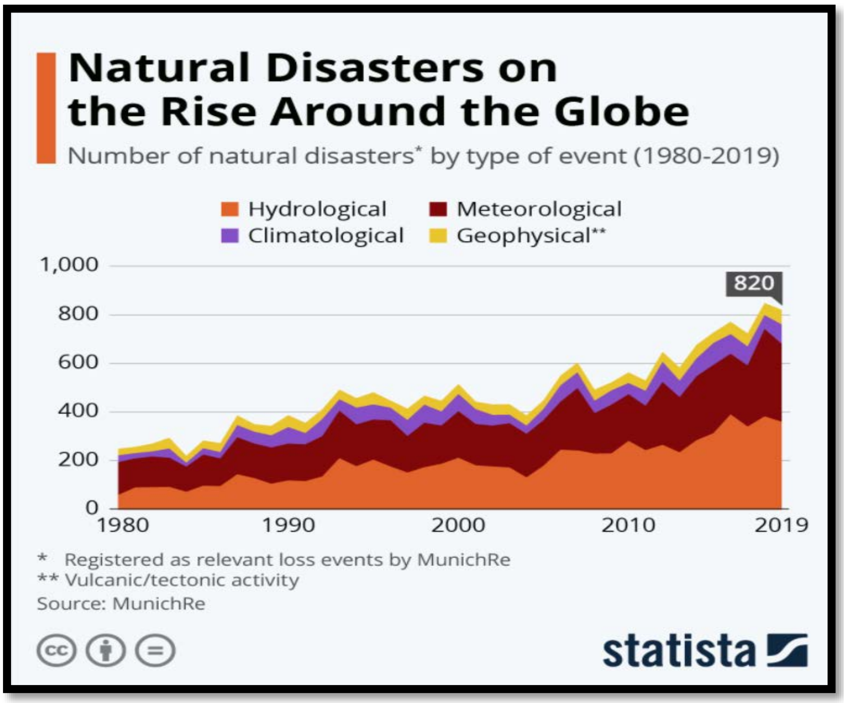


Fig 1.1: Natural Disasters on the Rise Around the World

(Source: The World Economic Forum)

The data acquired from The World Economic Forum states that, all around the world the occurrence of natural tragedies like Hydrological Disasters, Climatological Disasters, Meteorological Disasters and Geophysical Disasters are growing on fast pace. Also, it was observed from 1980 till 2019 that the number of events of Geophysical Disaster are way greater than any other type of disaster. Also the intensity of Geophysical disaster has also been increasing.

The figure 1.2 represents that the intensity of earthquakes is growing year after year.

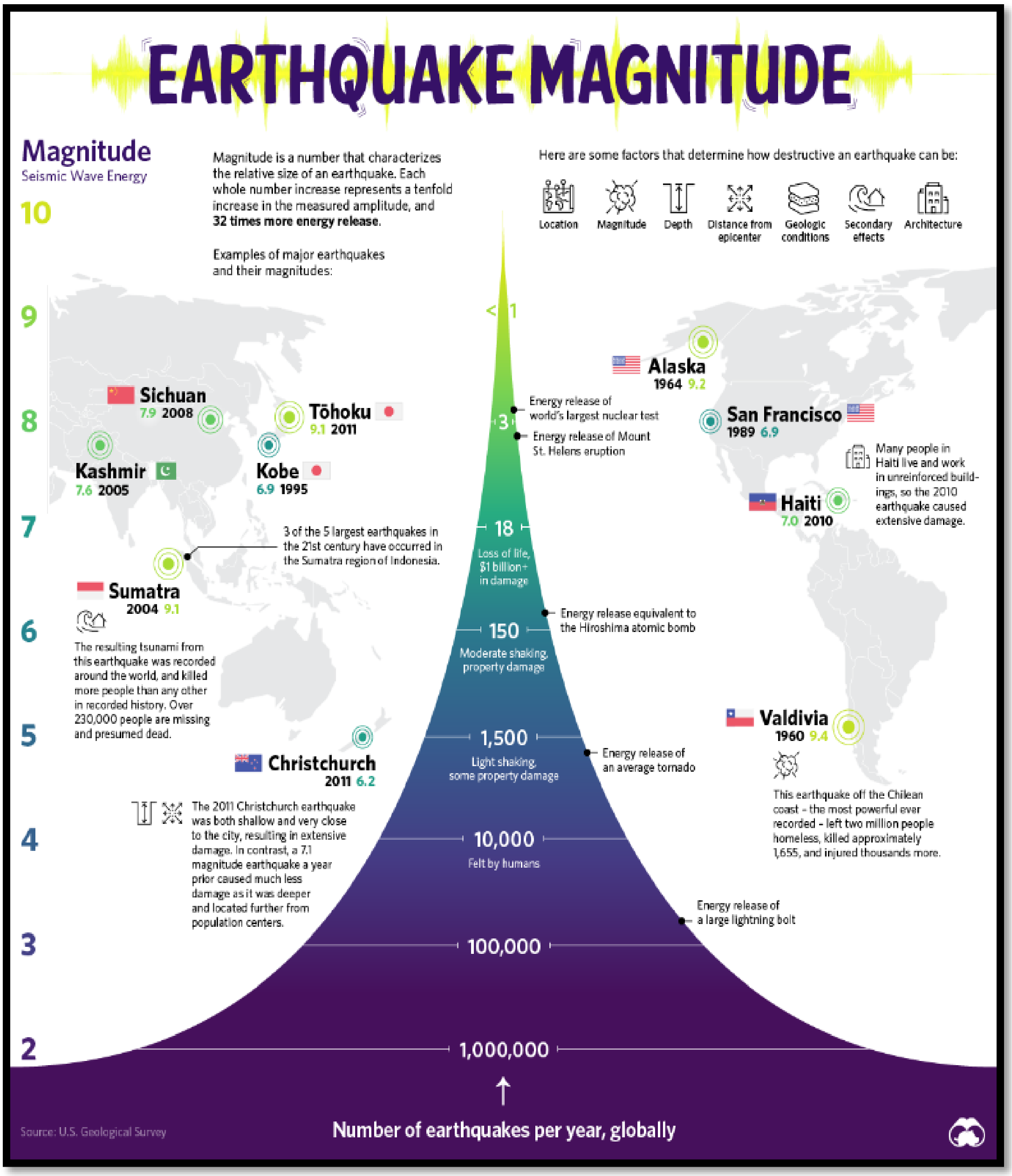


Fig 1.2: Magnitude of Earthquake (*Source: The World Economic Forum)*

One more data offered by The World Economic Forum showed that how the degree of the earthquakes is growing and as per the latest report in the year 2019, there are more than 180 earthquake events around the globe, which reported the magnitude on Richter Scale equivalent or greater than 6. Earthquake is the most catastrophic due to its erraticism and enormous power of destruction. Earthquakes do not kill people itself, rather the massive loss of human lives and properties happen due to the obliteration of buildings and other structures. Thus, there is a necessity of the structures to be protected against the disastrous consequences of earthquakes globally.

India, is a massive country with unalike topographical features. The Indian Standard Codal Provision used for evaluating the earthquake on any structure is IS:1893(Part 1)- 2016. Contemplating the topographical features, IS:1893(Part 1)- 2016 divides India into 4 seismic zones which starts from Zone II, then Zone III, then Zone IV and last Zone V; where Zone V witnesses worst and greatest intensity earthquakes.

Figure 1.3 represents different seismic zones in India.

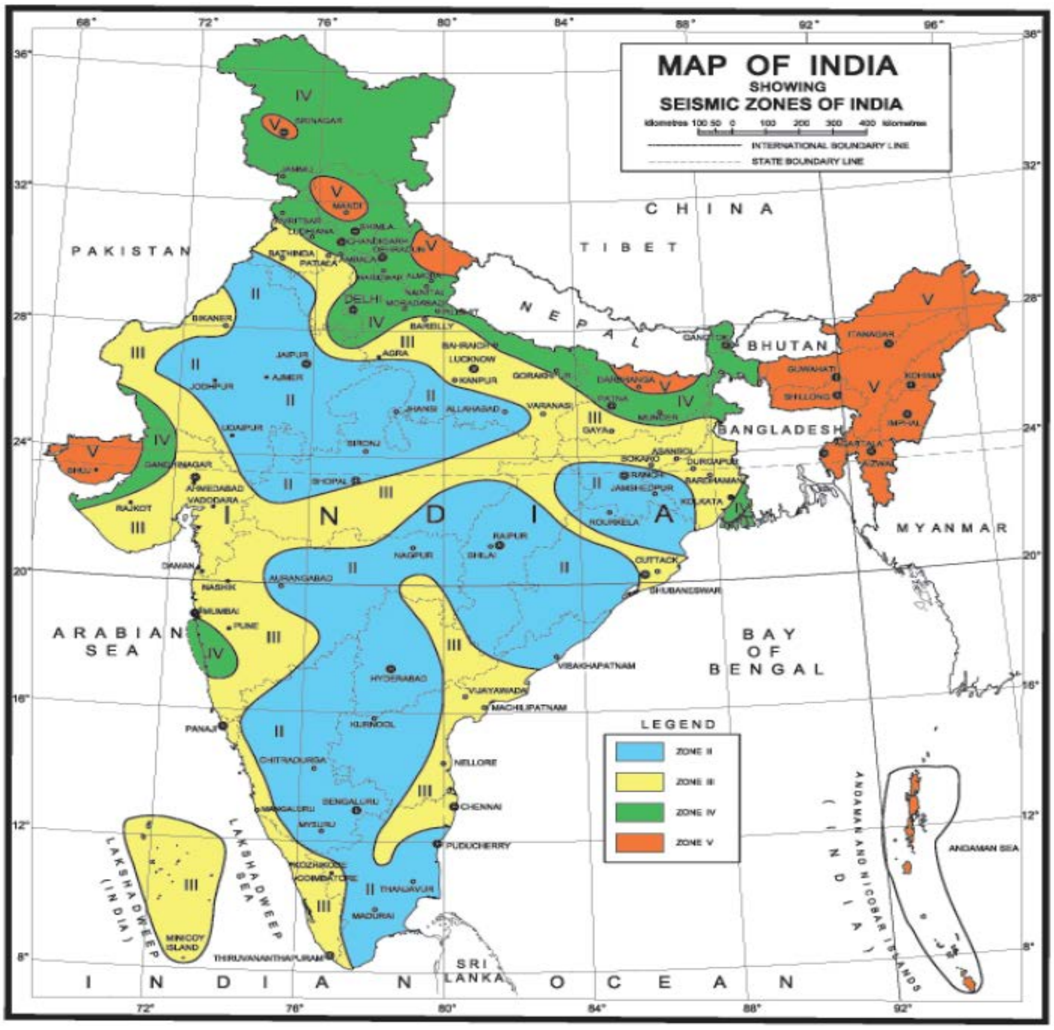


Fig 1.3: Earthquake Zones of India *(Source: IS 1893:2016)*

In present set-up, the structures are constructed based upon the newest Indian Standard Code Guidelines of IS: 1893(Part 1)-2016. But the distress is for the structures which are built before the revision of the IS codal provisions. With the rate of growth of the occurrence of earthquakes, there is not only the necessity for Post-Disaster Management, but also focus has to be on the requisite of various techniques under Disaster Risk Reduction. The United Nations Office for Disaster Risk Reduction (UNISDR) states that, its goal is to lower the destruction caused by natural hazards like cyclones, earthquakes, droughts and floods, through a code of prevention. Disasters often trail natural hazards. The extent of a disaster's harshness depends on its intensity of hazard on the environment and societies. Thus, there is crucial need for establishing various means which can help in prediction of the episode of the natural disasters. With technological developments, various researchers are able to develop a system which can detect the event of on surface natural disasters such as floods, cyclones, tornadoes and tsunamis. But they are still in route to develop the same technology for the disasters that appears from inside the earth’s surface such as earthquakes and landslides. Earthquakes are considered as one of the most important natural disasters as it may leads to the commencement of other disasters such as tsunamis, landslides, avalanches and floods. The after – effects of earthquakes cause an enormous loss of property and life of people. If the structures are short heighted, then the calamitous effect of earthquakes is less and it will rise as the height of the structures rises.

## 1.1 Tall Buildings and its Guidelines:

According to Indian Standard Codal Provision of IS 16700: 2017, a building with height exceeding 50 m and not more than 250 m is denoted to as Tall Building. When the height of the building exceeds 250 m, then it is called as a Super-Tall Building. For different structural systems, the maximum vertical length of buildings (in m) must not surpass limit provided in Table 1.1.

Table 1.1: Maximum limit of Height, H over top of Base Level
With Different Structural Systems, in meter

| SI No. | Seismic Zone | Structural System | | | | | |
|---|---|---|---|---|---|---|---|
| | | Moment frame | Structural wall | | Structural wall + Moment frame | Structural Wall + Perimeter Frame | Structural Wall + Framed Tube |
| i) | V | NA | 100 | 120 | 100 | 120 | 150 |
| ii) | IV | NA | 100 | 120 | 100 | 120 | 150 |
| iii) | III | 60 | 160 | 200 | 160 | 200 | 220 |
| iv) | II | 80 | 180 | 220 | 180 | 220 | 250 |

(Source IS 16700:2017-Clause 5.1.1)

While contemplating the seismic effects in tall buildings, in last seismic zone (Zone V) horizontal shaking and vertical shaking both should be taken into account. A site-specific spectrum has to calculated and shall be used in design of buildings in Zone IV, and zone V. When site-specific research, yields excessive hazard assessment, site – specific research results have to be used.

While doing structural analysis of tall buildings the nature of the structure in seismic environment is greatly influenced by P-Delta effect. Based on guidelines of National Building Codes when a structure is subjected to lateral forces there is spontaneous change in overturning moment, ground shear, and/or the axial force distribution at the base of the structure or at other structural components.
Structural modelling must follow a modest method, so that it shows the distribution of stiffness and mass properties which appropriately accounts for all significant inertial forces under deformation shapes and seismic actions.

