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COMPARATIVE ANALYSIS IN ASYMMETRICAL BUILDING WITH TRADITIONAL SHEAR WALL AND WITH STAGGERED SHEAR WALL OPENING

A DISSERTATION

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MASTER OF TECHNOLOGY

IN

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I, INDER KUMAR YADAV, 2K21/STE/12, of M.Tech (Structural Engineering), hereby declare that the project Dissertation titled "Comparative analysis in asymmetrical building with traditional shear wall and with staggered shear wall opening" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the 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 "Comparative Analysis In Asymmetrical Building With Traditional Shear Wall And With Staggered Shear Wall Opening" which is submitted by INDER KUMAR YADAV, 2K21/STE/12, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge, 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

Today, constructing building with regular shapes and designs are sometime not practical due to irregular plot dimensions and specific functions and aesthetics requirement in urban areas. Therefore, to overcome these problems, irregular buildings are taken into consideration. However, irregular structures, whether horizontal or vertical, are more prone to damage by wind and earthquake forces, which can lead to casualities, property damage and can also lead to potential collapse. To combat lateral forces, high rise buildings commonly use shear walls – reinforced concrete and masonry wall which are designed to resist in-plane lateral forces, including seismic and wind forces. There are several studies which shows that shear wall performs much better without openings, but in some cases it has been seen that there are requirement of openings in shear wall because of ventilation and mechanical movement of lifts.

The comparative study focuses on the horizontal and vertical irregularity with and without staggered shear wall opening under the effect of seismic load using ETABS software. The two models are modelled for with and without staggered shear wall opening for G+15 storey. The structure are modelled for 30 m x 30 m plan having two types of irregularity i.e Horizontal and vertical irregularity, with and without staggered shear wall opening. According to Indian Code (IS:1893-2016), dynamic analysis is to be conducted for building taller than 15 meters and located in Zone IV. Dynamic analysis can be done by either using the response spectrum method or time history method. In this particular study G+15 storey building was modelled and analyzed using the response spectrum method in the ETABS software. A response spectrum is a graph that shows the maximum response (maximum, displacement, velocity, and acceleration) as

compared to the natural frequency of a single degree of freedom system (SDOF). The main aim of this paper is to compare the result like Displacement, Stiffness, Shear & Drift values and find out which models performs better under the seismic excitation. In the present study vertical geometrical irregular building with staggered shear wall opening has shown better performance than the other building.

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Place: INDER KUMAR YADAV

Date:

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ABBREVIATIONS

MI = Horizontal irregularity without shear wall

MII = Horizontal irregularity with staggered shear wall opening

MIII = Horizontal irregularity without shear wall opening

VI = Vertical irregularity without shear wall opening

VII = Vertical irregularity with staggered shear wall opening

VIII = Vertical irregularity without shear wall opening

RSA = Response spectrum analysis

HIWoSW = Horizontal irregularity without shear wall

HIWSSWO = Horizontal irregularity with staggered shear wall opening

HIWoSWO = Horizontal irregularity without shear wall opening

VIWoSW = Vertical irregularity without shear wall opening

VIWSSWO = Vertical irregularity with staggered shear wall opening

VI|WoSWO = Vertical irregularity without shear wall opening

CHAPTER 1

INTRODUCTION

1.1 GENERAL

According to UN population estimates, the most significant shift in global demographics is that India has overtaken China as the world's most populous country. According to the Economic Survey 2016–17, over the course of the last five years, roughly 90 million people have moved between Indian states utilising trains, which is nearly twice as many as was the case during the initial decade of the century. The largest employment centre with the highest inflow of people was in North India's National Capital Region, which includes Delhi, Gurugram, and Gautam Budh Nagar. Due to the ever-increasing population and expanding economies in the world's main cities, urbanisation is increasing globally, so is the population density in urban areas. Suburban development expansion is continuously consuming arable land areas. Compared to a low-rise building, the tall skyscraper can house a lot more people on a smaller area of land. A high structure represents the vertical transformation of horizontal growth.

As per the National Building Code of India (NBC), a high-rise building is defined as any building with a height of 15 meters (or approximately 50 feet) or more from the ground level. However, the exact definition of a high-rise building may vary depending on the specific regulations and by-laws of the country, region, or city where the structure is situated. There are different types of structural systems:-

1. Braced frame structural system

- Braced frames are suspended upright structures that resist lateral stresses with cross-sectional components that, along with the girders, form the "web" of the vertical truss and its supporting columns as the "chords."

- It is utilised in buildings made of steel. This system works well for modest to mid-height multistory structures.

2. Wall-frame system (dual system)

- Wall and frame engage horizontally to provide a stronger and sturdier system. Generally, the walls are a solid (not perforated by apertures) and are located around stairwells, lift shafts and the perimeter.

3. Shear wall system

- It is a continuous, vertical wall made of concrete with reinforcement or masonry. As a narrow, deep cantilever beam, shear walls resist gravity as well as and lateral stresses.
- The shear wall system is appropriate for the hotel and housing developments with repetitive floor-by-floor design which allows vertical continuous walls.

4. Infilled frame structural system

- The infilled frame structure concept comprises of a beam-and-column framing with masonry, concrete with reinforcement, or block construction infilling some of the compartments. To accommodate the frame, infill walls may be of partial or full height.
- It is possible that the walls and formwork are not connected.

1.2 TYPES OF IRREGULARITY

Structure that have regular geometry and mass that are uniformly distributed and having stiffness in elevation and plan, tends to have much less damage, than the building which has irregularity. Below table shows about different types of irregularity and these irregularities must reduced by modifying structural configurations.

Table 1.1 Types of vertical and horizontal irregularity as per IS code 1893(part 1):2016

Types of plan and vertical irregularity	
Horizontal/plan irregularity	Vertical irregularity
1. Torsional irregularity 2. Re-entrant corner 3. Excessive cut-outs or opening in the floor slab. 4. Out of plane Offsets in Vertical Elements 5. Non-parallel Lateral Force System	1. Stiffness irregularity 2. Mass irregularity 3. Vertical Geometric irregularity 4. In-plane Discontinuity in vertical elements resisting lateral force 5. Strength irregularity 6. Floating or stub column 7. Irregular modes of oscillation in two principal directions

There are limitations according to IS 1893:(2016) Part 1 for the irregularity. These are :-

Table 1.2 limits of irregularity as per IS 1893:(2016) Part 1

Irregularity	Type	Limits
Mass	Vertical irregularity	$M_{i+1} > 1.5\ M_i$
Stiffness	Vertical irregularity	$S_i < S_{i+1}$
Torsion	Plan irregularity	$\Delta_{max}/\Delta_{avg}$=1.5 to 2.0 >2.0 extreme irregularity
Vertical Geometry	Vertical irregularity	A>0.1L

1.3 METHOD OF ANALYSIS

The seismic response of the building system is highly dependent on the employed seismic analysis method. Historically, analysis methods were restricted to a linear static approach due to its simplicity in application, computation, and interpretation. The methods produced secure designs, but they were deemed excessively conservative. With the advent of advanced computers and analysis software, scientists are now able to simulate actual earthquakes on models to acquire more accurate seismic responses. These techniques gained the name dynamic analysis. Static and dynamic analysis are further subdivided into linear and nonlinear methods based on the force-deformation relationship of the structural members.

The method of seismic analysis are briefly discussed below: -

1.3.1 Equivalent Lateral Force Method

The seismic analysis is completed with the presumption that the lateral force is equivalent to the actual loading. According to IS 1893 (Part1): 2016, only regular buildings with heights under 15 m in seismic zone II and regular structures with an approximative natural period Ta less than 0.4 s are eligible for use of the linear static method. The durations and forms of higher modes are disregarded in this procedure, which requires less computational labour. Using the formula specified by the code, the base shear is determined based on the mass, fundamental period, and geometry of the structure. Lateral pressures are then distributed along the height of the structure according to base shear.

1.3.2 Response Spectrum Analysis (RSA)

This approach is suggested for constructions whose response is significantly influenced by higher vibration modes. This technique is typically used to analyse the dynamic reactions of irregular structures or regions with discontinuous behaviour. It can be used to analyse the forces and deformations of tall buildings subjected to medium intensity ground vibrations that result in moderately substantial but essentially linear responses in structures. For a specific damping mode, this method calculates the response of each natural vibration mode independently of the other modes, and the modal responses can be added to get the overall response. According to IS 1893 - 2016 (Part 1), all buildings other than normal buildings that are lower than 15 m and in seismic zone II can use this technology.

1.3.3 Pushover Analysis (PoA)

Pushover analysis is a non-linear static analysis since it permits the structure's inelastic behaviour. This approach offers data on the structure's strength, deformation, and ductility as well as the distribution of demands. The technique also identifies the susceptible members most likely to hit their limit states and forecasts five probable structural weak points. The engineer can modify the design and detailing procedure during the design stage thanks to the identification of these crucial members. This method can be applied to existing structures when seismic retrofitting is required to meet current demands or when the structure's seismic resisting capacity has to be improved. However, this approach has drawbacks since it ignores resonance, higher modes of vibration, and variations in loading patterns. Additionally, the pushover analysis is not coded into IS.

1.3.4 Time History Method

Both elastic and inelastic analysis can use this technique. The most precise method for describing the real seismic behaviour of a structure is time history, a nonlinear dynamic analytic technique. A number of time intervals are used to calculate the structural response. To calculate the seismic response using this method, however, needs extensive computation and skilled interpretation. Therefore, this approach is only advised for the design of unique structures.

1.4 OBJECTIVES OF THE STUDY

- To model 3D frame having irregularity (plan and vertical) using ETABS software and perform response spectrum analysis to study and compare the various responses – storey displacement, storey stiffness, storey drift and base shear.
- Comparison of the behaviour of the structure with the traditional shear wall model with the staggered shear wall opening model on the basis of the seismic response.
- To find which irregularity configuration structure provides good performance under lateral loads for the given models and to enable incorporating irregularities in a structure without adversely affecting its seismic performance.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

N Lingeshwaran (2021) compared symmetrical and asymmetrical buildings subjected to seismic loads through the use of analysis. The author desired to examine the impact of load deployment upon the functionality of buildings of different shapes. Using the ETABS software, symmetric and asymmetric structures such as H-shape, L-shape, Rectangular shape, and T-shape buildings for G + 9 storey were studied. The structures are designed for earthquake forces in accordance with IS 1893 (Part 1): 2016. To investigate the response of various structures to applied loads. ETABS software analysis of buildings for storey drift and displacement of symmetric and asymmetric structures. The author concluded that symmetrical structures outperform asymmetrical ones. According to the preceding results, T-shaped structures are more susceptible to seismic loads than symmetrical structures. The storey displacement on the first floor is significantly less than that on the upper floor. In addition, L-shaped and H-shaped structures exhibit comparable seismic displacement.

Zahibullah, Priyanka Singh (2020) conducted the study on the effect of vertical and horizontal irregularity of the reinforced concrete structures on the Seismic response. The author used ground + 7 storeyed regular building and integrating with various irregularities in the vertical and horizontal planes and combination of irregularities. The comparison is done using Response Spectrum Method as per IS – 1893:2016. The comparison was based on fundamental period, Base shear, Storey stiffness, Storey Drift, Eccentricity, Torsional irregularity. In the study, the author concluded that the model having Vertical geometric irregularity has better seismic resistance whereas the model having Horizontal irregularity provides least seismic resistance. The study also concluded that the seismic mass of a structure varies with its position and degree of irregularities which has direct effects on the building's structural performance. Also, when dealing with a combination of irregularities, such as mass and stiffness irregularities, the author concludes that the ratio between stiffness reduction and mass reduction must be meticulously maintained.

Pradeep Pujar, Amaresh (2017) compared the irregular multi-storied building with and without shear wall. The author works on the different shapes of the building such as L-shape, I-shape, and C-shape which are of G + 9 storey. The examination was done using ETABS V 15.0 on the basis of Equivalent static technique. The parameters on the basis of which the comparison was done was Storey drift, storey displacement and base shear. The author has concluded that the model that has shear wall performs better by reducing the storey uprooting by upto 50-70%. Also the model that have L-shape, C-shape with shear wall are having better base shear, storey displacement and storey shear and also reduces the cross- section area of different section.

V. Naresh Kumar Varma (2021) analyses the seismic analysis of a structure, which is dependent on variables such as dead load, live load, and earthquake loads. Comparing structures with and without shear walls, the study demonstrates that the use of shear walls reduces shear and bending moments. In particular, structures with shear walls exhibit lower shear and bending moments than those without. Additionally, the study reveals that the breadth of openings has a greater effect on deflection than the height. Additionally, buildings with shear walls have greater story rigidity and less story drift than those without. The study concludes that total displacements are greater when openings are situated near the wall's borders than when they are situated in the wall's centre.