Analytical model of a structure must reflect the correct behaviour of its members as well as of the complete structure. Modelling which can be adopted are frame element modelling or finite element modelling or a combination of the two.
In reinforced concrete buildings, lateral deflections are estimated using section properties proposed for unfactored loads when unfactored lateral load is applied, and lateral deflections are estimated using section properties proposed for factored loads

when factored load is applied. For determining lateral effects on buildings, they should be taken as fixed at the base. If a tall building is being constructed in the seismic region of Zone IV and V, following recommendations have to considered. (IS 16700:2017)

1. The structural wall must not be transferred in plane, and also not out of plane and they should be continuous till the base;
2. The structural wall should be built with minimum thickness of 200mm;
3. The reinforcement in each direction i.e. longitudinal and transverse should be atleast 0.4 percent of gross cross-sectional area.
4. The distribution of reinforcement should be done in two curtains in respective directions.
5. To prevent rocking of structural wall, at their base they should be completely rooted and affixed in foundation.
6. In structural wall, a vertical alignment is preferable for all openings. Allowance of random opening in coupled walls is permitted only if their effect is insignificant.

### 1.2 Objectives of the Work:

Undermentioned are the objectives of the work done:

- To apply the latest Indian Standard Codal Provisions in the analysis.
- To perform P-Delta analysis for obtaining optimum results for seismic analysis of Tall Structures.
- To determine the Correlation Factor for the results obtained.

## 1.3 Composition of Project Work Report:

This report of the project work is reported in five chapters.

**Chapter I** presents the general introduction emphasizing on the related concepts and guiding principles for different structures when subjected to seismic forces.

**Chapter II** produces the literature review.

**Chapter III** consist of the methodology of performing the analysis of the structures to get the behavior of the same by using a software analytical tool.

**Chapter IV** shows the results obtained from the previous chapter and discuss about the difference in the observed magnitudes.

**Chapter V** deals with the conclusion of the whole thesis.

**Chapter VI** includes the future scope of the work done.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction:

In recent times, studies on earthquake–based vulnerability assessment had been conducted on structures, of varying dimensions and locations. On the basis of the parameters considered for this study, the conclusions made by the researchers are quite interesting in the analysis of the structures under the action of seismic loads, whether small buildings, Semi-Tall buildings, or tall buildings.

## 2.2 Earlier Research Work Done:

Hassaballa A. E. et. al. [17] have done a Seismic analysis of a multi-story RC frame structure in Khartoum city was analysed to investigate the performance of existing buildings if exposed to earthquake loads. The frame was analysed using the response spectrum method to calculate the stresses and seismic displacements with the earthquake provisions proposed for Sudan. The results showed that the nodal displacements caused drifts beyond permissible limits. The horizontal motion has significant effect on the axial compression force on the exterior columns. Seismic loads showed much larger values of bending moments in beams and columns compared to that due to static loads. The frame designed was inadequate to bear the applied seismic load.

Dinar Y. et. al. [7] have taken 6 RC structures starting from G+5 storey to G+30 storey which are varied by 5 storey in each model and have analysed them by linear static analysis and P-delta analysis. Results have been compared. In Analysis it was found, that with increasing height under P-Delta analysis, displacement varied exponentially and the axial force also varied appreciably. Moments decreased with the increment in storey height.

Patil S.S. et. al. [15] have analysed a high-rise structure using seismic analysis with different lateral stiffness systems on StaadPro. Some models are brace frame, some are bare frame, and some shear wall frame. The method of analysis is Response spectrum method. Authors concluded that building which have short period often undergo higher iacceleration but with smaller displacement. The structures with shear wall located at outer frame of X & Z direction all along the height is found very effective in carrying lateral loads. Lateral stiffness increased with an appreciable amount in braced model compared to another model.

Mallikarjuna B.N. et. al. [10] here have compared P-Delta analysis with linear static analysis. An 18-storey steel frame structure model is analysed with P-delta effect. The model is analysed on StaadPro The framed multistorey structure has been analysed for Wind load as per IS: 875(Part3): 1987. After analysis a comparison is done for Maximum storey displacement and Axial Force for P-Delta and linear static analysis. The storey displacements can be seen to be increasing at all level in the structure in P-Delta analysis. P-Delta analysis has given axial force two times of static analysis.

WIN N.N. et. al. [20] have analysed a G+11 storey RC Structure on ETabs. The structure is analysed statically and by response spectrum method. A parametric study is done with results obtained from static and dynamic method. In this paper, parameters like storey shear, displacement, storey drift, storey moment in X and Y direction are compared for both response spectrum analysis and static analysis. By static analysis displacements obtained are less than response spectrum analysis. Also, displacements obtained in static analysis are less than response spectrum analysis. Storey drift in both directions is insignificant. For high-rise buildings, it is important to use dynamic analysis as static analysis is insufficient.

Haque M. et. al. [19] have carried out static and dynamic analysis of regular and irregular RC building. Equivalent static analysis, response spectrum analysis and time history. Analysis have been carried out. Maximum displacement of different shaped RC structures has been studied under static and dynamic loads. Authors concluded that the displacements for irregular plan are more as seen in the response spectrum analysis and performance of buildings with irregular plan are much more susceptible to earthquake load than buildings with regular plan.

Farqaleet A. [14] has analysed a ten storey RCC building which is of symmetrical configuration. For analysis SAP 2000 has been used. Different response parameters such as story drift, lateral force, story shear, base shear are determined. It was noted that there is increase in storey drift from base to top storey. The maximum drift obtained for a ten-storey building was in permissible drift according to IS 1893:2002. The maximum base shear in two orthogonal direction x and y was also found to be in permissible limits. It is advisable that for analysis of buildings time history analysis should also be executed as it calculates the structural responses more precisely than the response spectrum analysis.

Firoj M. et. al. [13] Authors have analysed a G+10 storied building structure by response spectrum analysis on different commercial software like ETABS, SAP2000, STAD PRO. The axial forces displacements of joints, mass participating factors, and time period were studied. The structure is dynamically analysed based on IS: 1893 part 1. Authors concluded that the high-rise structure must analysed dynamically. The building is found to be very stiff with frequency above .44hz. Also, the displacement was found to be more in X direction because of the fact that seismic load was considered in X direction.

Jayakrishna T. et. al. [6] have done an analysis of residential building with eight storeys in STAAD PRO. The response spectrum analysis is done with load such as seismic and dead loads. Analysis is done for different seismic zones. Soil type taken is soft soil. In different zones and for different soils they have plotted response for base shear, storey drift. On comparing vertical irregular model to regular model Compared to vertical irregular model lateral displacement is less in regular model. Base shear is almost same in regular and irregular models, less displacement is seen in the regular model. The structure shows different behaviour for the different shape of the structure.

Verma A. et. al. [5] have analysed a G+30 building by p-delta analysis. The structure taken is a symmetrical regular RC frame. Analysis is done statically and dynamically as per IS 1893:2002. In analysis two seismic zones are considered i.e., zone III and zone V. P-Delta effects are included for seismic assessment on same model. Work is done in two parts: analysis of building is done without taking effect of P-Delta in former work and effects of P-Delta is counted in later one. Static, Dynamic, and P-Delta analysis results are also compared. It was noted that the change in the direction of drift curve started very early from lower stories in P-Delta analysis as compared to static and dynamic analysis where it started after as high as 15, 17 storeys. Axial loads and moments were much higher for P- delta analysis compared to static and dynamic analysis.

Dheeb A. S. et. al. [8] have investigated P-Delta effects considering wind load on multi-storey steel buildings. Tall steel building models have been analysed by Linear time history analysis and nonlinear time history analysis. Linear time history analysis is compared with nonlinear time history analyses. Results recommend that the dynamic response of buildings with storeys more than 20 is highly influenced by P-Delta effect. Including P-Delta effect in Nonlinear time history analysis have given larger lateral displacements so it's recommended to do non-linear time history analysis for taller structures.

BHIKSHMA V. et. al. [11] have studied the effect of wind and earthquake loads and analyzed the buildings in different seismic zones based on IS codes -IS 1893 and IS 875 codes. Multistorey structures with 6 floors, 9 floors and 12 floors are analysed for earthquake and wind. Parameters like story shears, story displacements and, story drifts are studied. Results showed that with greater wind speed in higher seismic zones, story displacements, story drifts also increased. Also, wind forces on the structure in no case were greater than the earthquake forces.

Jadav M. S. et. al. [9] Authors studied P-Delta effects on tall structure in this work. Three types of structural systems i.e., Moment frame structure, Moment frame fitted with structural wall, Tube structure fitted with structural wall have been analysed. Seismic loads have been applied and for analysing the structure the P-Delta effect is considered. The analysis is done on ETabs. Results show its necessary to incorporate effects of P-Delta in buildings with 20 storey or more. With increases in storey the P-Delta effects becomes more prominent. Moreover, for the long-term performance of the structure the P-Delta effect must be considered.

Kangle S. R. et. al. [16] have done a comparative study of a G+15 RC building on StaadPro and ETabs using response spectrum analysis. For design IS:1893 Part1 is used for dynamic analysis.it has been observed that the multi-storeyed structure is stiffer for seismic excitation when modal participation factor is more than 75%. Authors concluded that for high rise structure the dynamic analysis must be carried. RSA showed that the building has a resistance to smaller earthquake of moderate intensity and magnitude. Also, the displacement was found to be more in X direction because of the fact that seismic load was considered in X direction. Both software gave almost same base shear.

Pavan P. S. et. al. [12] have done a comparative study on wind loads to calculate the design loads of a multistorey structure. Authors have analysed two models i.e.one high rise other low rise, with dissimilar wind speeds according to IS 875(Part-III): 1987. Parameters for comparison are maximum displacements and story shears of high rise and low-rise buildings. After doing a detailed study authors concluded that, the lateral forces exerted on the structure increase with rise in the wind speed. With rise in wind speed the displacements, story shears also increases and that the high-rise buildings are more effected by the wind forces when compared to low rise buildings.

Dadawala S. et al. [18] have tried to highlight different methods utilised for earthquake analysis with their limitations. They have discussed response spectrum method and time history method. A case study of Gujarat earthquake has been done to show effects on various buildings and structures. The case study shows effects of an earthquake on human life and health of structures. Earthquakes have very damaging effects on the buildings if they are not properly designed for seismic loads. Hence, it’s important to consider seismic loads while designing various structure. Authors say that geotechnical investigation is of prime concern while designing the structure. Provisions of different seismic codes must be studied while designing the structure.

# CHAPTER 3
# METHODOLOGY

## 3.1 Introduction:

Readiness for different buildings against the natural disasters basically depends upon the kind of the natural disasters which is going to strike a specific area and the various structures in the neighborhood of that area. Structures such as Community Halls, Nuclear Power Plant, Hospitals, School Buildings, Thermal Plant, etc. are contemplated to be the vital structures of any nation as it serves various purposes. Particularly, considering the time and conditions when a particular nation or a group of nations are suffering from the effect of the natural disasters. The effect of the natural disasters on the buildings not only concentrates on the structural parameter, but also focuses on the non – structural and functioning parameter. This too depends on the locations of the buildings and the place which is affected by the natural disasters. If the structures are in the vicinity of the origin and effected zone of the natural hazards, then all the components of the structure are affected. The intensity of the blow of the natural disaster hangs only on the distance between the structures and the point of origin of the natural disaster. If the structures are not in the vicinity of the origin and effected zone of the natural hazards, then only two components of the structure are affected: Non – Structural and Functional. Here also, the amount of which these parameters are affected depends on the intensity and magnitude of the hazard.

The problem of this study is totally restricted to the Delhi / NCR Region of India. India is a diverse nation, having different topographical surfaces across the whole country. It has Great Himalayas in the North, beaches in the south, desert in the west and great ranges of mountains and rivers in the east. Thus, the topographical behavior of India changes as its states changes and also, the kind of natural disasters also changes in all the directions of the nation. It is massively affected by the earthquakes, avalanches, landslides in the upper fraction of the nation. Whereas, the bottom fraction of the country is affected by the hazards which are related to sea and oceans such as tsunami, storm, cyclones, etc. Contemplating the nature of the hazard which can hit the Delhi / NCR, the region is vastly affected by the earthquake scenarios. Due to the presence of the Himalaya range and movement of the plates underneath the earth, this Delhi / NCR is substantially prone to earthquakes.

For dealing these circumstances of the earthquake, the Bureau of India Standards (BIS) comes with the earthquake code IS 1893 in the year of 1984. But, after the Bhuj Earthquake which happened on January 26th, 2000 in Gujarat, India, which perceived the killing of thousands of lives, the BIS revised IS 1893 and came up with its first revision in 2002. As the technology developed and the world advanced, the different nations of the world reviewed their codal provisions after the episodes of the earthquake in their regions and also after discovering the loopholes in their researches while developing the code. The BIS also emphasises on the same aspect and decided to revise its codal provisions regarding IS 1893. So, after huge discussions and little differences, the BIS again revised IS 1893 in the year 2016 as IS 1893:2016. But, when the analysis of the model is done on any software, they are still having option of IS 1893: 2002. The analysis of the structure is done on various software platforms such as SAP 2000, ETABS, STADD Pro, etc.

### 3.2 Analysis Tool:

In this analysis, the software used is StaadPro-Connect edition V22 update 9. Based on IS:1893(Part1)-2016, the Delhi / NCR lies in Category ZONE IV, which means unique attention must be given to the structures which are based in this same region. Also, while modelling the structure in StaadPro, specific considerations must be given to the input data as per IS:1893(Part1)-2016. Models of three different existing structures are considered, of varying heights, falling under the category of normal building, semi tall building and tall building. Since, as per the IS codal provisions, the best possible analysis for considering seismic effects on the tall buildings is P-Delta analysis, so all the three models are analysed under P – delta Effect.

### 3.2.1 P-DELTA in StaadPro

When non-linear situations are not involved, a load combination type would be adequate. But otherwise *Repeat load* cases have to be taken for proper P-Delta analysis.

The **REPEAT Load** differs from the **LOAD COMBINATION** command in two ways:

1.) A REPEAT LOAD is treated as a new primary load. Therefore, an analysis will reflect correct secondary effects. (LOAD COMBINATIONS, on the other hand, algebraically combine the results such as displacements, member forces, reactions and stresses of previously defined primary loadings evaluated independently)

2.) In addition to previously defined primary loads, the user can also add new loading conditions within a load case in which the REPEAT LOAD is used.

A regular STAAD P-Delta Analysis performs a first order linear analysis and obtains a set of joint forces from member/plates based on the large P-Delta effect. If P-Delta analysis is specified, forces and displacements are recalculated, taking into consideration the P-Delta effect.

The PDELTA ANALYSIS command is an instruction to the program to execute a second-order analysis and account for P-delta effects. If a RESPONSE SPECTRUM is specified within a load case, dynamic analysis is performed.