Shaik Akhil Ahamad (2021) conducted a dynamic analysis of a G+20 multiple stories structure with a shear wall for various seismic zones. This study involves a dynamic assessment of a high-rise structure with a basement and twenty floors over basement, employing shear walls situated at various places in various seismic risk areas in India. In this investigation, the structure is generated and examined using the Etabs software. The goal of the study is to determine the optimal locations inside the building's framework for shear wall placement. In all four seismic zones (Zone II, Zone III, Zone IV, and Zone V), the maximum shift and storey drift values for all three cases (A, B, and C) are greatest in seismic zone V when correlated with zones II, III, and IV. This suggests that the displacement can be reduced by assuring the structure's uniform rigidity. According to the study, the structure with shear walls located at each corner accomplished better in terms of maximal displacement, storey drift, and base shear.

Liu Jianxin (2011) has conducted research on the design and nonlinear analysis of high-rise structures with staggered shear walls. Using the finite element analysis software ANSYS, the author discusses the nonlinear analysis and design of a staggered shear wall structure for high-rise buildings. The study contrasts the staggered shear wall structure with conventional shear wall structures and emphasises the benefits of the former, such as increased space and lateral stiffness, decreased dead weight and seismic force, and material savings. The results indicate that the staggered shear wall structure is 20% lighter than conventional shear wall structures while maintaining the same lateral stiffness. However, the complex joint stresses between the above and below shear walls can result in shear failure or failure due to diagonal cracking. At the joints, strengthening diagonal bars should be used to assure joint strength and stiffness. The staggered shear wall structure is economically advantageous and has numerous applications in the design of tall buildings.

Sanisha Santhosh (2017) conducted a seismic analysis of a multi-story building with various shear wall, having different shapes of the structure. For the analysis, the author considered buildings with G + 14 and G + 29 storeys, which were analysed in the Etabs software for their base shear and building drift. In two distinct zones (Zone – III and Zone – V), a dynamic method known as Response spectrum analysis was utilised to conduct the analysis. On the basis of base shear and drift of storey, the author concludes that W and U-shaped shear walls perform better in X-direction in Zone - V and Zone -

III, while H-shaped shear walls perform better in Y-direction. And G+29 buildings with W and H-shaped shear walls perform better in both orientations.

Hema Mukundan (2015) performs response spectrum analysis, investigated the effect of vertical rigidity on shear wall-framed structures. Under the influence of inert load, live load, and earthquake load, the study analysed a G+9-story building with and without shear wall openings. Regardless of their regularity or irregularity, structures with shear walls are more resistant to lateral pressures, according to the findings. The addition of shear walls to the structure decreased the column moments. In addition, the installation of shear walls decreased the maximum storey displacement by fifty percent. Torsional rotation in the structure was observed in irregular frames, making it imperative to locate shear walls symmetrically in layout to mitigate the negative consequences of turn in buildings. Shear walls must be positioned uniformly in one of the two plan orientations, and their placement along the building's outer perimeter is optimal. Such a design improves the structure's deformation resilience.

2.2 LITERATURE GAP

- Till now various research has been done on staggered opening of shear wall and different shapes of opening in shear wall in a symmetrical buildings
- But, in this research work the emphasis is going to be on the staggered shear wall opening in asymmetrical building and comparing the results with traditional shear wall in asymmetrical buildings.
- Furthermore, we can check which one is better at providing resistance to seismic response and give more strength to the structure and which of the model is more cost-effective.

CHAPTER 3

METHODOLOGY

3.1 BUILDING MODELS DEFINITIONS

The present study is done on G+15 storey building of different irregularity with and without staggered shear wall opening. The responses of staggered shear wall opening are compared with the building having irregularity with shear wall. The building models of various types are described below.

3.1.1 Horizontal Irregularity Without Shear Wall (HIWoSW)

Horizontal irregularity or the plan irregularity was introduced in the building by using the re-entrant corners. According to IS code 1893:2016, re-entrant corners is in the building in any plan direction, when its structural configuration in plan has a projection of greater size of 15 % if its overall plan dimensions in that direction. In this model horizontal irregularity is introduced having projection 33.34 % but the model do not have any shear wall.

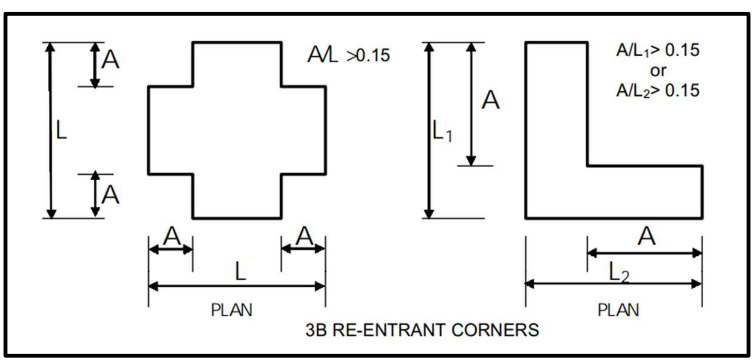

Fig. 3.1 Description of irregular building having re-entrant corners IS 1893 (Part 1) 2016

3.1.2 Horizontal Irregularity With Staggered Shear Wall Opening (HIWSSWO)

This model have shear wall with staggered opening with opening percentage 33.34 % which is greater than 15 % of the overall area. Horizontal irregularity was introduced in the building by using the re-entrant corners. This model have staggered shear wall opening and on the basis of the result generated by the model comparison is done with other models for different parameters.

3.1.3 Horizontal Irregularity Without Shear Wall Opening (HIWoSWO)

In this model horizontal irregularity is present having projection percentage of 33.34 % and the shear wall is present over the whole structure but without opening. This is the base model over which all the comparison (stiffness, displacement, drift, etc) is drawn. The presence of shear wall increases the rigidity, stiffness, and lower drift and displacement which increases the bearing capacity of the building.

3.1.4 Vertical Irregularity Without Shear Wall (VIWoSW)

According to IS CODE 1893:2016, Vertical geometric irregularity can be introduced in the building when the horizontal dimensions of any storey's horizontal force preventing system exceed 125% of the storey below. ie., A/L>0.25. This structure was modelled with a setback configuration having different height steps ie., ground to 5th floor, 6th to 10th floor and 10th to 15th floor. The model has horizontal dimension of 66.67 % more than the storey below it and the model do not have shear wall.

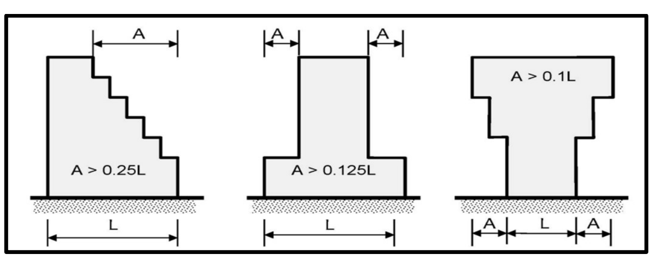

Fig. 3.2 Description for vertical irregular building as per IS 1893 (Part 1) 2016

3.1.5 Vertical irregularity with staggered shear wall opening (VIWSSWO)

This model have irregularity because of the setback configuration having horizontal dimensions greater than 125% and A/L ratio >0.25. research also says that structure having staggered shear wall opening can provide better resistance to seismic forces. Having opening in the shear wall reduces the dimension of the column and beams which overall reduces the shear of the building.

3.1.6 Vertical irregularity without shear wall opening (VIWoSWO)

In the model also irregularity was introduced using setback configuration. On the basis of this model result of the vertical irregularity was considered. The result were compared on the basis of stiffness, displacement, drift, and shear to find out which types of irregularity performs better.

3.2 STANDARD AND CODES

The software and the relevant codes that are used are listed below: -

- The analysis and modelling were carried out in CSI software ETABS 2020.
- The designing and detailing were carried out as per IS 456:2000 and IS 800:2007
- Seismic loading and seismic analysis were conformed to IS 1893:2016 (part 1).
- The wind load were conformed to IS 875: 2015 (part 2015)
- The load considered and combination of load were done in accordance with IS 875:1987 (part 2).

3.3 MODELLING

The modelling was done in Extended three-dimensional Analysis of building system (ETABS) 2020 software which has the function of response spectrum analysis. The procedure is initialize the model, defining the grid dimension and storey dimension, then define the geometry, dimension, material section, support restraints and creating the load patterns, assigning the loads, and then combination of loads are done. The subsequent steps are for Response Spectrum Analysis and its consists of defining the

Response Spectrum Function and Response Spectrum Load case. The analysis process is linear dynamic for Response Spectrum Analysis and the analysis output are base shear, drift and maximum storey displacement which have been discussed in detail in the later part of this study.

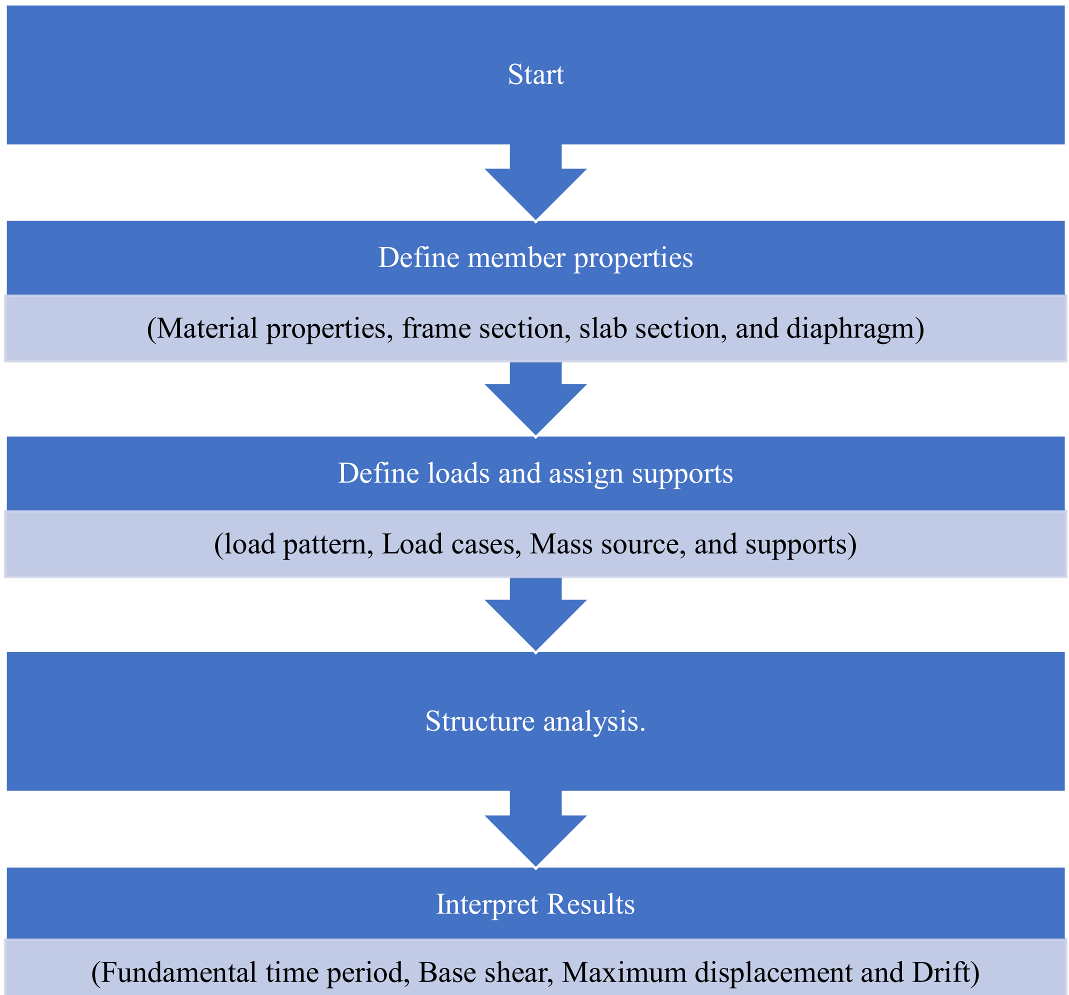

Fig. 3.3 Flowchart of modelling procedure in Etabs

3.4 INPUT PARAMETERS OF THE MODELS

Table 3.1 Input parameters of the models

Seismic parameters as per IS 1893 (part 1): 2016	
Type of Building	Residential building
Type of Frame	SMRF
Seismic zone and Zone Factor	Zone IV, 0.24
Type of soil	Medium (Type II)
Response Reduction factor (R)	5
Importance Factor (I)	1.5
Damping ratio	5 %
Type of support	Fixed
Time period	Program calculated
Method of seismic analysis	Response spectrum analysis

Geometric parameters	
Storey height	3 m
Overall height of the building	51 m
Overall dimensions of plan in X direction	30 m
Overall dimensions of plan in Y direction	30 m

Dimensions of structural members	
Cross section of column (mm)	400 × 650 (GF to 15th floor)
Cross section of beam (mm)	400 × 400 (GF to 15th floor)
Depth of Slab (mm)	150
Thickness of partition wall (mm)	125
Thickness of main wall (mm)	250

Properties of grade of concrete and steel	
Grade of concrete	M 30
Grade of steel	Fe 550
Density of Reinforced concrete	30 kN/m^2
Density of brick	19 kN/m^2

Loads on frame	
Floor finish load	1.5 kN/m^2
Live load	4 kN/m^2
Dead load of the main wall	14.25 kN/m^2

CHAPTER 4

ANALYSIS AND RESULTS

4.1 RESPONSE SPECTRUM ANALYSIS

All the various models are seismically analysed as per Response Spectrum analysis as it is recommended by Indian Code (IS:1893–2016) stipulates that dynamic analysis needs to be conducted if the building is taller than 15 metres and is located in Zone IV. The response of model as per response spectrum analysis are discussed below: -

4.1.1 Horizontal Irregularity Without Shear Wall

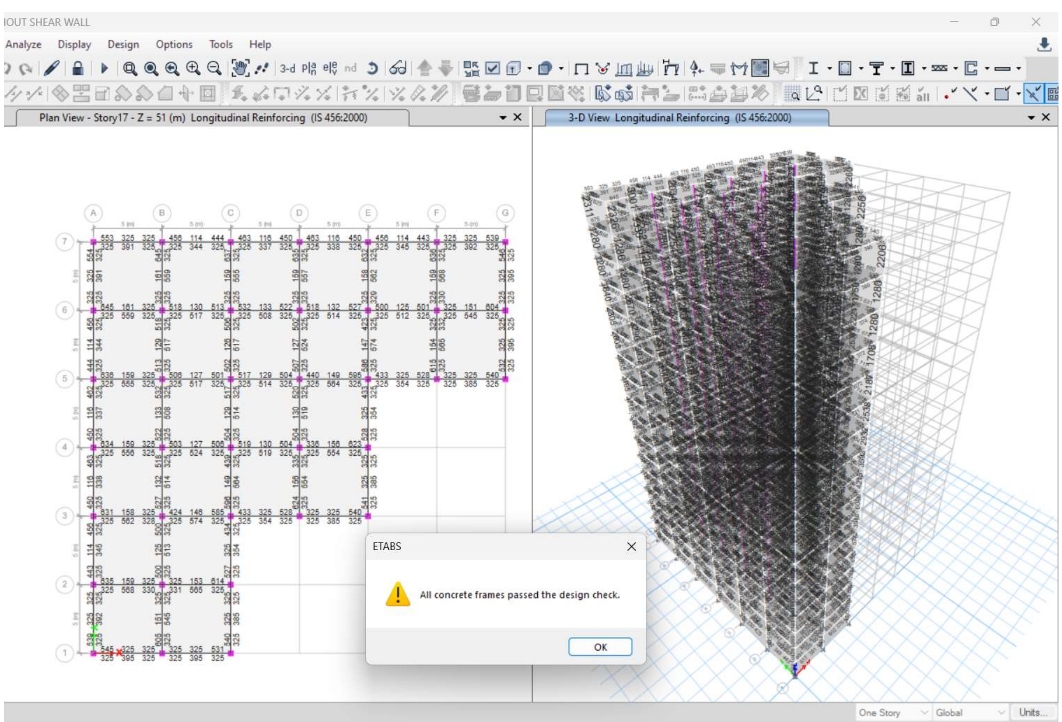

Fig 4.1 Plan and 3D view of Model MI (HIWoSW).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The design model was found to be adequate as per concrete frame design check. This model is used as a reference for showing the increase or decrease in the different parameters checks.

The response and limit of various parameters are discussed below in the table.

Table 4.1 Response of (HIWoSW) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	92.22 mm (Storey 15)	96 mm
Maximum Storey drift	0.001463 (Storey 12)	<0.004
Maximum stiffness	523462.78 kN/m	
Horizontal irregularity limit	0.333	A/L>0.15
Remark	Building has Horizontal irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.1.2 Horizontal Irregularity With Staggered Shear Wall Opening

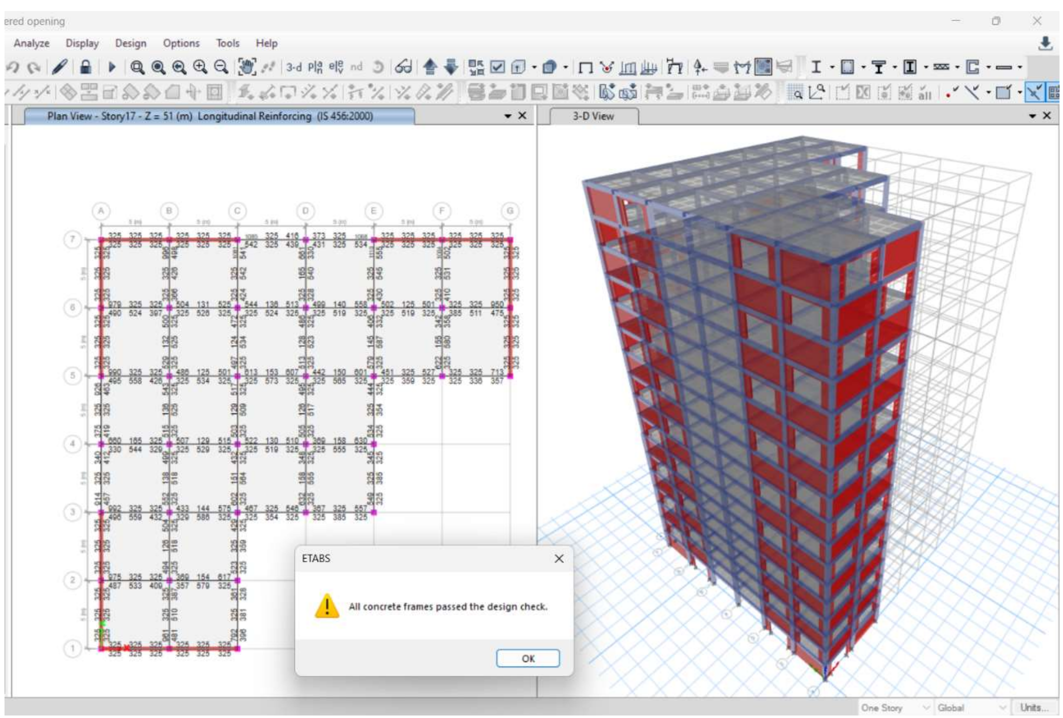

Fig 4.2 Plan and 3D view of Model MII (HIWSSWO).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The horizontal irregularity was introduced in the building according to Indian standard code IS 1893 (PART 1): 2016 (Table 6). The building has staggered shear wall opening and has horizontal irregularity of A/L = 0.333 which is much greater than limit given by the code. The design model was found to be adequate as per concrete frame design check. The building has been used for the comparison with the building having shear wall without opening.

The response and limit of various parameters are discussed below in the table.

Table 4.2 Response of (HIWSSWO) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	52.389 mm (Storey 15)	96 mm
Maximum Storey drift	0.000798 (Storey 12)	<0.004
Maximum stiffness	8745955 kN/m^2	
Horizontal irregularity limit	A/L= 0.333	A/L>0.15
Remark	Building has Horizontal irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.1.3 Horizontal irregularity without shear wall opening (HIWoSWO)

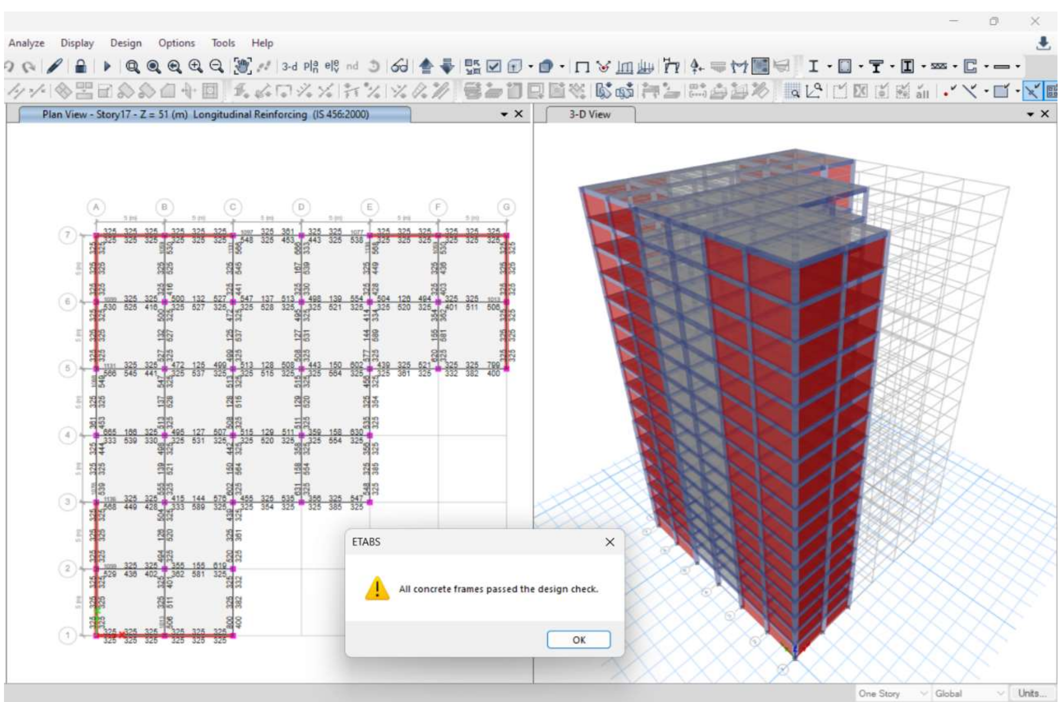

Fig 4.3 Plan and 3D view of Model MIII (HIWoSWO).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The horizontal irregularity was introduced in the building according to Indian standard code IS 1893 (PART 1): 2016 (Table 6). This building also has similar irregularity and are used as a comparison for different parameters with the building having staggered shear wall opening.

The response and limit of various parameters are discussed below in the table.

Table 4.3 Response of (HIWoSWO) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	47.353 mm (Storey 15)	96 mm
Maximum Storey drift	0.0007175 (Storey 12)	<0.004
Maximum stiffness	12337465 kN/m^2	
Horizontal irregularity limit	A/L= 0.333	A/L>0.15
Remark	Building has Horizontal irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.1.4 Vertical irregularity without shear wall

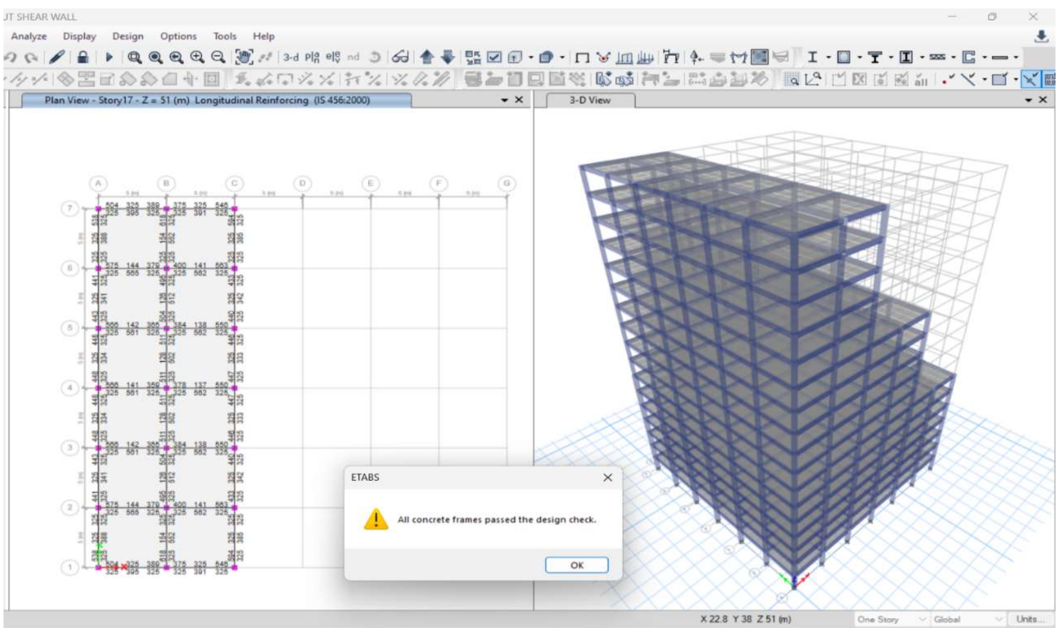

Fig 4.4 Plan and 3D view of Model VI (VIWoSW).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The vertical irregularity was introduced in the building according to Indian standard code IS 1893 (PART 1): 2016 (Table 6). The building do not have shear wall and the building has vertical irregularity A/L=(2/3) which is much greater than the limit set by the code. The model is used as a reference for showing the increase or decrease in the different parameters checks.