**RESTRICTIONS:**

Modal dynamic analysis load cases (Response Spectrum, Time History, Steady State) should not be used in REPEAT LOAD. It is also not available for loads generated using some of the program's load generation facilities such as MOVING LOAD Generation. However, load cases with WIND LOAD may be used in Repeat Load.

The basic steps involved in the analysis done on StaadPro are as follows:

1) Modelling
   i) Geometry
   ii) Properties
   iii) Materials
   iv) Specifications
   v) Supports
   vi) Loading
      a) Defining definitions
      b) Defining Loads
      c) Defining Load Combination/ Defining Repeat Load Cases

2) Analysis

**Geometry**

Figure 3.1 shows geometry of G+4 Model.

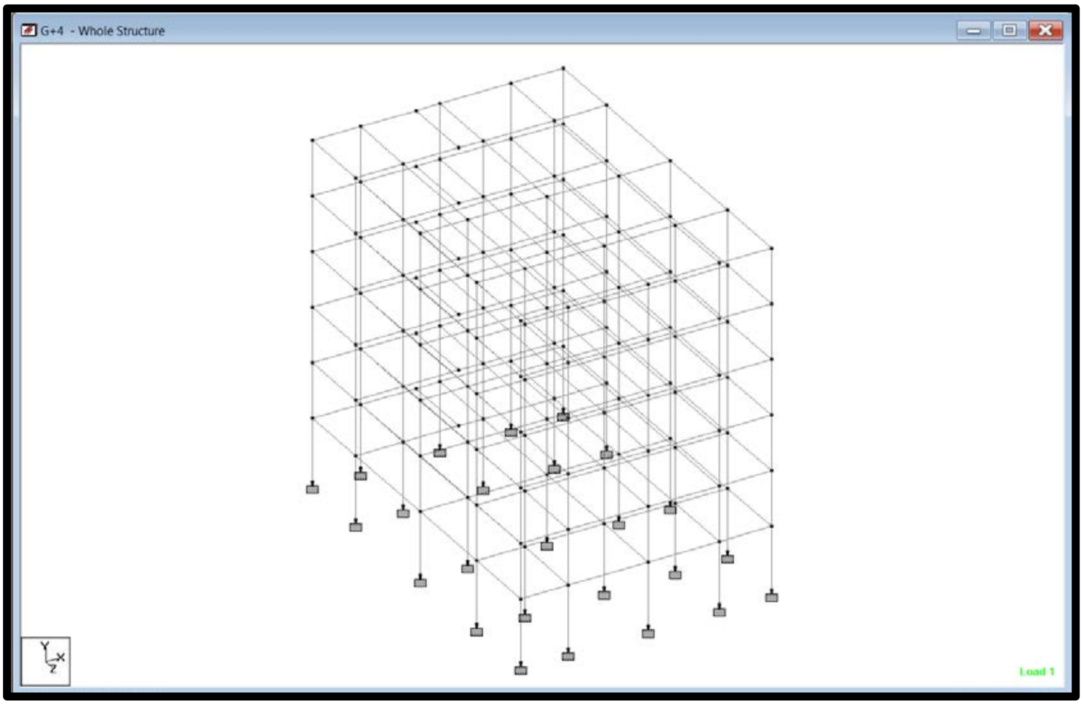


Fig. 3.1 Geometry of G+4 model

Figure 3.2 shows geometry of G+10 Model.

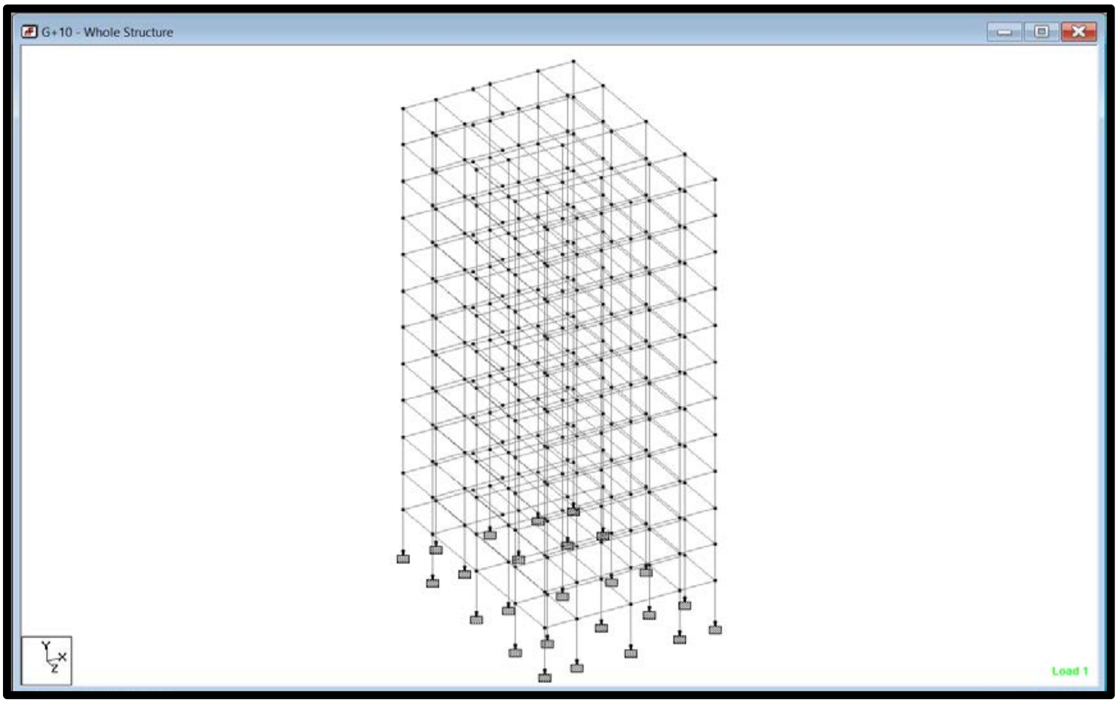


Fig. 3.2 Geometry of G+10 model

Figure 3.3 shows geometry of G+22 Model.

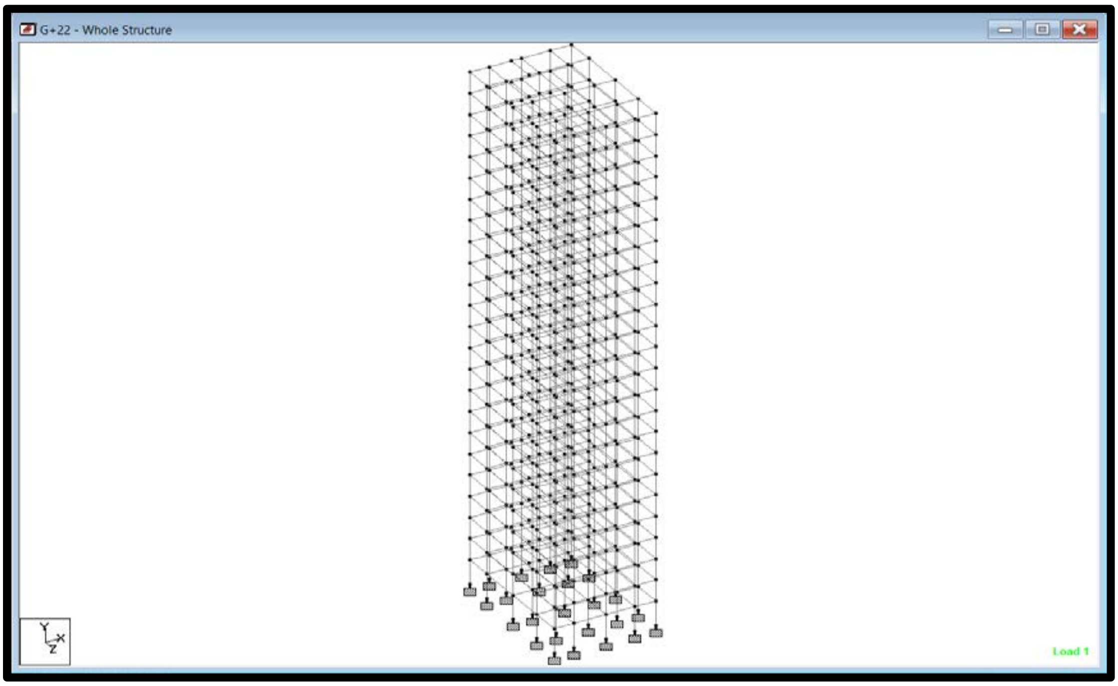


Fig. 3.3 Geometry of G+22 model

The modelling stage includes the modelling of all the 3 different buildings. It includes the provision of the structural components such as beams, columns, slabs. Firstly, the loads ae defined: Dead Load, Live Load, Wind Load, Earthquake Loads (in both lateral directions). Then the analysis is done, by P-Delta Effect. The results attained from the P-Delta effect are considered to be the final results and further modification/investigation of a particular structure are based on the same results.

### 3.3 STRUCTURAL DETAILING AND ANALYSIS OF BUILDINGS:

All the three models are of a Residential Complex located in the area of East Delhi. The overall plan area of the structure is 15.770 m X 22.700 m. The other important detials regarding the structural models are given below:

The grade of concrete used in this model is same for all structural member. The grade of the concrete used for columns and beams and slab is M25. The cross – sectional size of the structural members of the models are as follows:

- Thickness of the slab : 150 mm
- Column Size : 800 mm x 800 mm
- Beam in Z direction : 600 mm x 350 mm
- Beam in X direction : 400 mm x 300 mm

Figure 3.4 shows plan of Model.

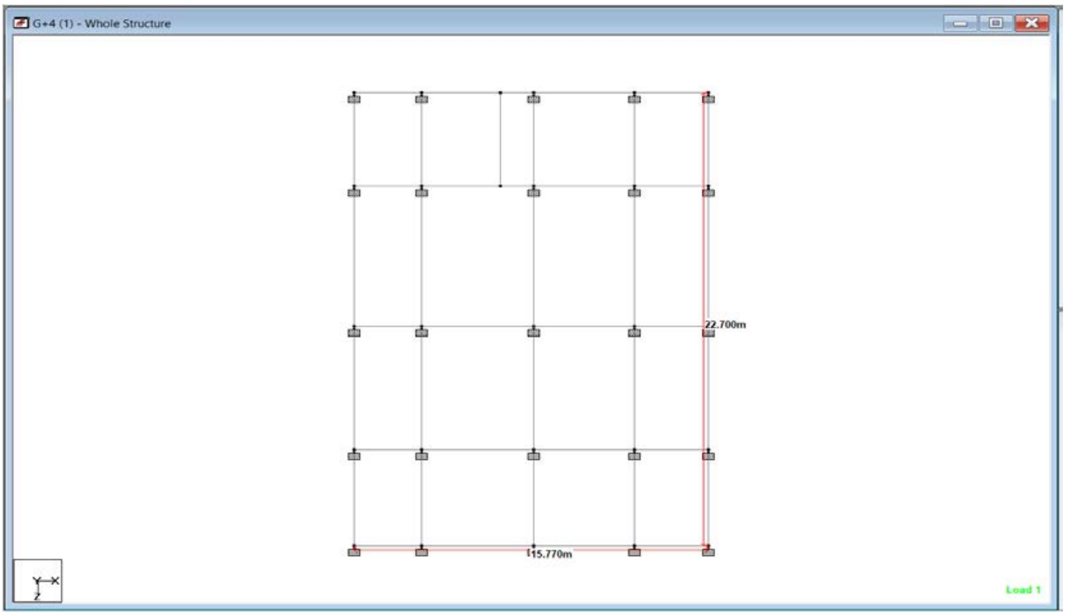


Figure 3.4: Plan of Model

Table 3.: Details regarding models

| | |
|---|---|
| Type of Structure | Multi – Story Rigid Jointed Frame |
| No. of Storeys | Model 1: **G+4**<br>Model 2: **G+10**<br>Model 3: **G+22** |
| Floor to Floor Height | 3.5 m |
| External Walls | 230 mm |
| Internal Walls | 115 mm |
| Exposure Conditions | Mild Environment |

Figure 3.5 represents 3D rendered model of G+4 building.

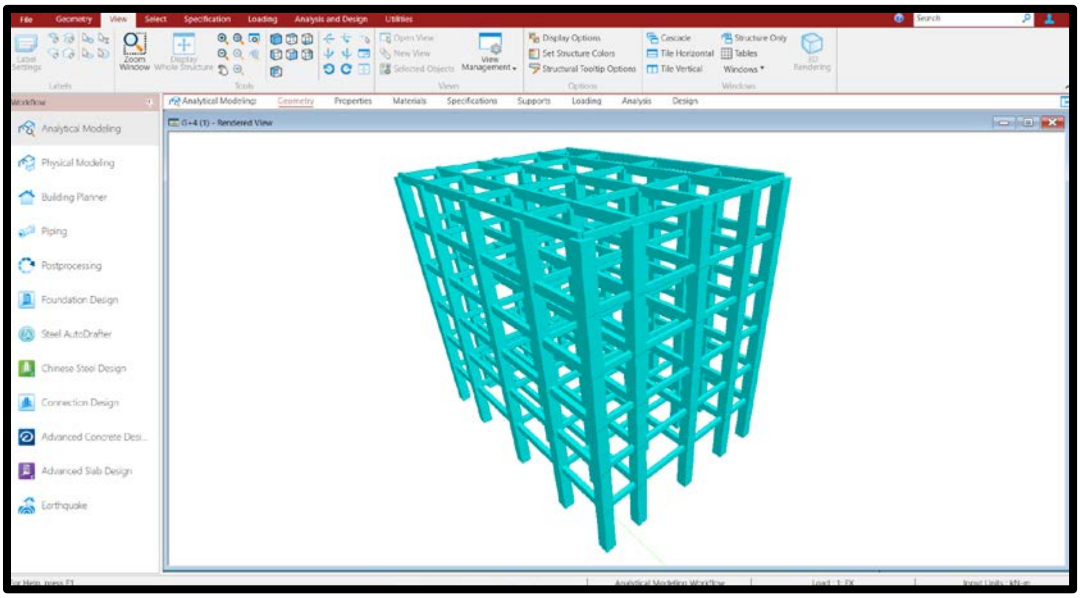


Fig 3.5: 3D rendered Model of G+4

Figure 3.6 represents 3D rendered model of G+10 building.