The response and limit of various parameters are discussed below in the table.

Table 4.4 Response of (VIWoSW) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	91.107 mm (Storey 15)	96 mm
Maximum Storey drift	0.00133	<0.004
Maximum stiffness	726763.5 kN/m^2	
Vertical irregularity limit	A=20m L=30m	A>0.25L
Remark	Building has Vertical geometric irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.1.5 Vertical irregularity with Staggered shear wall opening.

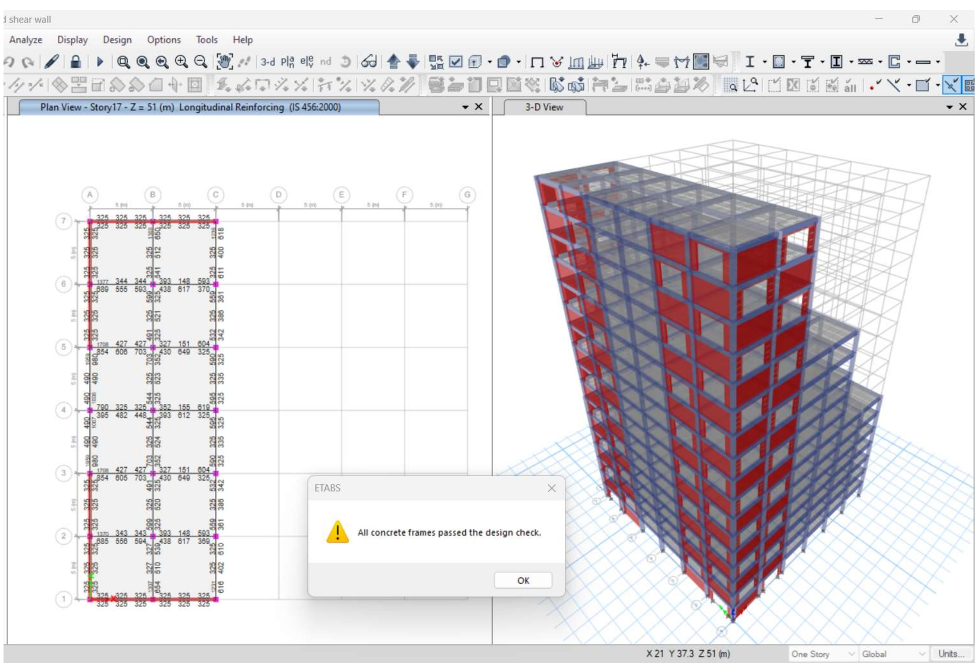

Fig 4.5 Plan and 3D view of Model VII (VIWSSWO).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The vertical irregularity was introduced in the building according to Indian standard code IS 1893 (PART 1): 2016 (Table 6). The building has staggered shear wall opening and has vertical irregularity of (A/L=0.666) which is much greater than limit given by the code. The design model was found to be adequate as per concrete frame design check. The building has been used for the comparison with the building having shear wall without opening.

The response and limit of various parameters are discussed below in the table.

Table 4.5 Response of (VIWSSWO) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	52.63 mm (Storey 15)	96 mm
Maximum Storey drift	0.000675	<0.004
Maximum stiffness	9398762 kN/m^2	
Vertical irregularity limit	A=20m L=30m	A>0.25L
Remark	Building has Vertical geometric irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.1.6 Vertical irregularity without shear wall opening.

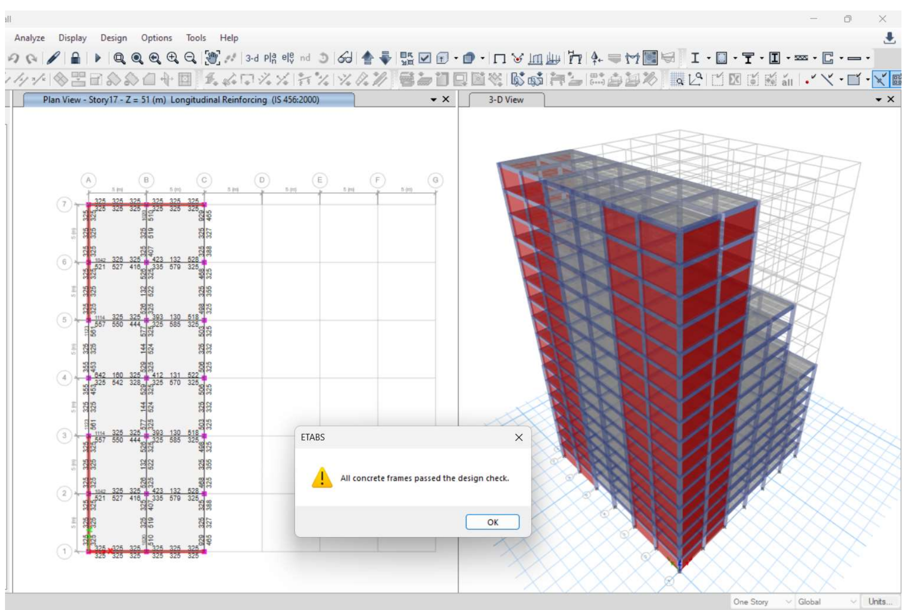

Fig 4.6 Plan and 3D view of Model VIII (VIWoSWO).

The modelling was done on the basis of Indian standard code and it was checked in accordance with IS CODE 456:2000. The vertical irregularity was introduced in the building according to Indian standard code IS 1893 (PART 1): 2016 (Table 6). The building has shear wall without opening and has vertical irregularity of (A/L=0.666) and the design model was found to be adequate as per concrete frame design check.

Table 4.6 Response of (VIWoSW) as per Response spectrum analysis

Seismic response parameter	Value	Limit
Maximum storey displacement	60.657 mm	96 mm
Maximum Storey drift	0.0006574	<0.004
Maximum stiffness	9161991 kN/m^2	
Vertical irregularity limit	A=20m L=30m	A>0.25L
Remark	Building has Vertical geometric irregularity as per IS CODE:1893 (PART 1): 2016 (Table 6)	

4.2 COMPARISON OF THE RESPONSES OF ALL MODELS AS DERIVED FROM RESPONSE SPECTRUM ANALYSIS (RSA)

The responses of all the models are computed and recorded in tabular or graphical form and the result are then compared and on the basis of that the conclusion are drawn.

4.2.1 STOREY STIFFNESS FOR DIFFERENT FLOOR (kN/m)

The responses for storey stiffness are computed in X and Y-direction.

4.2.1.1 Storey Stiffness For Seismic X-Direction

The table shows the value of the story stiffness for different irregular models for each floor for seismic – x direction. The table shows that the maximum stiffness we get at the plinth level with the maximum value of 12318153 kN/m^2 in the case of (HIWoSWO) and minimum in the case of (HIWoSW). From the graph and table it has been found that for (MII) the stiffness is about 22.38% less than (MIII). But in a similar case building (VIWSSWO) performs than (VIWoSWO) as the building gives about 17.605% more stiffness.

Table 4.7 storey stiffness of structure in seismic x-direction for each floor

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	107580.14	230430.4	300683.2	51892.37	280215.9	194984.5
STOREY14	129369.44	444842.5	589420.6	63684.3	442158	387066.5
STOREY13	134499.44	631714.2	839052.6	67108.85	685412	553222.8
STOREY12	136646.02	793421.3	1056922	70656.38	886575	698319.8
STOREY11	137891.72	942757.8	1251628	83154.47	1054286	828290
STOREY10	138766.61	1077191	1431488	127720	1254951	1029201
STOREY9	139455.69	1216470	1605033	133014.4	1549862	1208571
STOREY8	140070.34	1351909	1781478	134910.7	1785429	1381501
STOREY7	140606.18	1513339	1972182	138331.5	1986547	1556819
STOREY6	141520.3	1695003	2189541	155219.7	2154258	1746011
STOREY5	171556	1920714	2452917	238740.3	2347165	2015224
STOREY4	174301.6	2155225	2754745	247611.8	2765821	2279630
STOREY3	177488.6	2535235	3169612	253514.2	3254856	2631245
STOREY2	183617.89	3037883	3777651	261918.2	3867454	3121175
STOREY1	198531.72	4017073	4777722	281696	4587697	3899244
GROUND	243974.39	5998771	6775192	343089.8	5604218	5405609
PLINTH	523462.78	8745955	12318153	726763.5	9398762	9161991

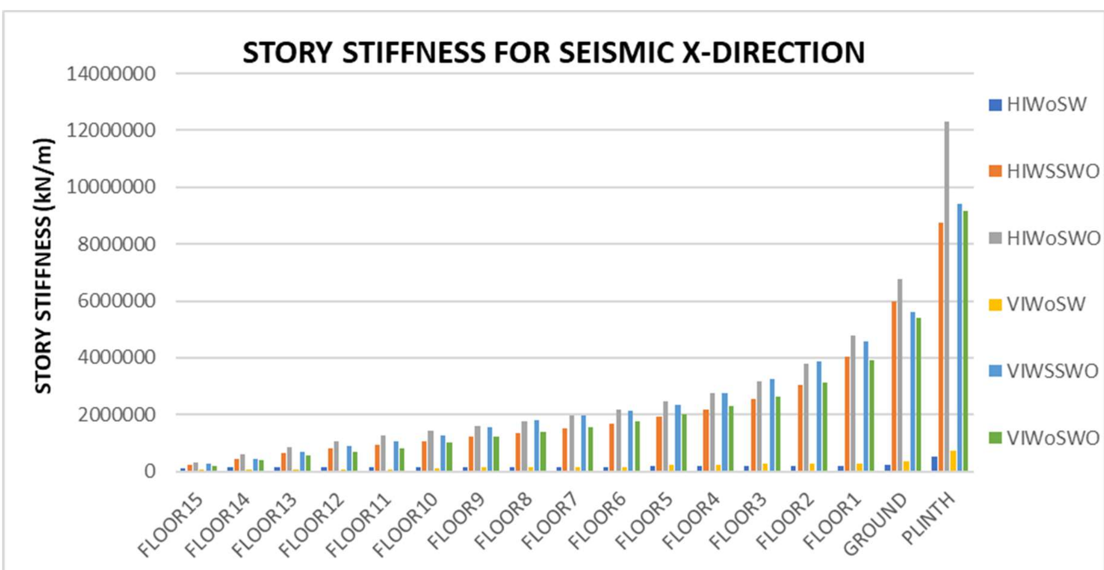

Fig 4.7 graph of storey stiffness in x-direction for different floors

4.2.1.2 Storey Stiffness For Seismic Y-Direction

Table 4.8 storey stiffness of structure in seismic y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	107377.1	226081.3	300295.8	69057.01	156247.3	113951.5
STOREY14	129220.7	438550.4	588669.7	80022.13	298245.5	226846.8
STOREY13	134386.3	621101.9	837991	82211.53	423192.6	325460.5
STOREY12	136553	783271.5	1055584	84165.81	526336	412066
STOREY11	137810.8	926607.8	1250029	91079.53	622484.3	489928
STOREY10	138692.9	1064639	1429621	137181	684334.2	516990.7
STOREY9	139387.6	1192723	1602867	140692.7	788456.1	608135.7
STOREY8	139994.1	1335327	1778969	141774.3	903530.9	697191.6
STOREY7	140539.6	1482317	1969074	143350.1	1008037	788075.7
STOREY6	141202	1660781	2186875	150117	1152969	888298.6
STOREY5	155242.5	1842631	2442686	218542	1236669	901998.9
STOREY4	156260	2102819	2746556	222155.1	1381652	1023631
STOREY3	157120.8	2414215	3158989	223505.7	1578633	1190469
STOREY2	158797.4	2943539	3764692	225403	1864065	1427575
STOREY1	163876.6	3737250	4760864	231636.2	2326562	1817487
GROUND	184317	5466002	6744901	258517.9	3192548	2619561
PLINTH	342313.2	7889707	12337465	473307.6	5325812	4872529