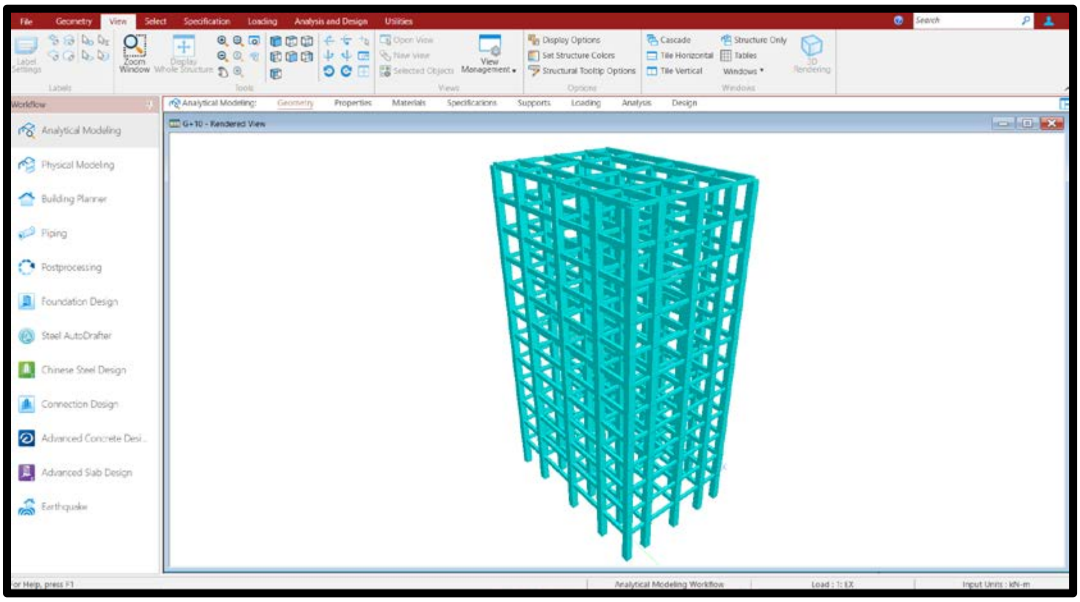

Fig 3.6: 3D rendered Model of G+10

Figure 3.7 represents 3D rendered model of G+22 building.

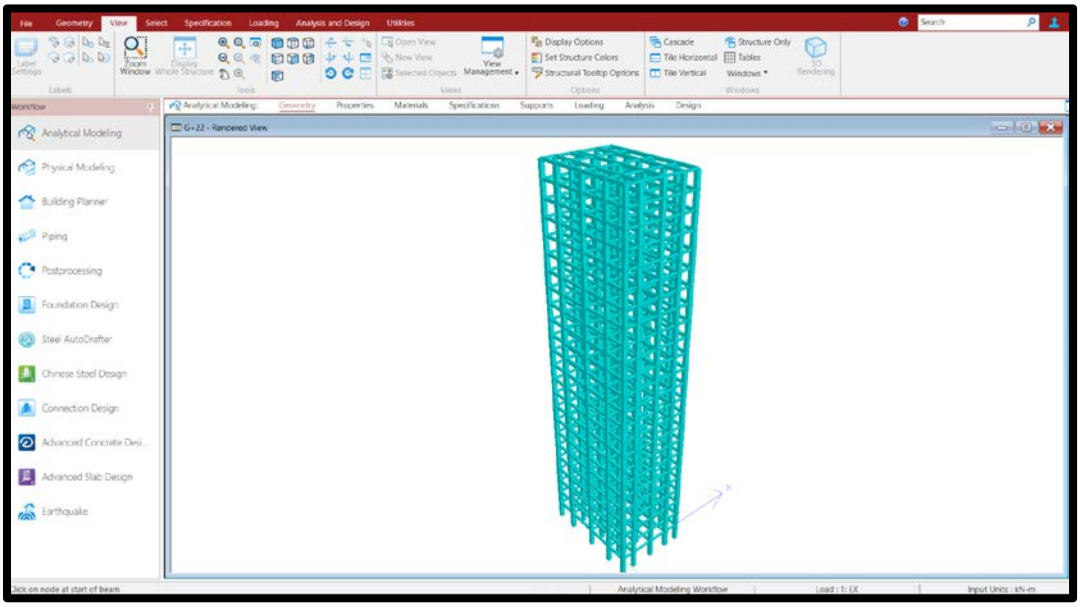

Fig 3.7: 3D rendered Model of G+22

First, we make geometry, in which according to the plan we make the column layout. First, we make the ground storey and then we can transition it in Y direction so in that way we can make as many storeys as we need.

Then we assign property to all geometry using the property window and then using the define tab. Here we select the sections and their material. We have selected rectangular section and concrete as material, and three different sections are selected i.e., 800 x 800mm, 600 x 350mm, 400 x 300mm.

### 3.3.1 LOADS DETERMINATION

Load values have been taken from IS:875 (Part I)-1987, and IS:875 (Part II)-1987

1. Dead Load: (As per IS:875 (Part I)-1987)

It consists of the wall loads and the floor finish loads.

- Outer wall loading : 3 x .23 x 22 = **15.18 kN/m**
- Inner wall loading : 3 x .115 x 22 = **07.09 kN/m**
- Slab Load : 0.15 x 25 = **3.75 kN/m$^2$**
- Floor Finish taken as **1KN/m$^2$**

2. Live Load: (As per IS:875(Part 2)-1987)

The live load is considered to be **2 kN/m$^2$**. (As per Clause 3.1)

3. Seismic Loads: (As per IS:1893(Part 1)-2016)

The Seismic Loading is applied as per IS:1893(Part 1)-2016, by defining the following parameters as per the location of the building structure:

- Zone Factor = .24 : Zone IV (from table 3.1)
- Type of Soil = II : Medium
- Importance Factor = 1 : Residential Complex (from table 3.2)
- Reduction Factor = 5 : SMRF (from table 3.2)

Table 3.1: Seismic Zone Factor

| Seismic Zone Factor Z | | | | |
|---|---|---|---|---|
| Seismic Zone Factor | II | III | IV | V |
| Z | .10 | .16 | .24 | .36 |

(Source- IS:1893(Part1)-2016 - Clause 6.4.2)

Table 3.2: Importance factor (I)

| SI No. | Structure | I |
|---|---|---|
| i) | Important service and community buildings or structures (for example, critical governance buildings, schools). Signature buildings, monument buildings, lifeline and emergency buildings (for example. hospital buildings, telephone exchange buildings, television station buildings, radio station buildings, bus station buildings, metro rail buildings and metro rail station buildings), railway stations, airports, food storage buildings (such as warehouses), fuel station buildings, power station buildings, and fire station buildings), and large community hall buildings (for example, cinema halls, shopping malls, assembly halls and subway stations) | 1.5 |
| ii) | Residential or commercial buildings (other than those listed in SI No. (i) with occupancy more than 200 persons | 1.2 |
| iii) | All other buildings | 1.0 |

(Source IS:1893(Part1)-2016 - Clause 7.2.3)

Table 3.2: Response Reduction Factor (R) for Building Systems

| SI No. | Lateral Load Resisting System | R |
|---|---|---|
| i) | **Moment Frame Systems** | |
| | a) RC buildings with ordinary moment resisting frame (OMRF) | 3.0 |
| | b) RC buildings with special moment resisting frame (SMRF) | 5.0 |
| | c) Steel buildings with ordinary moment resisting frame (OMRF) | 3.0 |
| | d) Steel buildings with special moment resisting frame (SMRF) | 5.0 |

(Source: IS: 1893(Part 1)-2016)

We can always change the dimension of the section if our structure fails.
We now decide the support condition and here we have assigned fixed supports. The supports have been taken on -4m.
We move onto the loading tab of the analytical modelling.

### 3.3.2 LOAD APPLICATION ON THE MODELS

We come to load case details. We add those loads here which we need to analyze by the software and for which the structure is to be designed. Firstly, we add seismic H from ‘Add new: load cases’ window, a case is added for X direction we have titled it as EX and then for Z direction we again add seismic H and we have titled it as EZ.

In EX all dead loads, live loads are defined in all three directions as we consider the vibration of nodes in all the three directions.

Fig. 3.8 shows earthquake load defined in X- direction

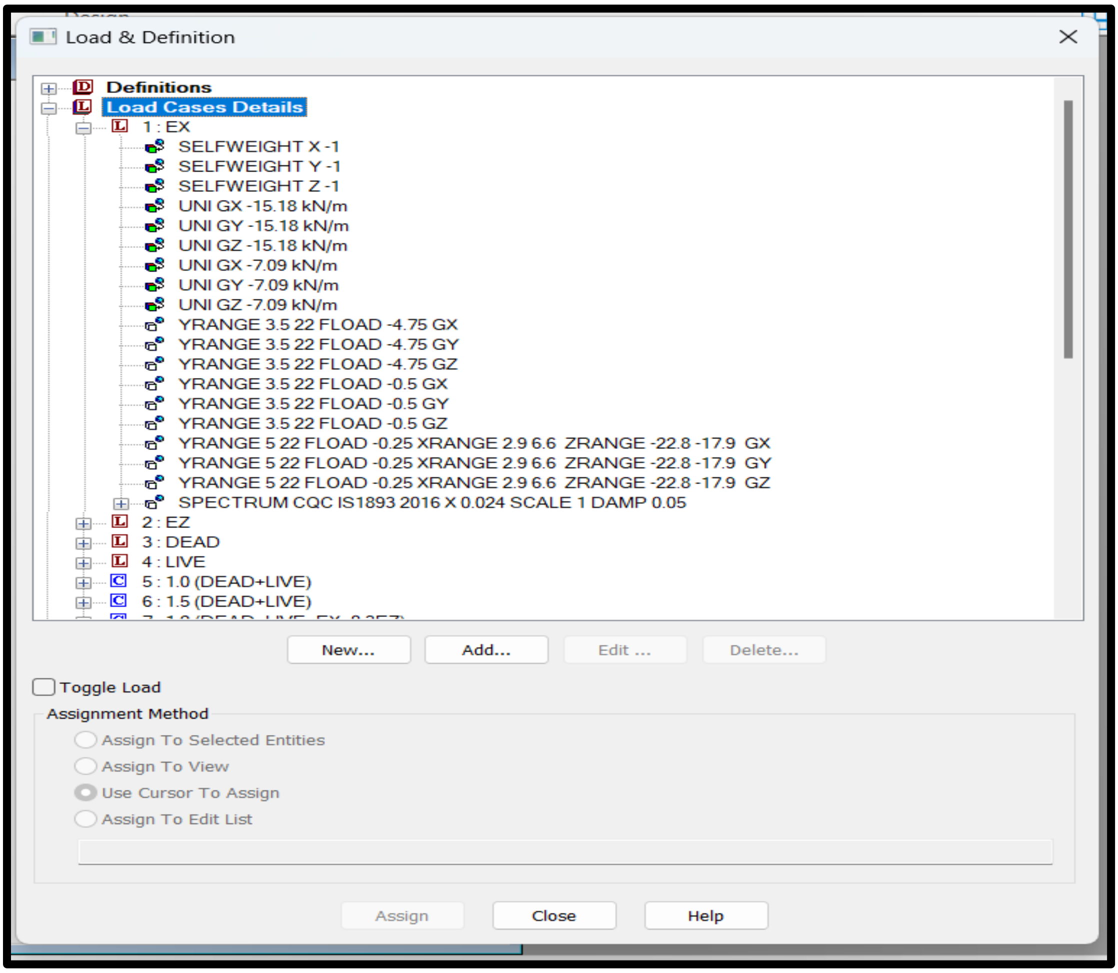


Fig. 3.8: Earthquake loads in x direction

To analyse these load we define a response spectrum in EX itself , after defining the response spectrum all these loads successfully gets analysed by response spectrum analyses. In EX response spectrum is assigned, for this a whole new window of response spectrum appears. In this we need to select the code i.e., IS:1893(Part 1)-2016 and combination method as CQC and subsoil class as medium soil. Spectrum type is acceleration. Now we define acceleration in X direction and Z direction. This value can be taken from IS:1893(Part 1)-2016, clause 6.4.2.

Fig. 3.9 shows response spectrum defined for EZ

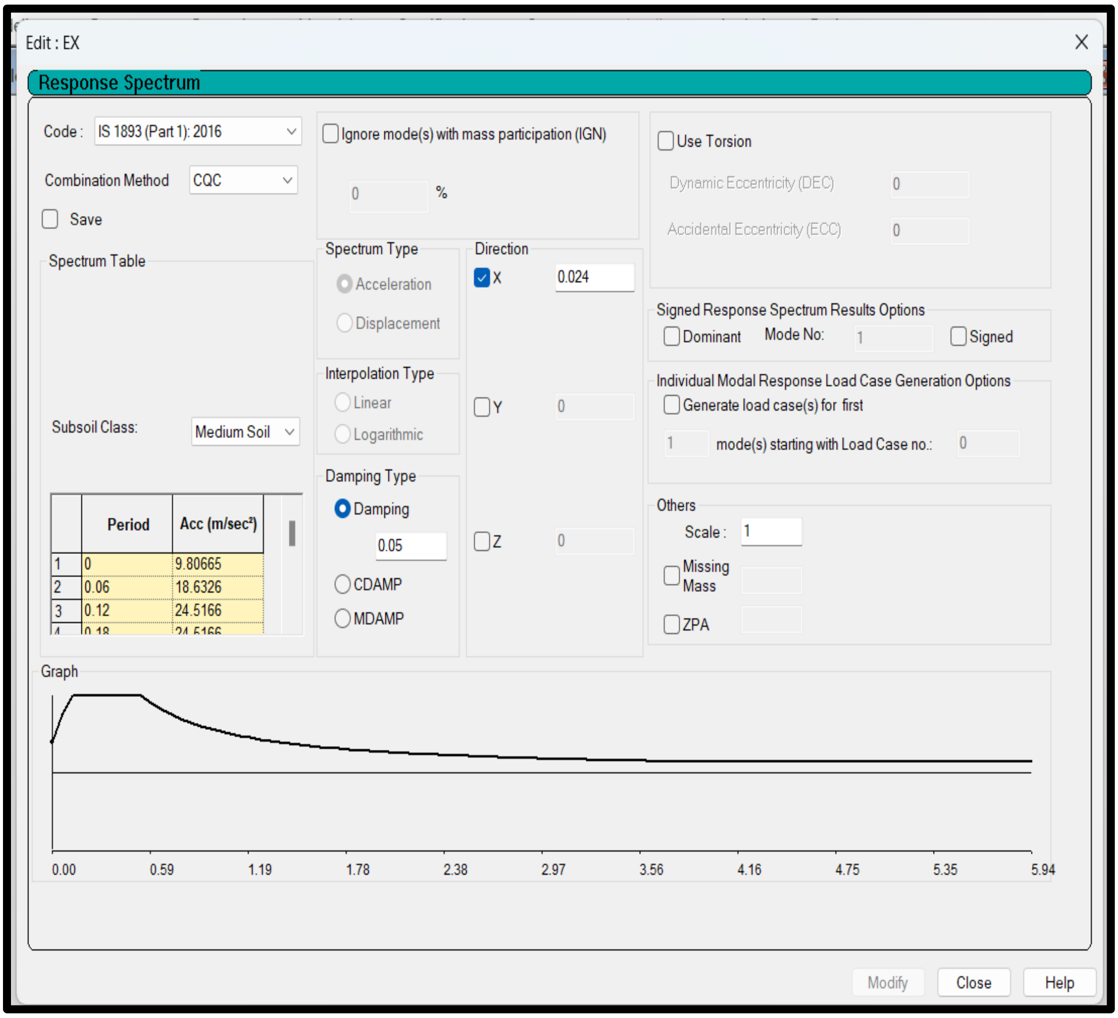


Fig. 3.9: Response spectrum details for X direction

In same manner one more load case detail is added which is SEISMIC-H and we title it as EZ. It contains response spectrum defined in Z direction.

Fig. 3.10 shows response spectrum defined for EZ

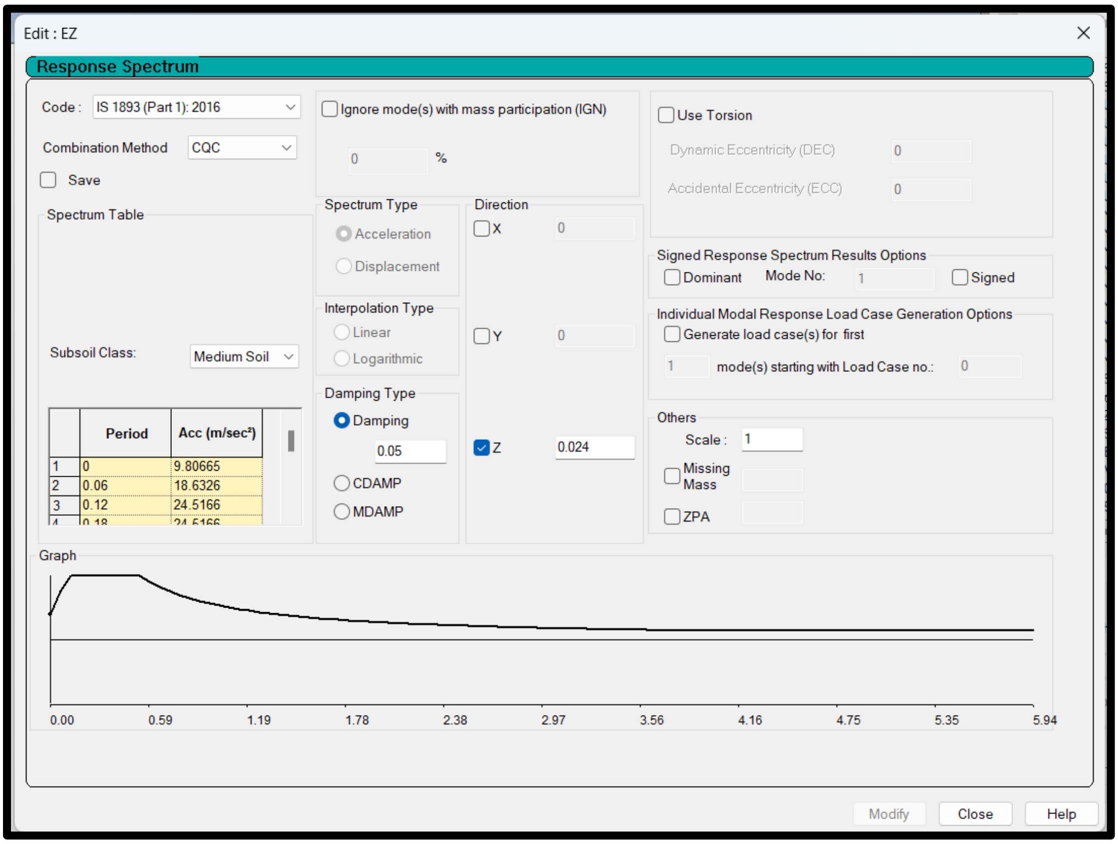


Fig. 3.10: Response spectrum details for Z direction

The design horizontal seismic coefficient $A_h$ for a structure shall be determined by:

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{Sa}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where

Z = Seismic zone factor

I = Importance factor

R = Response reduction factor

$\left(\frac{Sa}{g}\right)$ = design acceleration coefficient

(Source: IS:1893(Part1)-2016- Clause 6.4.2)

After this, dead load and then live load are also defined. Load calculation for dead load and live load has been discussed in section 3.3.1

Fig. 3.11 shows dead loads and live loads details.

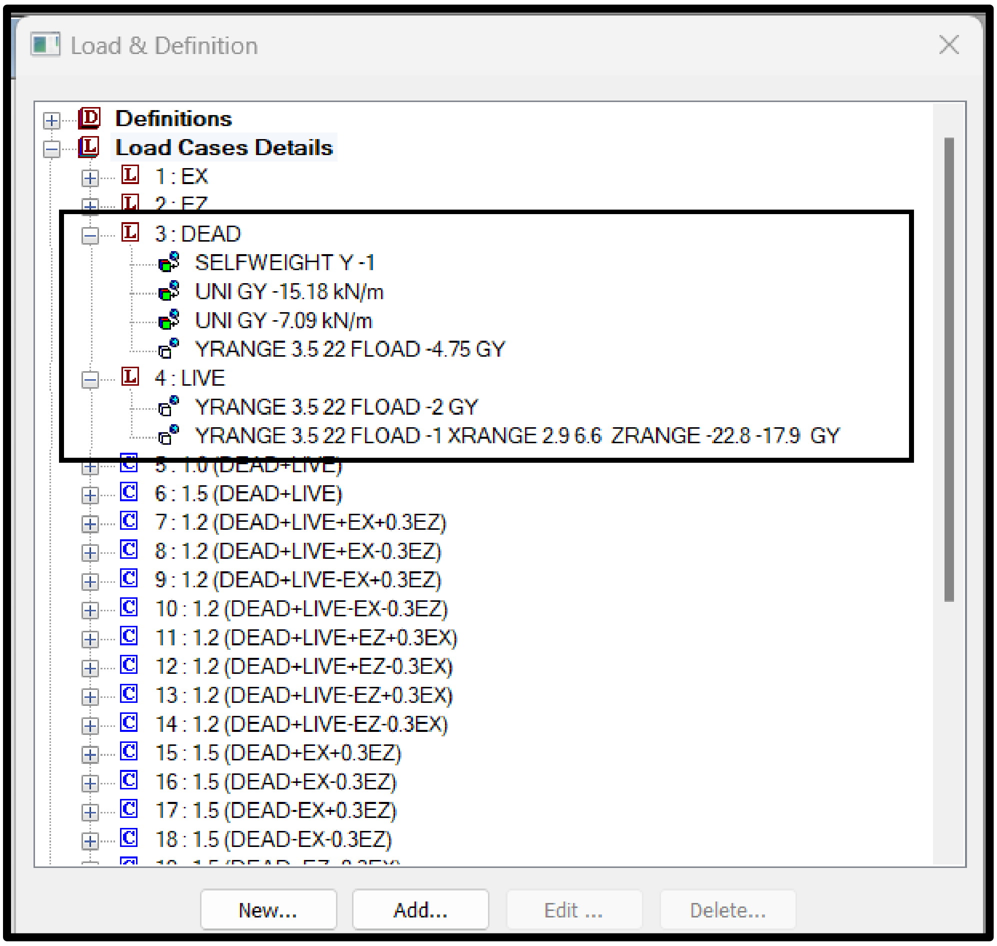


Fig. 3.11: Dead loads and Live loads details

And now we will be defining LOAD COMBINATIONS.

This work is done in two phase, load combinations are defined for analysis which is being done without P-Delta and ***REPEAT LOAD CASE*** with load combination is defined for P-Delta as mentioned in section 3.2.1 of this thesis.

**REPEAT LOAD:**

A P-DELTA analysis will correctly reflect the secondary effects of a combination of load cases only if they are defined using the REPEAT LOAD specification. Secondary effects **will not be** evaluated correctly for LOAD COMBINATIONS.

After adding primary loads, we need to add different load combinations for which we use add new load cases window and by using. Define combinations. We define load combinations. These are available in IS:1893(Part 1)-2016, clause 6.3.2.2

Table 3.3: Different load combinations considered

| | |
|---|---|
| 1. | $1.2\ [DL + IL \pm (EL_x \pm 0.3\ EL_y)]$<br>$1.2\ [DL + IL \pm (EL_y \pm 0.3\ EL_x)]$ |
| 2. | $1.5\ [DL \pm (EL_x \pm 0.3\ EL_y)]$<br>$1.5\ [DL \pm (EL_y \pm 0.3\ EL_x)]$ |
| 3. | $0.9\ DL \pm 1.5\ (EL_x \pm 0.3\ EL_y)$<br>$0.9\ DL \pm 1.5\ (EL_y \pm 0.3\ EL_x)$ |

(Source: IS 1893(Part1)-2016, clause 6.3.2.2)

Fig.3.12 shows Load Combinations for analysis without P-Delta Analysis

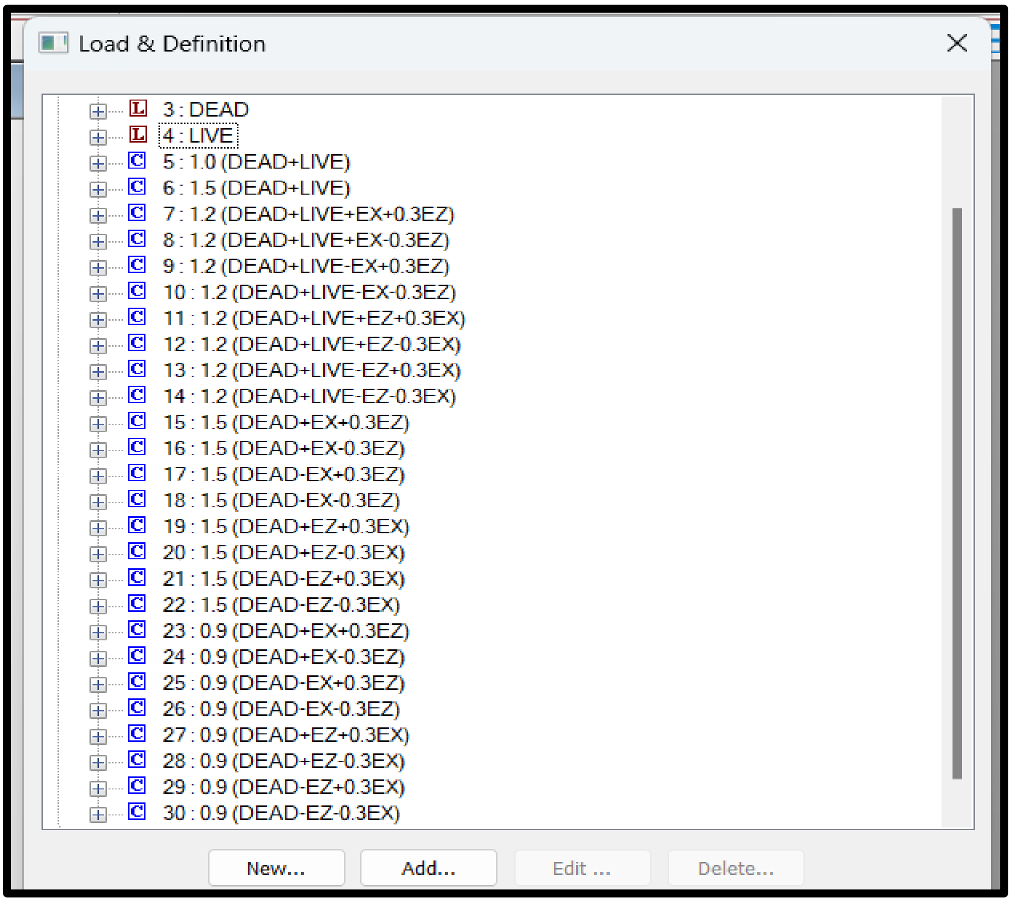


Fig.3.12: Load Combinations used for analysis without P-Delta

Fig.3.13 shows load combination for P-Delta analysis.