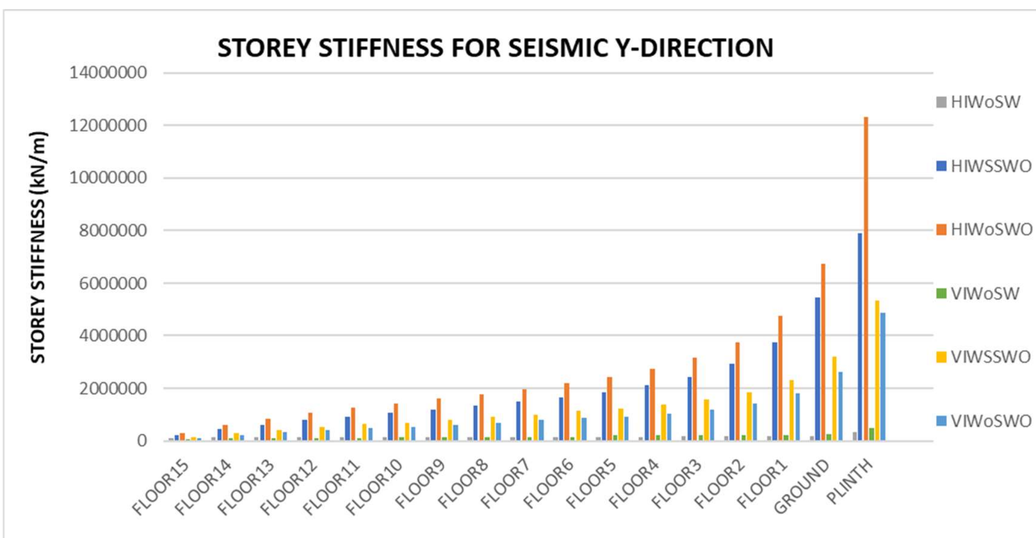

Fig 4.8 graph of storey stiffness for different floors for seismic y-direction

The table shows the value of the story stiffness for irregular model for each floor for seismic – Y direction. The table shows that the maximum stiffness we get at the plinth level with the maximum value of 12337465 kN/m^2 in the case of (HIWoSWO) and minimum in the case of (HIWoSW). From the graph and table it has been found that for (MII) the stiffness is about 24.852% (avg.) less than (MIII). But in a similar case (VIWSSWO) performs better than (VIWoSWO) as it gives about 22.4332% more stiffness.

4.2.1.3 Response Spectrum Table And Graph For Storey Stiffness In Seismic X&Y-Direction

Table 4.9 Response spectrum for storey stiffness of structure in x-direction

	HIWSSWO	HIWoSWO	HIWoSW	VIWSSWO	VIWoSWO	VIWoSW
STOREY15	286561.8	384363.1	112674.5	228212.7	228062.4	57236.34
STOREY14	533026.3	712178.5	126238.5	430590.7	444885.9	63938.8
STOREY13	726543.7	957021	125497	588945.7	622049.1	64752.1
STOREY12	871554.9	1142976	124844.5	706887	764851.1	66867.82
STOREY11	988737.7	1294768	124376.2	814540	880751.9	78601.56
STOREY10	1080730	1433788	124351.3	959722.5	1042511	122107.2
STOREY9	1183647	1578182	124714.9	1089811	1178087	126590.5
STOREY8	1292258	1743557	125052.8	1211754	1313799	127995.5
STOREY7	1457804	1945046	125701.8	1371365	1468380	131104.4
STOREY6	1664502	2197242	126534.9	1555639	1661460	147763.4
STOREY5	1958478	2522266	151457.5	1893809	1994380	228265.6
STOREY4	2275833	2916793	154666.2	2183695	2383685	238527.6
STOREY3	2775530	3454812	157846.7	2618218	2903253	244337.9
STOREY2	3386304	4220036	163739.8	3189105	3586829	253194.3
STOREY1	4479123	5415754	178563.5	4025222	4570089	273545.9
GROUND	6559838	7640850	221018.9	5363285	6272825	336103
PLINTH	9099160	13121707	471293.7	6789212	9937350	709114.4

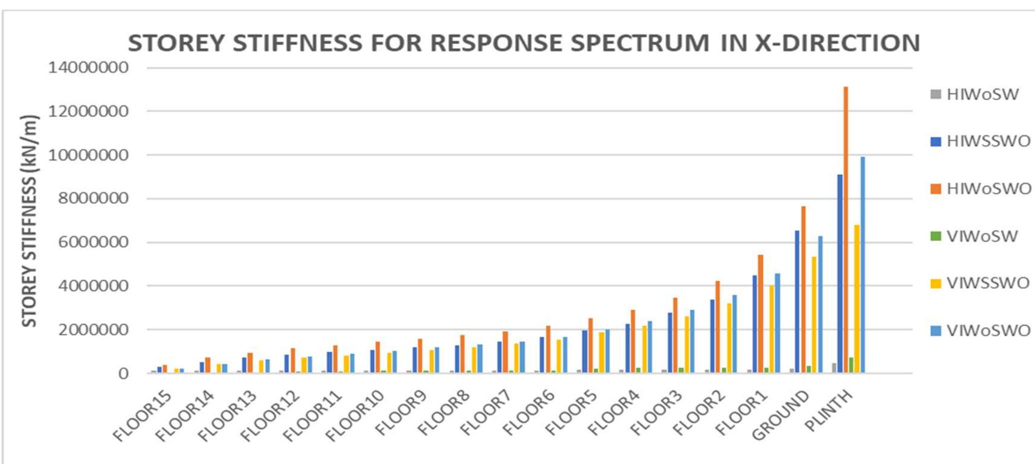

Fig. 4.9 Graph of Response spectrum for storey stiffness of structure in x-direction

Table 4.10 Response spectrum for storey stiffness of structure in y-direction

	HIWSSWO	HIWoSWO	HIWoSW	VIWSSWO	VIWoSWO	VIWoSW
STOREY15	277267.9	383445	111898.9	156263.7	121212	74552.05
STOREY14	519749.1	710484.9	125417.3	285582.4	230581	80969.39
STOREY13	705785.4	954707.8	125218.4	392520.3	316145.2	80780.54
STOREY12	850321.5	1140129	124686.7	468935	381115.2	81623.52
STOREY11	957818.6	1291410	124282.5	539096.5	430523	90869.46
STOREY10	1053789	1429898	124479.7	555907.7	424112.3	123975.4
STOREY9	1140686	1573698	124747.2	646876.7	488410.7	126355.5
STOREY8	1256966	1738410	125167	738318.4	555734.3	125935.2
STOREY7	1398409	1938974	125663.5	833609.4	637119.3	126211
STOREY6	1605973	2191210	126246	964050	744208.8	132511.5
STOREY5	1843322	2508672	139577.9	1058405	807725	177741.6
STOREY4	2194379	2904428	140777.5	1253435	1017349	182392.8
STOREY3	2603091	3439304	141735.2	1512299	1292602	183531
STOREY2	3253508	4201182	143535.4	1841222	1648761	185311.1
STOREY1	4148006	5391638	148948.7	2312715	2157147	193225.1
GROUND	5913916	7601188	169977.6	3035604	3051007	221781.8
PLINTH	8376703	13119271	319471.1	3787815	5050507	418959.9

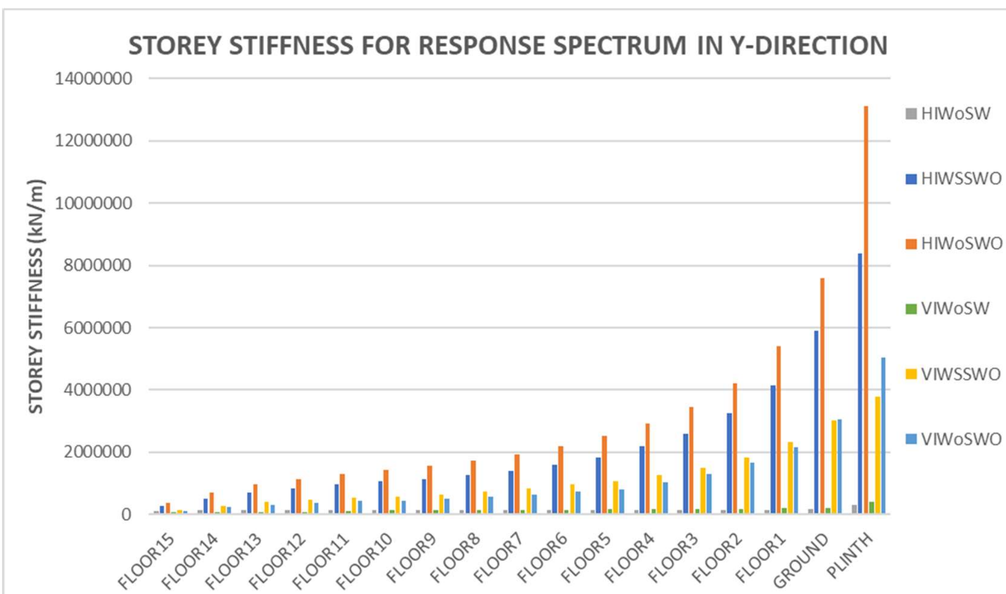

Fig. 4.10 Graph of Response spectrum for storey stiffness of structure in y-direction

4.2.2 STORY DRIFT FOR DIFFERENT STOREYS (Unitless)

The responses of all the models for storey drift are computed and recorded in tabular or graphical form and investigation is carried out in X and Y-direction.

4.2.2.1 Storey Drift In Seismic X-Direction

Table 4.11 storey drift of structure in seismic x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	0.000587	0.001302	0.001183	0.001057	0.001079	0.001089
STOREY14	0.000926	0.00131	0.0012	0.001676	0.001117	0.001127
STOREY13	0.001259	0.001343	0.00121	0.002274	0.001118	0.001128
STOREY12	0.001555	0.001331	0.001215	0.002728	0.001145	0.001155
STOREY11	0.00181	0.001354	0.001211	0.002736	0.001124	0.001134
STOREY10	0.002026	0.001312	0.001196	0.002217	0.001114	0.001124
STOREY9	0.002206	0.001315	0.00117	0.002491	0.001092	0.001102
STOREY8	0.002352	0.001238	0.00113	0.002754	0.001076	0.001096
STOREY7	0.002468	0.001212	0.001077	0.002925	0.001027	0.001037
STOREY6	0.002547	0.001103	0.001009	0.002777	0.000986	0.001006
STOREY5	0.002187	0.001036	0.000929	0.001935	0.000859	0.000879
STOREY4	0.002198	0.000917	0.000845	0.001964	0.000837	0.000847
STOREY3	0.002187	0.000839	0.000744	0.001989	0.0007	0.00075
STOREY2	0.002129	0.000683	0.000629	0.001973	0.000654	0.000674
STOREY1	0.001971	0.000568	0.000498	0.001864	0.000528	0.000548
GROUND	0.001597	0.000382	0.00035	0.001544	0.00041	0.00043
PLINTH	0.000737	0.000221	0.000189	0.000732	0.000284	0.000294

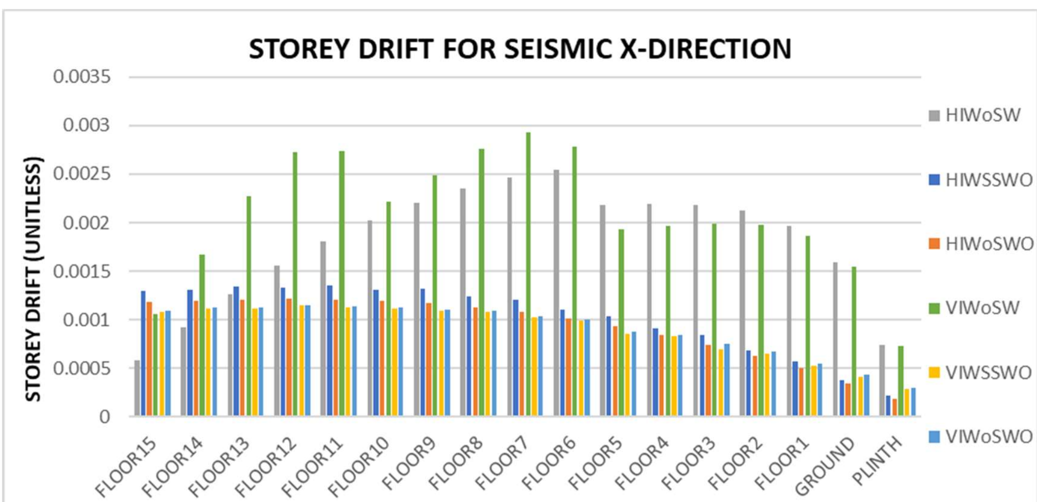

Fig 4.11 graph of storey drift for different storeys for seismic x- direction

The table shows the value of the story drift for irregular model for each floor in seismic X – direction. The table shows that the maximum drift we get at the 6th floor with the maximum value of 0.002925 (unitless) in the case of (VIWoSW) and minimum in the case of (HIWoSWO) with a value of 0.000189 (unitless) at the plinth level. We can also infer from the table that (MII) the drift is 9.875% more in model (MIII). But in a similar case building with (VIWSSWO) performs than (VIWoSWO) as the building gives about 2.11% less drift which is negligible.