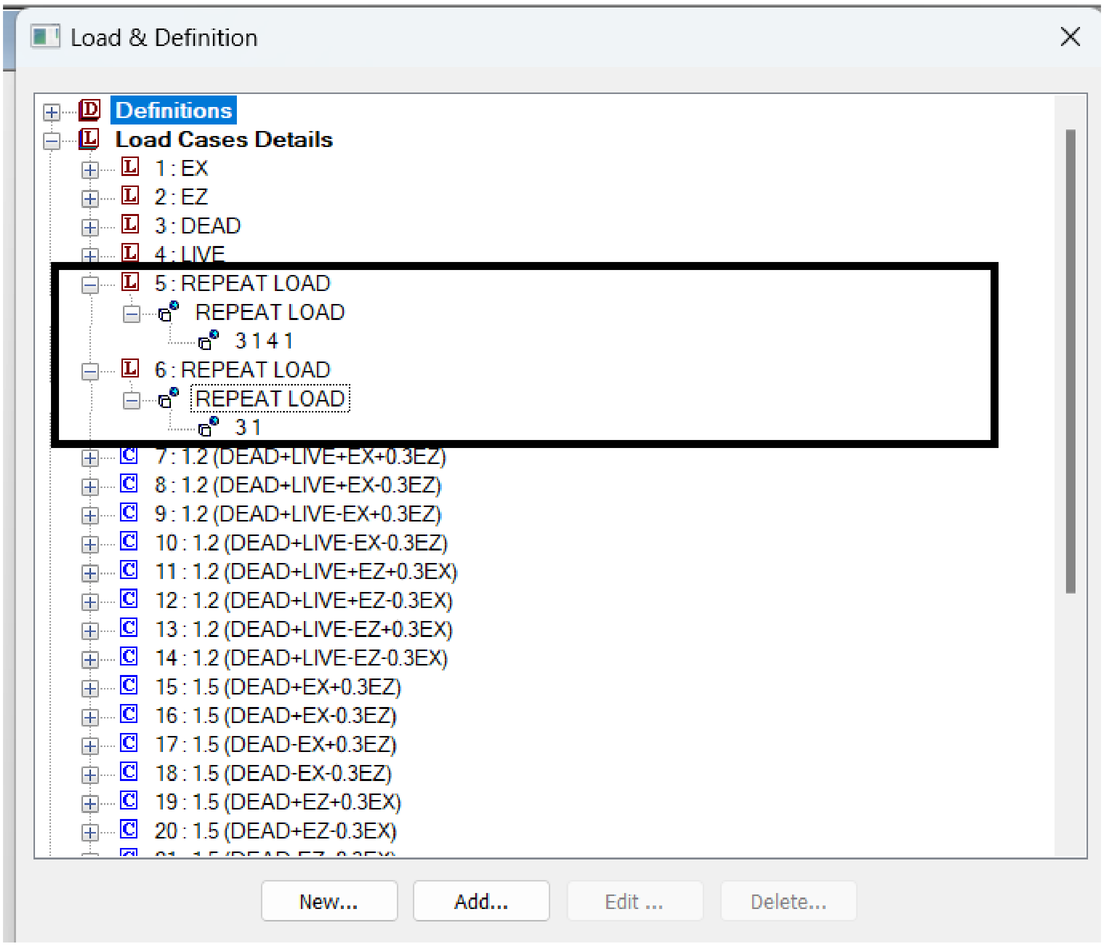


Fig.3.13: Load combination for P-Delta analysis

After this we are all set to analyse our 3 models. We analysed them with and without P-Delta. Without P-Delta "PERFORM ANALYSIS" command has to be used. While in P-Delta analysis, P-Delta analysis command has to be used. Also we define number of iterations for P-Delta analysis, which were 30 in my case. we also add post processing command for storey drift, in which we can see storey displacement and storey drift of each storey.

Results have been discussed in next section.

# CHAPTER 4

## RESULTS AND DISCUSSION

When any structure is subjected to seismic waves, the structural members get displaced from their original state. Thus, the basic parameters on which the results can be compared is maximum displacement. Thus, in this study, the results include the observation of:

1. Maximum Storey Displacement
2. Maximum Storey Drift

Also, since the earthquake analysis has been considered, the results are further divided into two categories:

1. Displacement observed without P-Delta Effect
2. Displacement observed after P-Delta Effect

### 4.1 WITHOUT P-DELTA ANALYSIS:

### 4.1.1 G+4 MODEL:

- The Maximum Storey Displacement is found to be ***20.137 mm*** in **X – direction** and ***13.631 mm*** in **Z – direction**

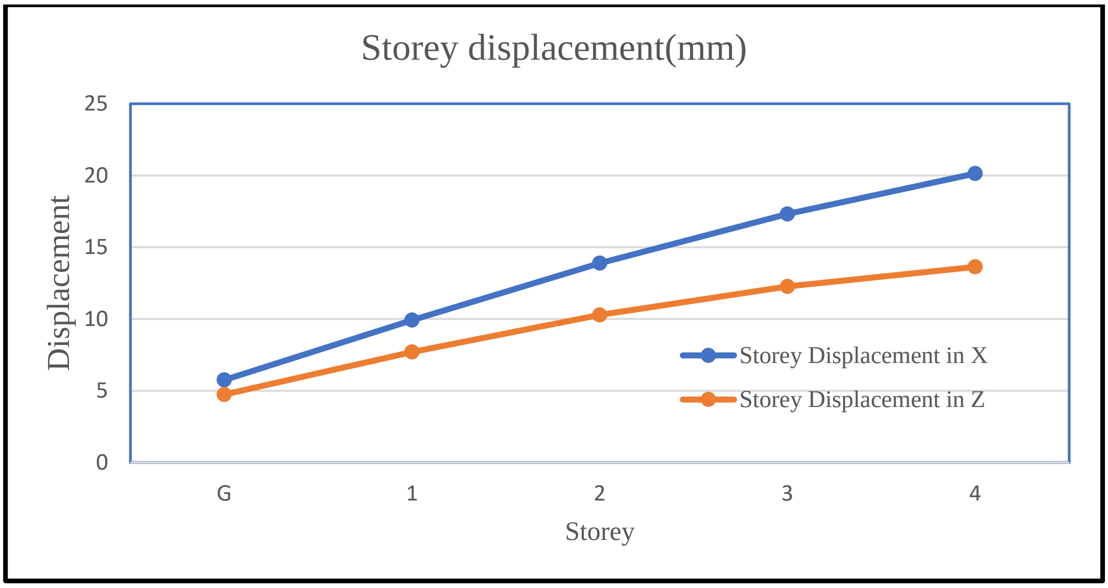


Fig 4.11: Storey Displacement for G+4 Model

We can see from Storey Displacement for G+4 Model graph that the value of storey displacement has increased from ground storey towards the 4th storey and is highest on top most storey. Also, storey displaces more in X-direction and comparatively lesser in Z-direction.

- The magnitude for Maximum Storey Drift is found to be ***4.167 mm*** in **X – direction** and ***2.962 mm*** in **Z – direction.**

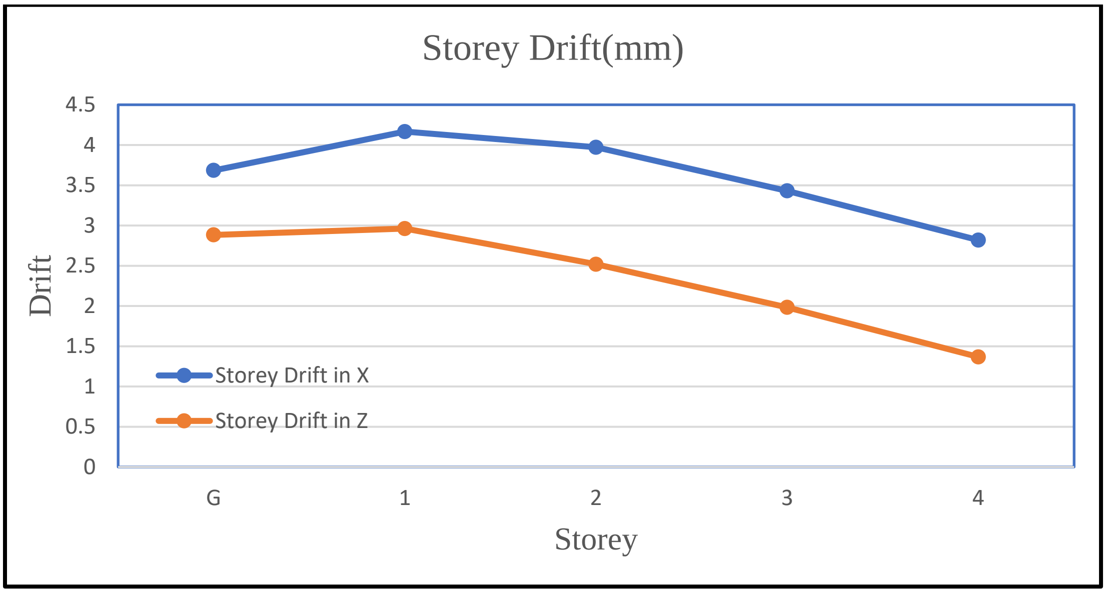


Fig 4.12: Storey Drift for G+4 Model

We can see from Storey Drift for G+4 Model graph that the drift increases initially from ground storey towards 1st storey, but again starts to decline towards the 4th storey, with maximum storey drift on 1st storey.

### 4.1.2 G+10 MODEL:

- The Maximum Storey Displacement is found to be ***44.958 mm*** in **X – direction** and ***29.044 mm*** in **Z – direction.**
- The maximum storey displacement is on top most storey in both directions.

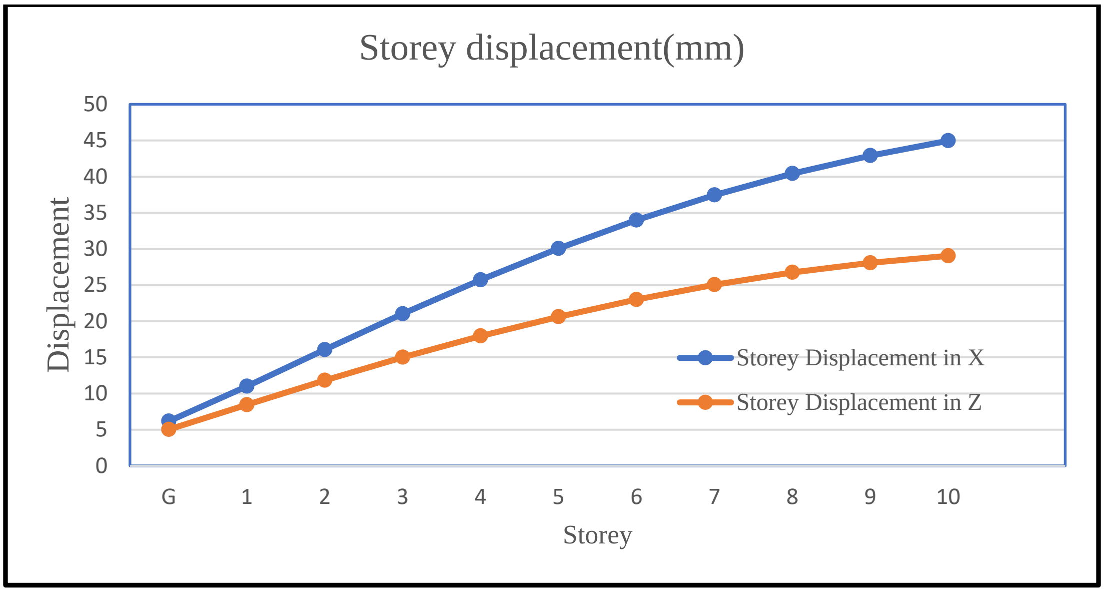


Fig 4.13: Storey Displacement for G+10 Model

- The magnitude for Maximum Storey Drift is found to be ***5.053 mm*** in **X – direction** and ***3.421 mm*** in **Z – direction.**
- The max storey drift is on 2nd storey in X direction while on 1st in Z direction.

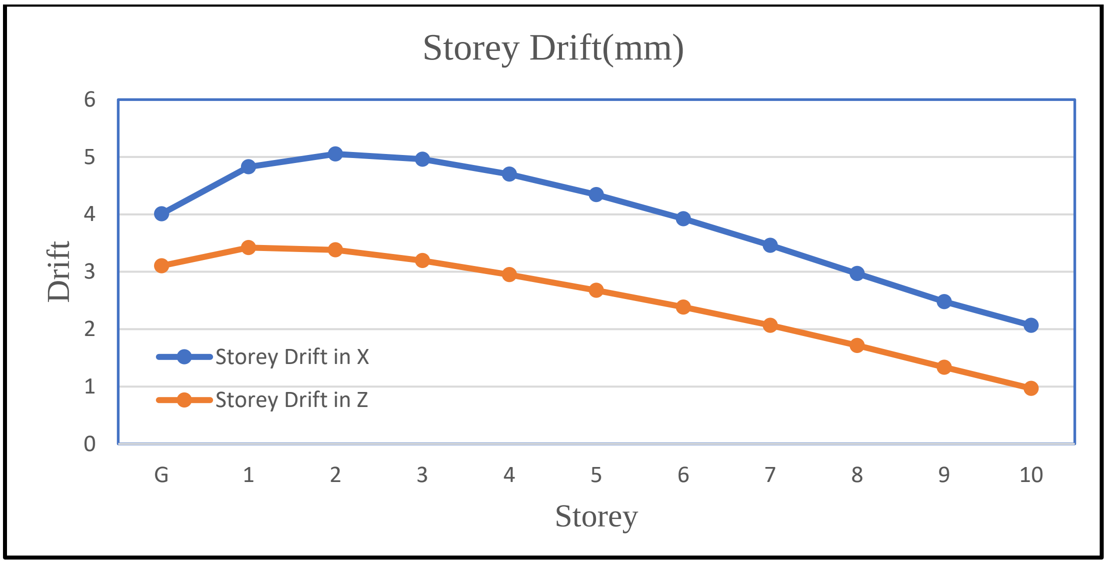


Fig4.14: Storey Drift for G+10 Model

#### 4.1.3 G+22 MODEL:

- The Maximum Storey Displacement is found to be ***155.171 mm*** in **X – direction** and ***67.053 mm*** *in* ***Z – direction.***
- The maximum storey displacement is on top most storey in both directions.

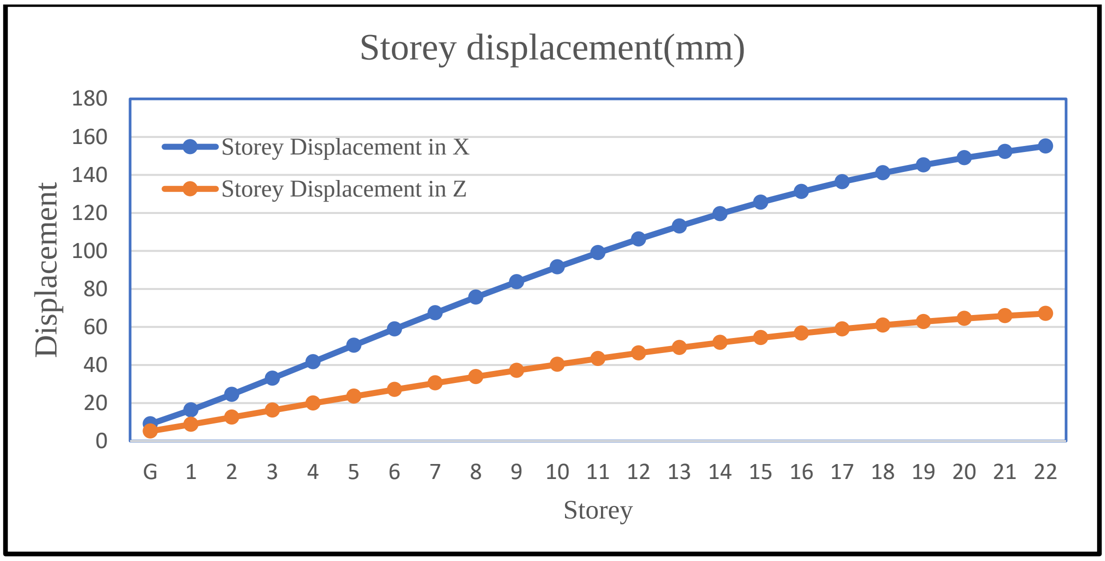


Fig4.15: Storey Displacement for G+22 Model

- The magnitude for Maximum Storey Drift is found to be ***8.672 mm*** in **X – direction** and ***3.741 mm*** in **Z – direction.**
- The max storey drift is on 5$^{th}$ storey in X direction while on 2$^{nd}$ in Z direction.