4.2.2.2 Storey Drift In Seismic Y-Direction

Table 4.12 storey drift of structure in seismic y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	0.000572	0.001076	0.001185	0.000695	0.00122	0.001523
STOREY14	0.000902	0.00111	0.001201	0.001166	0.001266	0.001538
STOREY13	0.001226	0.001108	0.001212	0.001625	0.001284	0.001546
STOREY12	0.001513	0.001132	0.001216	0.002017	0.001301	0.001547
STOREY11	0.001762	0.001111	0.001212	0.002259	0.001313	0.001537
STOREY10	0.001972	0.001122	0.001197	0.002276	0.001586	0.001982
STOREY9	0.002147	0.001074	0.001171	0.002545	0.001622	0.001954
STOREY8	0.00229	0.001066	0.001132	0.002786	0.001571	0.001899
STOREY7	0.002402	0.000987	0.001078	0.00298	0.001552	0.001819
STOREY6	0.002485	0.000952	0.001011	0.003092	0.00145	0.001712
STOREY5	0.002333	0.000856	0.000932	0.002765	0.001507	0.001912
STOREY4	0.002368	0.000807	0.000847	0.002846	0.001407	0.001765
STOREY3	0.002388	0.00069	0.000747	0.002909	0.001311	0.001564
STOREY2	0.002382	0.000612	0.000631	0.002933	0.00112	0.00133
STOREY1	0.002313	0.00047	0.0005	0.00287	0.000965	0.001055
GROUND	0.002051	0.000356	0.000351	0.002553	0.000695	0.000733
PLINTH	0.001096	0.000201	0.000188	0.001363	0.000501	0.000523

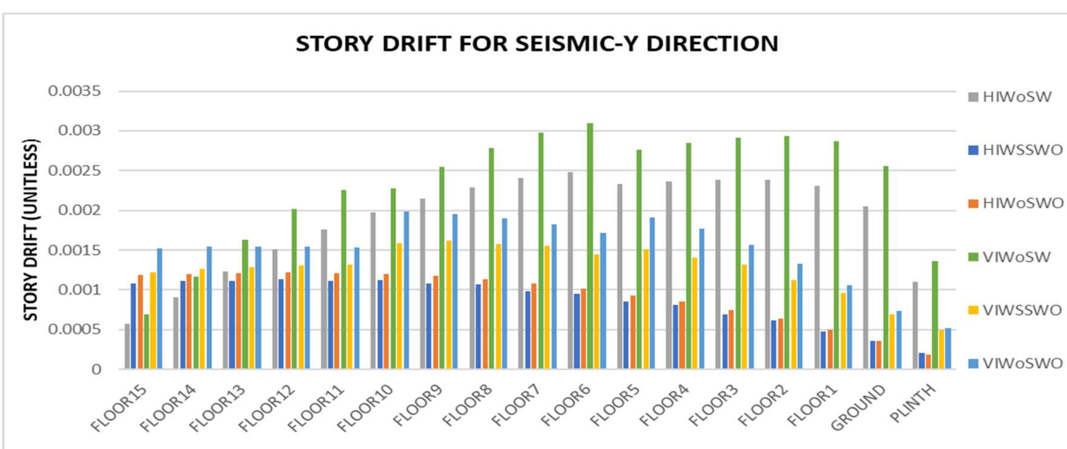

Fig 4.12 graph of storey drift for different floors for seismic y- direction

The table shows the value of the story drift for irregular model for each floor in seismic Y – direction. The table shows that the maximum drift we get at the 6th floor with the maximum value of 0.003092 (unitless) in the case of (VIWoSW) and minimum in the case of (HIWoSWO) with a value of 0.000189 (unitless) at the plinth level. We can also infer from the table that (MIII) the drift is 5.67% more in model with (MII). But in a similar case building with (VIWSSWO) performs better than (VIWoSWO) as the building gives about 15.328 % less drift.

4.2.2.3 Response Spectrum Table And Graph For Storey Drift In Seismic X&Y-Direction

Table 4.13 Response spectrum for storey drift of structure in x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	0.000724	0.001032	0.000977	0.001259	0.000832	0.000862
STOREY14	0.001112	0.00104	0.000991	0.001912	0.000863	0.000873
STOREY13	0.001419	0.001065	0.001	0.002434	0.000863	0.000881
STOREY12	0.001654	0.001056	0.001004	0.002754	0.000882	0.000884
STOREY11	0.001844	0.001069	0.000999	0.002606	0.000864	0.00088
STOREY10	0.00201	0.001037	0.000986	0.00194	0.000852	0.000868
STOREY9	0.002162	0.001033	0.000964	0.002141	0.000832	0.000855
STOREY8	0.002301	0.000975	0.000933	0.002355	0.000825	0.000831
STOREY7	0.002429	0.000951	0.00089	0.002504	0.00078	0.000798
STOREY6	0.002535	0.000872	0.000838	0.002379	0.000759	0.000756
STOREY5	0.002233	0.000823	0.000775	0.00167	0.000665	0.0007
STOREY4	0.002289	0.000738	0.00071	0.001744	0.000652	0.000654
STOREY3	0.002342	0.000682	0.000632	0.001835	0.00059	0.000593
STOREY2	0.00236	0.000568	0.000541	0.001904	0.000547	0.00052
STOREY1	0.002273	0.000483	0.000437	0.001886	0.000462	0.000433
GROUND	0.001913	0.00034	0.000315	0.001633	0.000385	0.000327
PLINTH	0.000911	0.000214	0.000182	0.0008	0.000286	0.000209

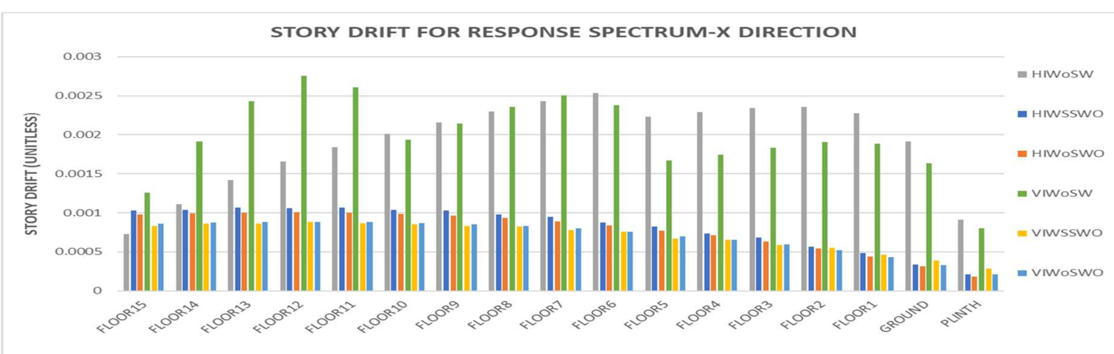

Fig. 4.13 Graph of Response spectrum for storey drift of structure in x-direction

Table 4.14 Response spectrum for storey drift of structure in y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	0.00068	0.000903	0.00098	0.000834	0.000884	0.001002
STOREY14	0.001045	0.00093	0.000995	0.001335	0.000921	0.001012
STOREY13	0.001344	0.00093	0.001003	0.001738	0.000928	0.001016
STOREY12	0.001576	0.000947	0.001007	0.001988	0.000943	0.001015
STOREY11	0.001765	0.00093	0.001002	0.001912	0.000938	0.001005
STOREY10	0.001932	0.000933	0.000989	0.001862	0.001251	0.001373
STOREY9	0.002082	0.000895	0.000967	0.002105	0.001258	0.001348
STOREY8	0.00222	0.000882	0.000936	0.002322	0.001227	0.001305
STOREY7	0.002348	0.000823	0.000893	0.002503	0.00119	0.001246
STOREY6	0.002461	0.000791	0.00084	0.002616	0.001127	0.001173
STOREY5	0.00233	0.000719	0.000779	0.002357	0.001227	0.001363
STOREY4	0.002414	0.000681	0.000713	0.002488	0.001189	0.001278
STOREY3	0.0025	0.000593	0.000635	0.002612	0.001133	0.001163
STOREY2	0.00257	0.000532	0.000544	0.002708	0.001034	0.001027
STOREY1	0.002575	0.00042	0.000439	0.002734	0.000932	0.000857
GROUND	0.002341	0.000327	0.000317	0.002503	0.000746	0.000641
PLINTH	0.00126	0.000198	0.000182	0.001362	0.000598	0.000399

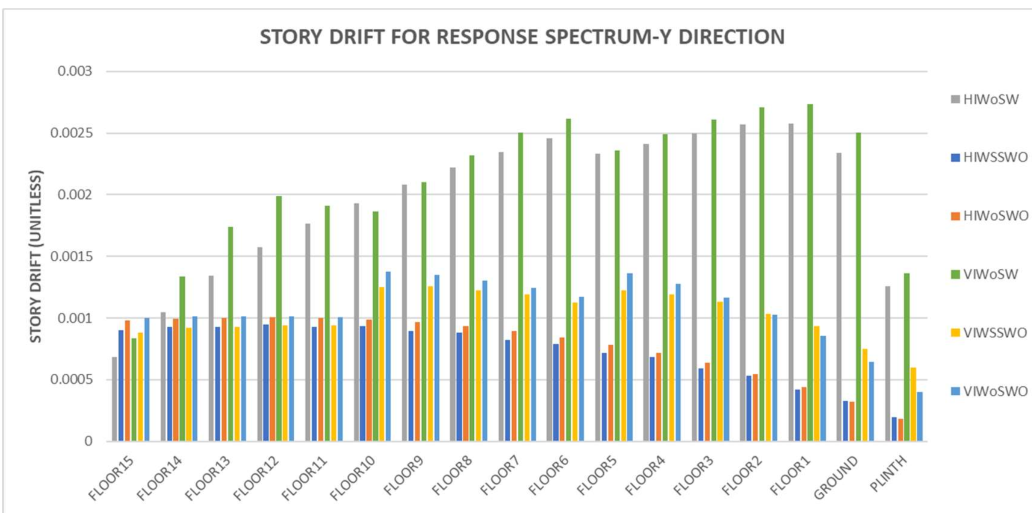

Fig. 4.14 Graph of Response spectrum for storey drift of structure in y-direction

4.2.3 Story Displacement For Different Floors (mm)

The responses of all the models for storey displacement are computed and recorded in tabular or graphical form and investigation is carried out in X and Y-direction.

4.2.3.1 Storey Displacement In Seismic X-Direction

Table 4.15 storey displacement of structure in seismic x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	91.228	52.389	47.353	91.107	46.267	44.523
STOREY14	89.466	48.485	43.803	89.737	43	41.275
STOREY13	87.688	44.556	40.203	86.707	39.618	37.983
STOREY12	83.912	40.528	36.572	82.885	36.233	34.662
STOREY11	79.248	36.535	32.928	78.702	32.769	31.327
STOREY10	73.819	32.474	29.296	73.495	29.367	28.004
STOREY9	67.74	28.538	25.708	65.844	25.993	24.717
STOREY8	61.121	24.594	22.2	61.371	22.686	21.473
STOREY7	54.063	20.879	18.809	53.108	19.397	18.313
STOREY6	46.659	17.243	15.578	44.333	16.287	15.277
STOREY5	39.017	13.934	12.55	36.001	13.268	12.406
STOREY4	32.455	10.826	9.764	30.197	10.632	9.761
STOREY3	25.862	8.074	7.231	24.304	8.09	7.318
STOREY2	19.301	5.558	4.998	18.336	5.839	5.137
STOREY1	12.915	3.51	3.11	12.416	3.818	3.263
GROUND	7.002	1.806	1.615	6.826	2.174	1.748

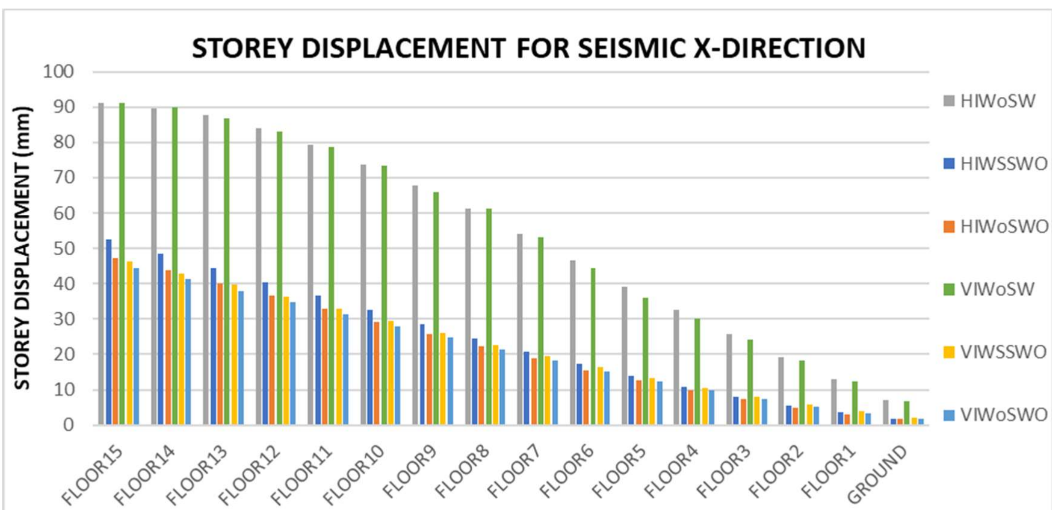

Fig 4.15 graph of storey displacement for each floor for seismic x- direction

The table shows the value of the storey displacement for different irregular models for each floor for seismic x - direction. The table shows that the maximum displacement we get at the 15th floor with the maximum value of 91.228 mm in the case of (HIWoSW) and minimum in the case of (HIWoSWO) with a value of 1.625 mm at the plinth level. From the graph and table it has been found that for (MII) the displacement is about 9.61

% more than). (MIII). Also in (VIWSSWO) have a displacement of 3.77% more than (VIWoSWO

4.2.3.2 Storey Displacement In Seismic Y-Direction

Table 4.16 storey displacement of structure in seismic y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	91.7738	44.19	47.437	91.037	52.63	60.657
STOREY14	90.1417	40.962	43.883	86.951	48.972	56.088
STOREY13	87.57195	37.631	40.279	82.452	45.174	51.473
STOREY12	84.0788	34.308	36.644	78.578	41.321	46.835
STOREY11	79.7658	30.911	32.995	74.528	37.417	42.195
STOREY10	74.746	27.579	29.359	69.752	42.095	49.337
STOREY9	69.12485	24.212	25.766	64.925	37.336	43.391
STOREY8	63.00495	20.992	22.253	59.29	32.469	37.528
STOREY7	56.48035	17.795	18.858	54.932	27.756	31.832
STOREY6	49.63275	14.833	15.622	49.991	23.099	26.374
STOREY5	42.54955	11.977	12.59	44.715	22.519	26.254
STOREY4	35.90145	9.409	9.794	40.42	17.999	20.517
STOREY3	29.1536	6.988	7.253	35.882	13.778	15.221
STOREY2	22.34685	4.919	5.013	29.156	9.845	10.528
STOREY1	15.56005	3.081	3.119	20.359	6.485	6.539
GROUND	8.96705	1.671	1.618	11.749	3.589	3.375

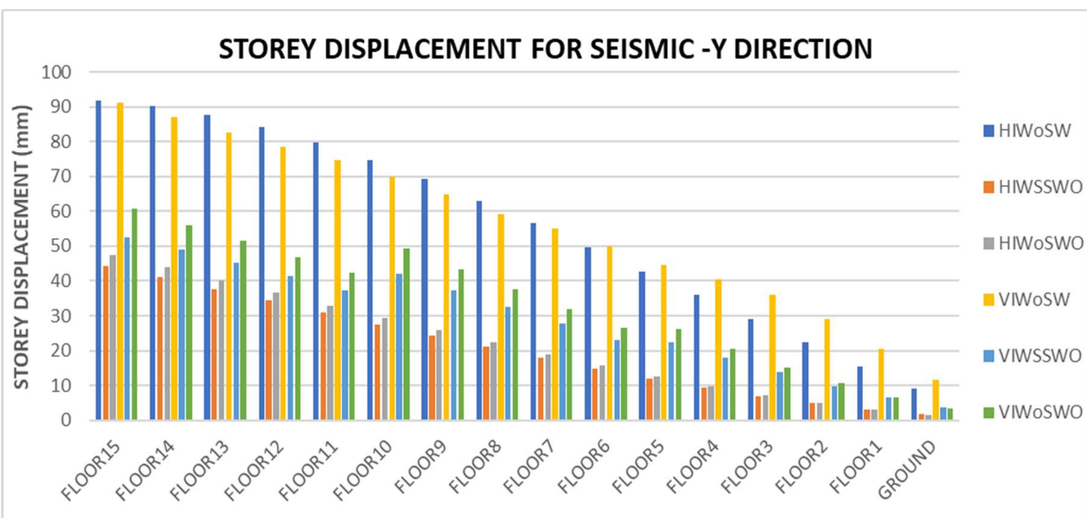

Fig 4.16 graph of storey displacement for different floors for seismic y- direction

The table shows the value of the storey displacement for different irregular models for each floor for seismic y - direction. The table shows that the maximum displacement we get at the 15th floor with the maximum value of 91.778 mm in the case of (HIWoSW) and minimum in the case of (HIWoSWO) with a value of 1.618 mm at the plinth level. From the graph and table it has been found that for (MII) the displacement is about 6.85 % less than the (MIII). Also in (VIWSSWO) have a displacement of 13.23 % less than (VIWoSWO).

4.2.3.3 Response Spectrum Table And Graph For Storey Displacement In Seismic X&Y-Direction

Table 4.17 Response spectrum for storey displacement of structure in x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	88.604	53.5873	50.843	87.484	45.2413	45.7171
STOREY14	87.063	49.6223	47.0639	84.756	42.0628	42.3943
STOREY13	84.679	45.6365	43.2393	80.56	38.7881	39.0377
STOREY12	81.494	41.574	39.3874	75.111	35.5238	35.6603
STOREY11	77.599	37.5479	35.529	68.874	32.2075	32.2829
STOREY10	73.064	33.4815	31.6888	62.897	28.9666	28.9289
STOREY9	67.942	29.5373	27.898	58.168	25.7829	25.6256
STOREY8	62.275	25.6048	24.1891	52.75	22.6681	22.373
STOREY7	56.101	21.8842	20.5985	46.645	19.5793	19.2088
STOREY6	49.445	18.2429	17.1665	40.052	16.6517	16.1642
STOREY5	42.309	14.8967	13.9308	33.637	13.7878	13.273
STOREY4	35.878	11.7221	10.9343	28.937	11.2658	10.5872
STOREY3	29.21	8.8738	8.1835	23.936	8.775	8.0704
STOREY2	22.304	6.2296	5.7343	18.574	6.513	5.7811
STOREY1	15.276	4.0313	3.6335	12.932	4.4018	3.7661
GROUND	8.472	2.1541	1.937	7.298	2.6117	2.0865
PLINTH	2.734	0.8333	0.7111	2.401	1.1141	0.8164

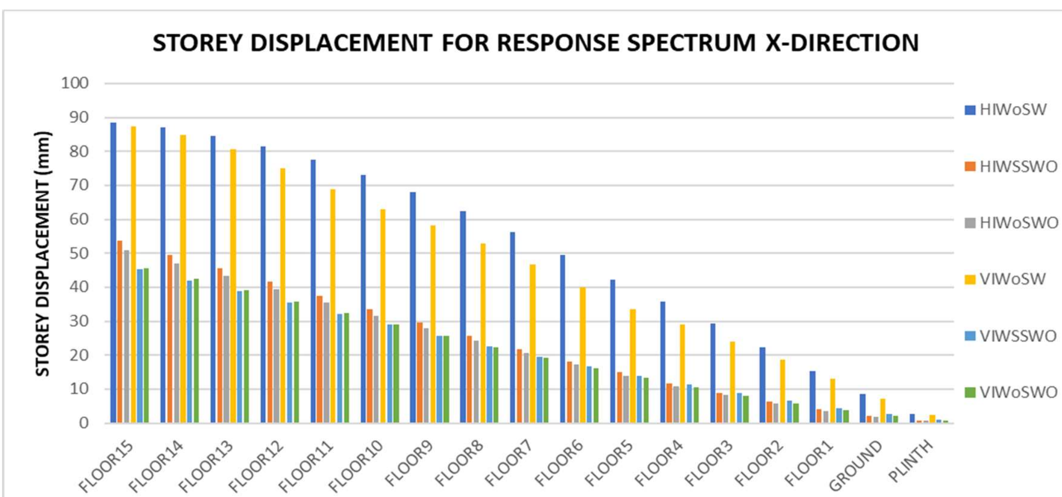

Fig. 4.17 Graph of Response for storey displacement of structure in x-direction

Table 4.18 Response spectrum for storey displacement of structure in y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	91.373	45.87125	49.05625	95.85	52.0352	54.8814
STOREY14	89.917	42.53125	45.41125	94.47	48.4736	50.7766
STOREY13	87.66	39.10625	41.7225	92.162	44.7916	46.6522
STOREY12	84.632	35.6875	38.00875	88.93	41.111	42.5334
STOREY11	80.914	32.22	34.2875	84.878	37.401	38.4412
STOREY10	76.57	28.815	30.58375	80.263	45.878	47.5538
STOREY9	71.651	25.4	26.9275	75.407	41.0158	42.0602
STOREY8	66.197	22.12	23.35	69.813	36.1256	36.6744
STOREY7	60.245	18.87875	19.8875	63.512	31.3698	31.465
STOREY6	53.826	15.85	16.57625	56.578	26.7232	26.4782
STOREY5	46.964	12.9225	13.4575	49.213	28.119	27.7074
STOREY4	40.356	10.2575	10.56	42.496	23.226	22.1872
STOREY3	33.405	7.72375	7.905	35.335	18.4296	16.968
STOREY2	26.098	5.51875	5.5375	27.726	13.7844	12.1786
STOREY1	18.491	3.53125	3.5075	19.733	9.5144	7.924
GROUND	10.8	1.96375	1.87	11.586	5.6322	4.3554
PLINTH	3.781	0.74125	0.68375	4.086	2.5116	1.6772

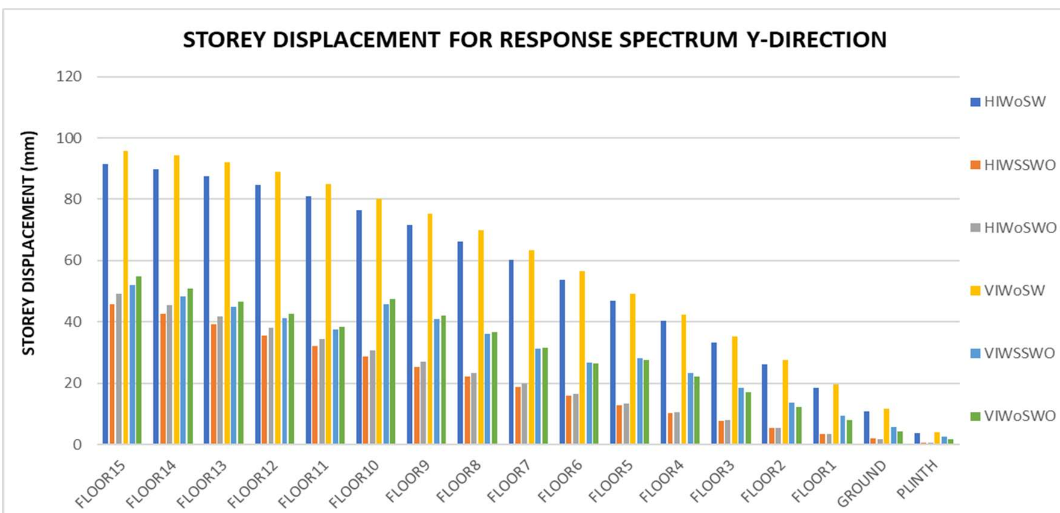

Fig. 4.18 Graph of Response for storey displacement of structure in y-direction

4.2.4 Story Shear For Different Floors

The responses of all the models for storey shear are computed and recorded in tabular or graphical form and investigation is carried out in X and Y-direction.