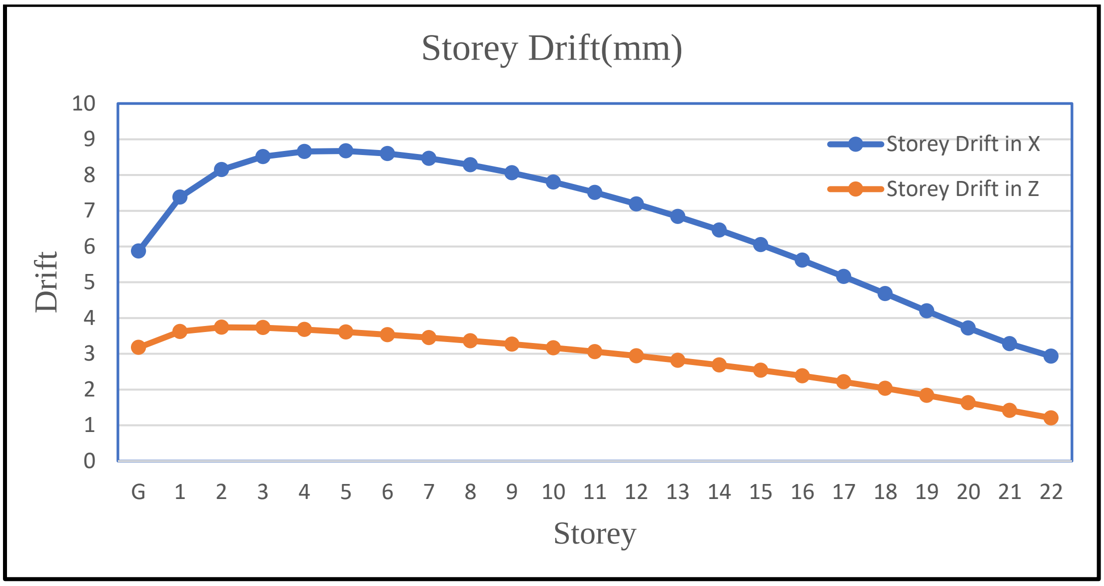


Fig 4.16: Maximum Storey Drift for G+22 Model

### 4.2. P-DELTA ANALYSIS:

The results obtained after using "PDelta Analysis" command for performing P-Delta analysis with 30 iterations are mentioned below.

#### 4.2.1 G+4 MODEL:

- The Maximum Storey Displacement is found to be ***20.382 mm*** in **X – direction** and ***13.676 mm*** in **Z – direction.**
- The maximum storey displacement is on top most storey in both directions.

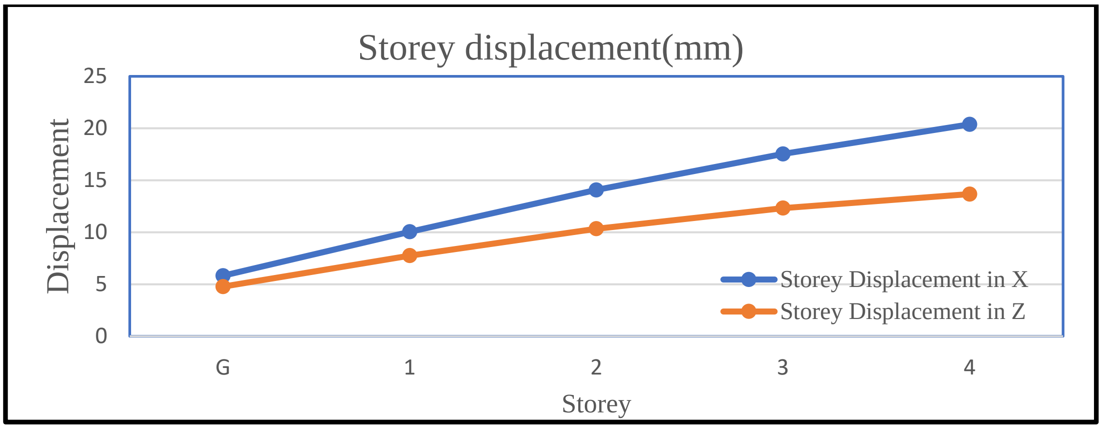


Fig 4.21: Storey Displacement for G+4 Model (P-Delta)

- The magnitude for Maximum Storey Drift is found to be ***4.225 mm*** in **X – direction** and ***2.977 mm*** in **Z – direction.**
- The max storey drift is on 1$^{st}$ storey in both directions.

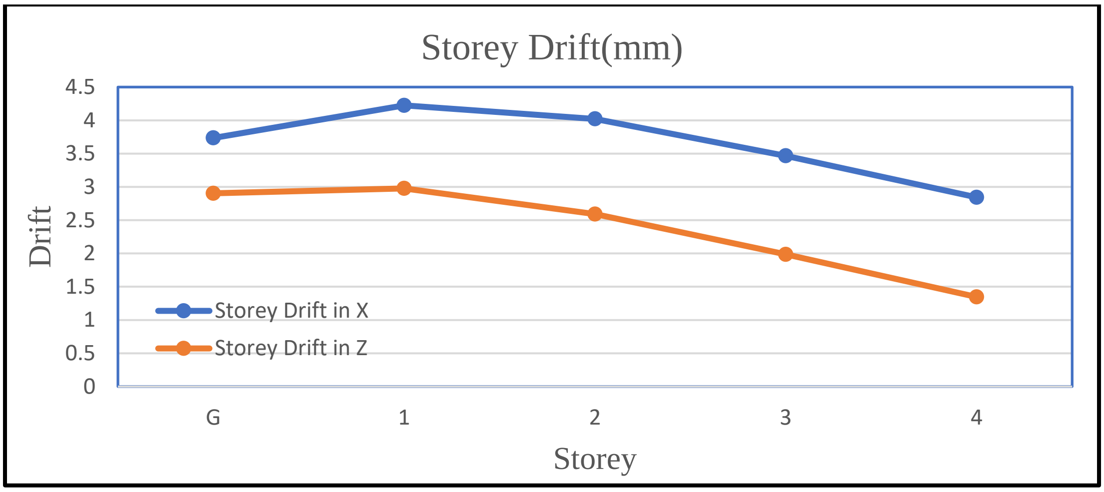


Fig 4.22: Storey Drift for G+4 Model (P-Δ)

### 4.2.2 G+10 MODEL:

- The Maximum Storey Displacement is found to be ***46.379 mm*** in **X – direction** and ***29.516 mm** in **Z – direction.***
- The maximum storey displacement is on the top most storey in both directions.

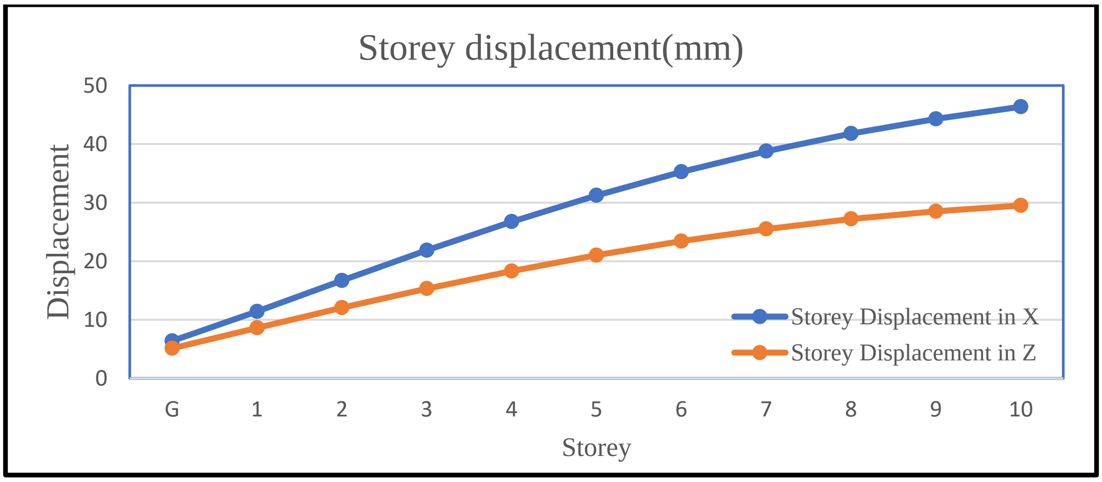


Fig 4.23: Storey Displacement for G+10 Model (P-Delta)

- The magnitude for Maximum Storey Drift is found to be ***5.274 mm*** in **X – direction** and ***3.496 mm*** in ***Z – direction.***
- The max storey drift is on 2nd storey in X direction while on 1st in Z direction.

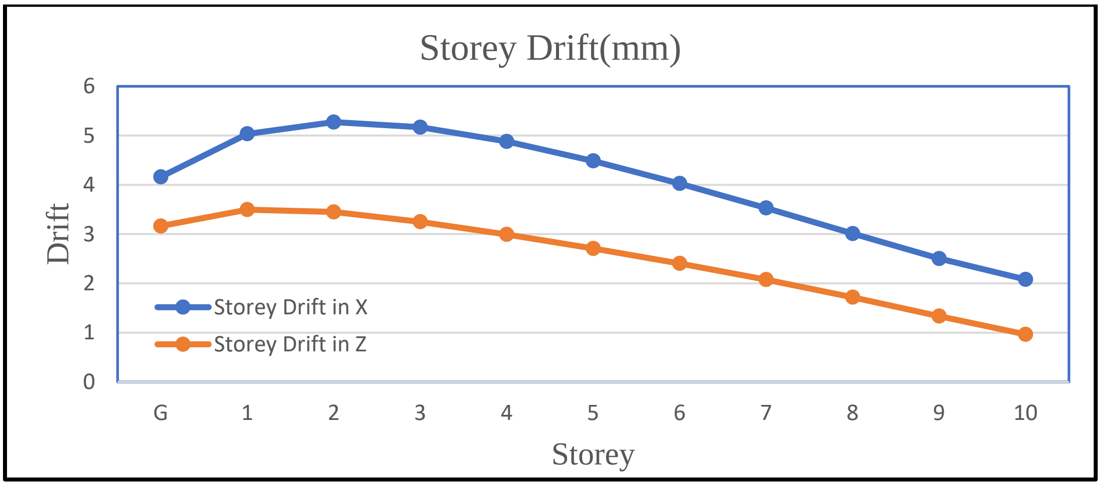


Fig4.24: Storey Drift for G+10 Model (P-Delta)

### 4.2.3 G+22 Model:

- The Maximum Storey Displacement is found to be ***185.099* mm** in **X – direction** and ***70.818 mm*** in **Z – direction.**
- The maximum storey displacement is on the top most storey in both directions.

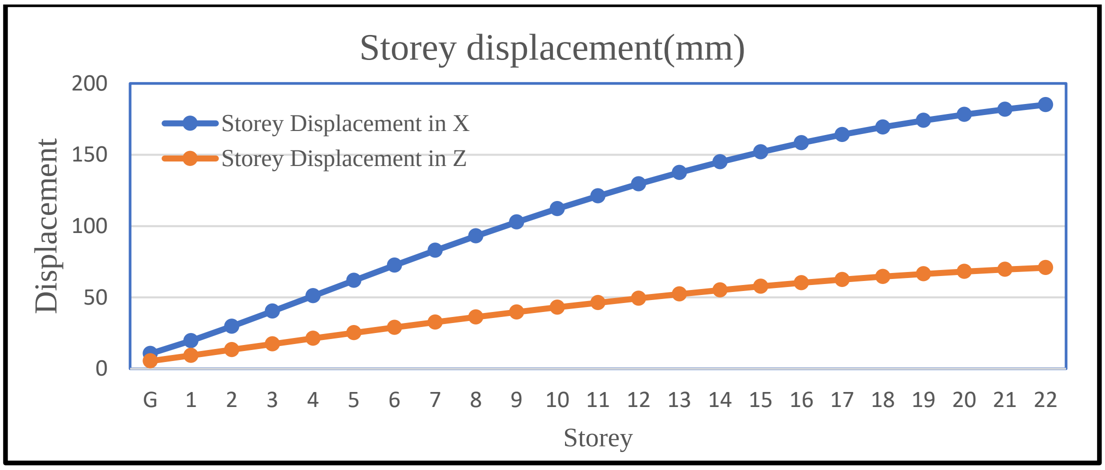


Fig4.25: Storey Displacement for G+22 Model (P-Delta)

- The magnitude for Maximum Storey Drift is found to be ***10.79 mm*** in ***X – direction*** and ***4.016 mm*** in ***Z – direction.***
- The max storey drift is on 4$^{th}$ storey in X direction while on 3$^{rd}$ in Z direction.

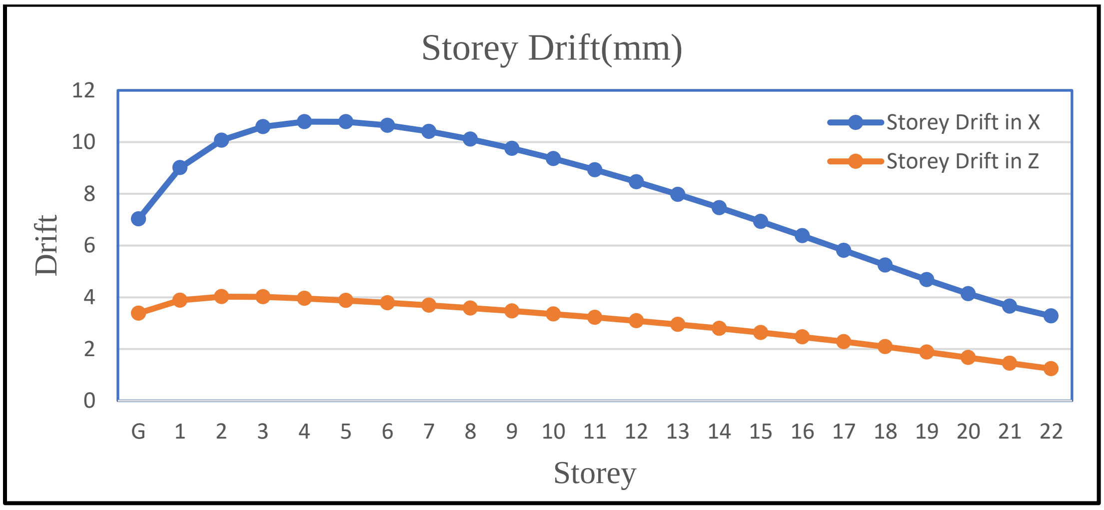


Fig 4.26: Storey Drift for G+22 Model (P-Delta)

## 4.3 TIME PERIOD AS PER P-DELTA ANALYSIS *(Magnitude in seconds)*

**Table No. 4.2: Results obtained of Time Period for 12 Modes**

| | Mode No. | G+4 | G+10 | G+22 |
|---|---|---|---|---|
| P-Δ Analysis | 1 | 1.23266 | 2.81162 | 6.71388 |
| | 2 | 0.98826 | 2.04508 | 4.42856 |
| | 3 | 0.8625 | 1.83826 | 4.08869 |
| | 4 | 0.65843 | 0.89995 | 2.03695 |
| | 5 | 0.56294 | 0.83377 | 1.46841 |
| | 6 | 0.43551 | 0.69426 | 1.30244 |
| | 7 | 0.33834 | 0.64154 | 1.09042 |
| | 8 | 0.33602 | 0.58033 | 1.00756 |
| | 9 | 0.30584 | 0.49308 | 0.87407 |
| | 10 | 0.30418 | 0.48918 | 0.81903 |
| | 11 | 0.27483 | 0.48537 | 0.72701 |
| | 12 | 0.26032 | 0.42431 | 0.71155 |

## 4.4 CIRCULAR FREQUENCY AS PER P-DELTA ANALYSIS

*(Magnitude in cycles/seconds)*

**Table No. 4.4: Results obtained of Circular Frequency for 12 Modes**

| | Mode No. | G+4 | G+10 | G+22 |
|---|---|---|---|---|
| P-Δ Analysis | 1 | 5.09931 | 2.23562 | 0.936227 |
| | 2 | 6.36039 | 3.07358 | 1.419359 |
| | 3 | 7.28778 | 3.41938 | 1.537342 |
| | 4 | 9.54652 | 6.98452 | 3.085846 |
| | 5 | 11.1659 | 7.53891 | 4.280626 |
| | 6 | 14.433 | 9.05383 | 4.826107 |
| | 7 | 18.5781 | 9.79785 | 5.764489 |
| | 8 | 18.7064 | 10.8313 | 6.238551 |
| | 9 | 20.5523 | 12.7479 | 7.191317 |
| | 10 | 20.6645 | 12.8495 | 7.674584 |
| | 11 | 22.8713 | 12.9504 | 8.645981 |
| | 12 | 24.1461 | 14.814 | 8.833834 |

## 4.5 CORRELATION FACTOR

Value of Correlation factor lies between -1 to +1. When correlation factor tends to +1 or -1, it is considered as good correlation factor.

### 4.5.1. G+4 & G+10:

a) The correlation between the **Maximum Displacement** for G+4 & G+10: ***y = 0.9976x.***

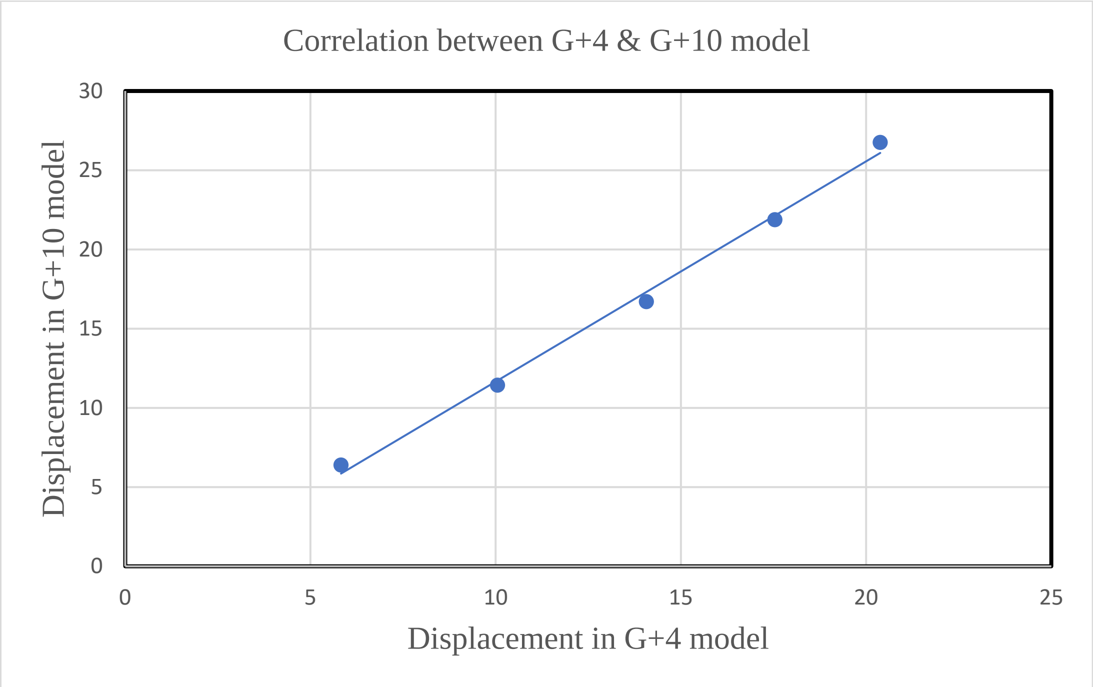


Fig. 4.5.1: Correlation between G+4 and G+10 model

### 4.5.2 G+10 & G+22

a) The correlation between the **Maximum Displacement** for G+10 & G+22 is ***y=0.992x.***

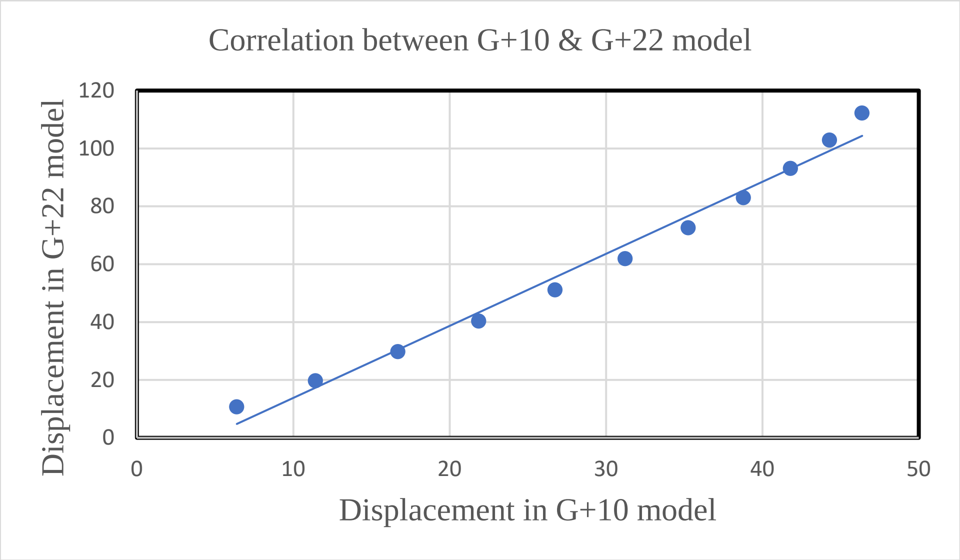


Fig. 4.5.2: Correlation between G+10 and G+22 model

### 4.5.3 G+4 & G+22

a) The correlation between the **Maximum Displacement** for G+4 & G+22 is ***y=0.9943x.***

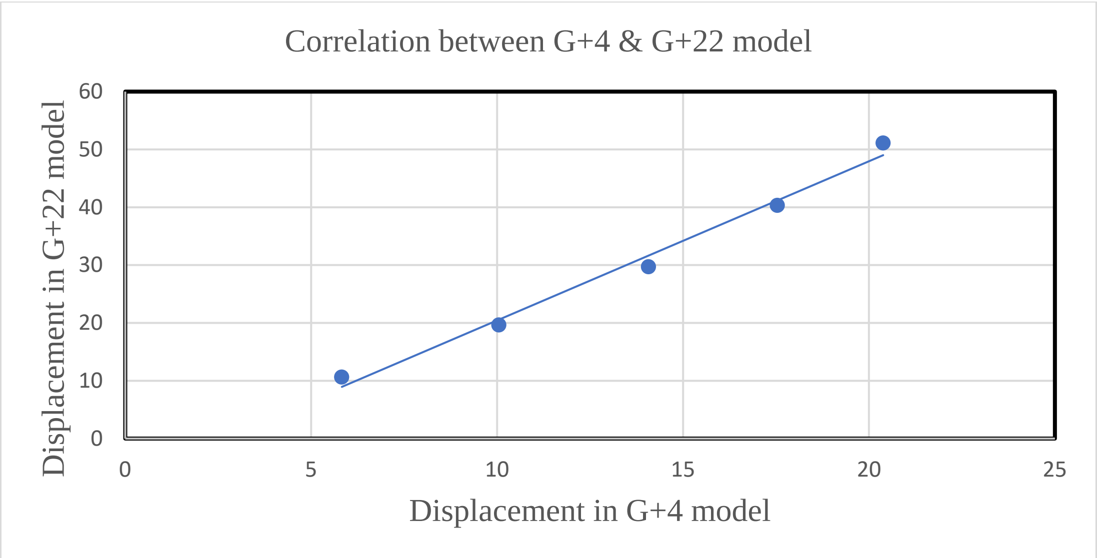


Fig. 4.5.3: Correlation between G+4 and G+22 model

# CHAPTER 5

# CONCLUSION

Earthquakes are considered as one of the disasters which causes widespread loss of both human life and property. Thus, it a necessity that all the newly – constructing structures must be designed and analysed as per the revised and latest considerations of the standard codal provisions. Also, the existing structures must be analysed so that their behavior can be noted and necessary rehabilitation or retrofitting techniques must be adopted for re – strengthening the structure.

In this study, three different models of existing structures are considered under the area of high seismic zone, analysed under StaadPro while considering the P - Δ Analysis. the following data is recorded as:

1) Maximum Displacement:

   a) For G+4 Model, the **Maximum Storey Displacement** observed is 20.382 mm in X-direction and 13.676 mm in Z-direction.
      The P-Delta analysis has given higher Maximum Storey displacement by **1.22%**

   b) For G+10 Model, the **Maximum Storey Displacement** observed is 43.379 mm in X-direction and 29.516 mm in Z-direction.
      The P-Delta analysis has given higher Maximum Storey displacement by **3.16%**

   c) For G+22 Model, the **Maximum Storey Displacement** observed is 356.969 mm in x – direction and 139.93 mm in z – direction.
      The P-Delta analysis has given higher Maximum Storey displacement by **19.29%**

2) Maximum Storey Drift:

a) For G+4 Model, the **Maximum Storey Drift** observed is 4.225 mm in X-direction and 2.977 mm in Z-direction.

b) For G+10 Model, the **Maximum Storey Drift** observed is 5.274 mm in X-direction and 3.496 mm in Z-direction.

c) For G+22 Model, the **Maximum Storey Drift** observed is 10.79 mm in X-direction and 4.023 mm in Z-direction.

3) Correlation Factor:

a) The correlation between the **Maximum Displacement** for G+4 & G+10 is **y = 0.9976x**

b) The correlation between the **Maximum Displacement** for G+10 & G+22 is **y = 0.992x**

c) The correlation between the **Maximum Displacement** for G+4 & G+22 is **y = 0.9943x**

It can be concluded that as height of the building increases, P-Delta Analysis gives a significant increment in Maximum Storey Displacement. So, it is recommended that High-rise structure must always be analysed with P-Delta analysis to account for these extra displacements.

In this study the correlation factor is tending towards 1, and graph of correlation is nearly linear, so we can also interpolate displacements for other building given structural members and dimensions, zone remain the same. This kind of study is beneficial for residential projects because of their nearly same plan and dimensions.

# FUTURE SCOPE

When any structure experiences seismic forces, it is subjected to a lateral force, which may come from any direction, making the structure oscillates, being fixed at the base. Thus, a proper management has to be required for at least safeguarding the structure so that in meantime, the people must be evacuated from the structures and no casualties would be reported because of the demolition of the structures.

Such analysis of the structures, especially on the existing structures, should be made mandatory while considering the current scenarios of increase rate of earthquakes all over the world. Once these structures had been analysed and if they found that any of the structural member fails as per the “Building Performance Level” criteria, those structural members need to be rehabilitated or retrofitted, depending upon the level of the typical performance of a building.

Retrofitting is a technique to re – strengthen the building by employing various techniques to the existing structure, to make them stronger so that they didn’t get failed when they experienced actual earthquake. The various techniques considered for bracing includes bracing, jacketing and composite materials. Bracings can be done with in different ways, with different cross – sectional elements such as angle sections, channel sections, rod sections and many more. Jacketing is a technique in which a particular structural element is re – strengthened by providing extra reinforcement bars, known as rebars, in the periphery of the structural element; making its size bigger than the original one so that they can withstand the required loading conditions. Composite material is another technique in which by providing necessary scaffolding, the damaged structural element under consideration is totally removed and then, replaced by a newly constructed composite element, made up of generally a standard steel section, embedded in the concrete framework. If the structural element or whole structure falls beyond the “Collapse Prevention” category of building performance level, then its beneficial for the people as well as the society to demolish the same; reducing the number of casualties observed in aftermath of the event of earthquake

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