4.2.4.1 Storey Shear In Seismic X-Direction

Table 4.19 storey shear of structure in seismic x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	176.393	780.9591	924.2389	164.52	598.4421	633.2467
STOREY14	341.7698	1539.505	1839.085	320.2915	1189.982	1274.066
STOREY13	487.1204	2206.736	2643.646	457.8109	1710.195	1837.588
STOREY12	613.737	2788.511	3345.013	578.1811	2163.673	2328.787
STOREY11	722.9115	3290.697	3950.273	682.5096	2554.998	2752.636
STOREY10	815.9359	3719.147	4466.512	849.433	3147.902	3382.966
STOREY9	894.1023	4079.729	4900.817	994.0166	3653.883	3920.639
STOREY8	958.7026	4378.291	5260.273	1114.781	4072.672	4365.582
STOREY7	1011.029	4620.706	5551.965	1213.828	4412.518	4726.584
STOREY6	1052.373	4812.819	5782.98	1293.248	4681.694	5012.429
STOREY5	1084.883	4963.098	5963.408	1385.623	4982.481	5329.357
STOREY4	1109.57	5076.571	6099.376	1459.148	5211.461	5570.299
STOREY3	1126.713	5156.044	6194.404	1513.016	5371.621	5738.624
STOREY2	1137.685	5207.579	6255.846	1550.521	5475.379	5847.397
STOREY1	1143.857	5237.298	6291.054	1574.827	5535.079	5909.68
GROUND	1146.6	5251.244	6307.381	1588.865	5563.155	5938.535
PLINTH	1147.286	5255.567	6312.184	1595.134	5571.982	5947.044

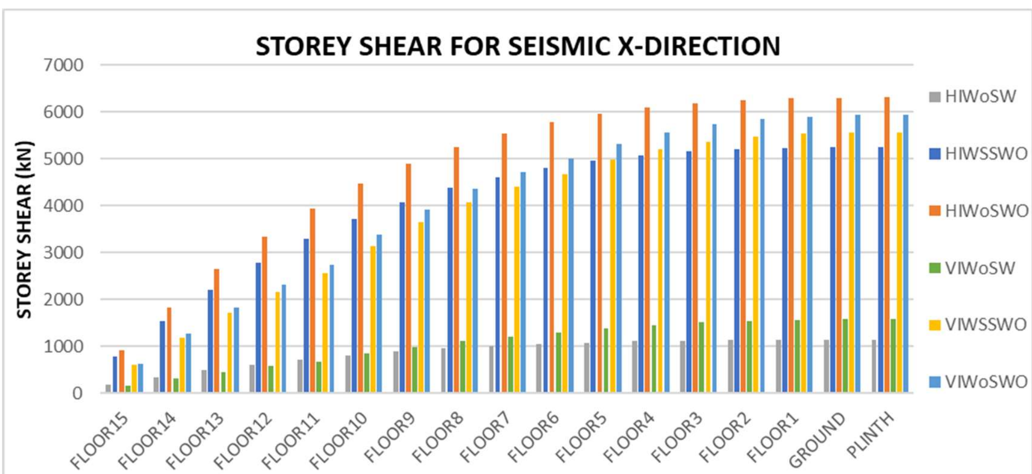

Fig 4.19 graph of storey shear for different floors for seismic x- direction

The table shows the value of the storey shear for irregular models for each floor for seismic x – direction. The table shows that the maximum shear we get at the plinth level with the maximum value of 6312.184 in the case of (HIWoSWO) and minimum in the case of (HIWoSW) with a value of 1147.286 kN at the plinth level. From the graph and table, it has been found that for (MIII), the shear is about 16.74 % (MII). Also in (VIWSSWO) have a shear of 6.31% less than (VIWoSWO).

4.2.4.2 Storey Shear In Seismic Y-Direction

Table 4.20 storey shear of structure in seismic y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	171.571	644.3451	924.2475	142.7661	393.8827	437.0059
STOREY14	332.4269	1270.214	1839.103	278.0872	783.2559	879.3388
STOREY13	473.8042	1820.75	2643.675	397.7309	1125.723	1268.441
STOREY12	596.9595	2300.797	3345.051	502.672	1424.298	1607.731
STOREY11	703.1495	2715.184	3950.321	593.8868	1681.996	1900.625
STOREY10	793.631	3068.752	4466.57	739.3513	2073.029	2337.321
STOREY9	869.6605	3366.326	4900.885	865.6665	2406.899	2710.179
STOREY8	932.4949	3612.752	5260.352	971.5859	2683.374	3019.07
STOREY7	983.3907	3812.85	5552.054	1058.963	2907.884	3270.023
STOREY6	1023.605	3971.471	5783.079	1129.642	3085.838	3469.066
STOREY5	1055.226	4095.575	5963.519	1211.331	3285.496	3691.234
STOREY4	1079.238	4189.333	6099.497	1276.898	3437.862	3860.867
STOREY3	1095.913	4255.023	6194.533	1325.625	3544.834	3980.076
STOREY2	1106.585	4297.691	6255.983	1360.364	3614.509	4057.81
STOREY1	1112.588	4322.329	6291.197	1383.849	3655.038	4103.012
GROUND	1115.256	4333.996	6307.527	1398.531	3674.497	4124.626
PLINTH	1115.923	4337.676	6312.329	1406.157	3681.145	4131.634

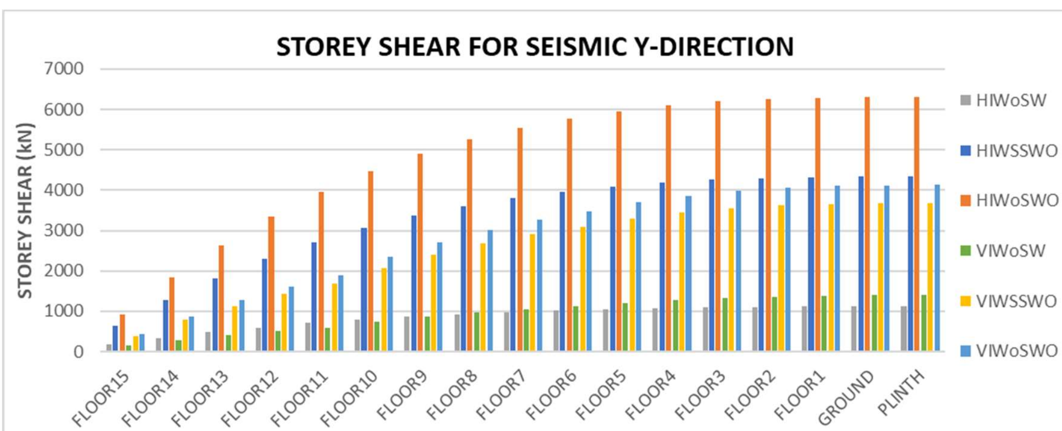

Fig 4.20 graph of storey shear for different floors for seismic y- direction

The table shows the value of the storey shear for irregular models for each floor for seismic y – direction. The table shows that the maximum shear we get at the plinth level with the maximum value of 6312.329 kN in the case of (HIWoSWO) and minimum in the case of (HIWoSW) with a value of 1115.923 kN at the plinth level. From the graph and table, it has been found that for (MIII), the shear is about 31.282 % more than (MII). Also in (VIWSSWO) have a shear of 10.9 % less than (VIWoSWO).

4.2.4.3 Response Spectrum Table And Graph For Storey Shear In Seismic X&Y-Direction

Table 4.21 Response spectrum for storey shear of structure in x-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	215.6873	745.6289	939.3088	199.5814	551.6135	555.0931
STOREY14	373.9599	1415.993	1767.637	338.1035	1063.669	1097.685
STOREY13	475.2225	1948.359	2399.155	435.7794	1469.949	1548.695
STOREY12	551.0903	2347.438	2877.314	509.1585	1783.148	1910.799
STOREY11	611.9041	2639.062	3248.468	567.2252	2015.539	2190.367
STOREY10	666.8969	2850.424	3554.307	663.3476	2337.927	2559.346
STOREY9	719.8006	3023.68	3828.079	759.1113	2614.575	2849.803
STOREY8	768.5279	3195.726	4092.956	844.3739	2859.34	3091.963
STOREY7	816.1035	3398.103	4362.235	919.7333	3081.882	3320.407
STOREY6	858.3667	3641.404	4640.885	987.0225	3301.05	3560.632
STOREY5	896.6304	3924.792	4932.759	1079.213	3647.435	3958.699
STOREY4	938.9541	4226.585	5234.239	1177.357	4048.541	4419.594
STOREY3	981.1829	4516.006	5528.541	1268.428	4450.359	4882.147
STOREY2	1026.783	4762.672	5800.549	1363.051	4829.198	5294.83
STOREY1	1079.905	4952.887	6031.64	1456.896	5158.403	5617.427
GROUND	1127.13	5072.311	6201.415	1547.416	5412.083	5827.455
PLINTH	1147.286	5127.306	6292.001	1595.859	5547.271	5923.89

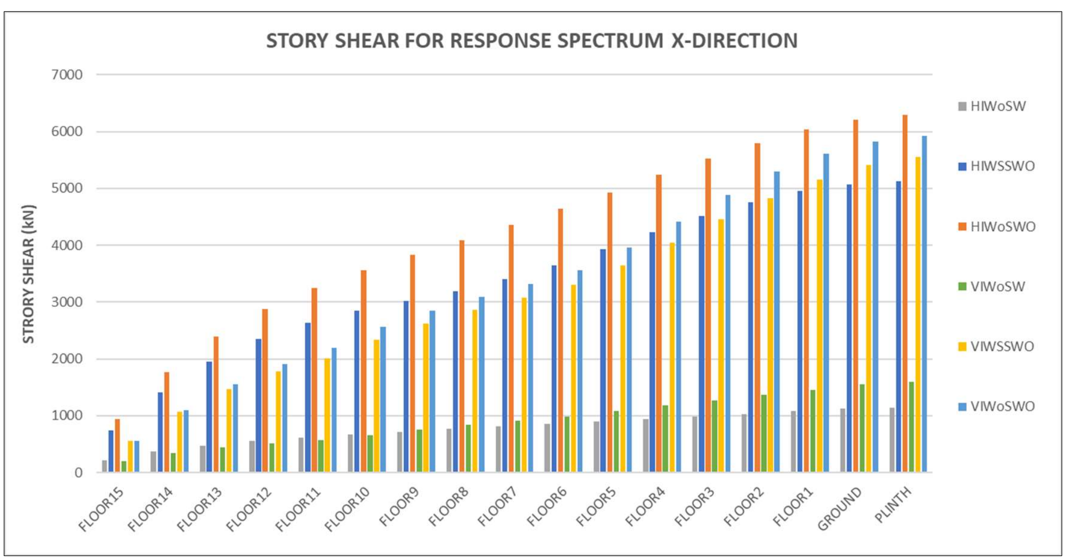

Fig. 4.21 Graph of Response for storey shear of structure in x-direction

Table 4.22 Response spectrum for storey shear of structure in y-direction

	HIWoSW	HIWSSWO	HIWoSWO	VIWoSW	VIWSSWO	VIWoSWO
STOREY15	201.1609	634.3981	939.3422	167.3443	332.4776	292.324
STOREY14	349.7057	1208.787	1767.665	291.8938	635.7523	561.7936
STOREY13	449.6517	1660.089	2399.043	381.8782	879.063	773.4429
STOREY12	525.11	2000.809	2876.93	449.7967	1068.683	931.5247
STOREY11	586.3173	2244.953	3247.701	503.657	1216.098	1043.457
STOREY10	642.9512	2422.789	3553.086	599.0544	1512.962	1254.662
STOREY9	694.9004	2564.917	3826.391	692.3995	1760.945	1420.725
STOREY8	743.9663	2707.496	4090.869	763.6348	1964.115	1566.941
STOREY7	790.3349	2875.406	4359.894	820.4699	2146.154	1720.161
STOREY6	833.2155	3080.652	4638.491	873.0988	2329.066	1896.82
STOREY5	874.913	3319.901	4930.588	960.2725	2672.784	2242.673
STOREY4	915.3393	3579.111	5232.334	1052.859	3067.462	2650.919
STOREY3	955.6311	3825.881	5527.008	1129.553	3474.062	3069.489
STOREY2	997.1192	4041.465	5799.482	1201.846	3857.14	3457.252
STOREY1	1041.512	4204.552	6031.083	1288.582	4188.661	3775.096
GROUND	1089.284	4311.512	6201.32	1382.863	4435.996	3991.253
PLINTH	1115.923	4358.898	6292.119	1451.482	4575.987	4093.425

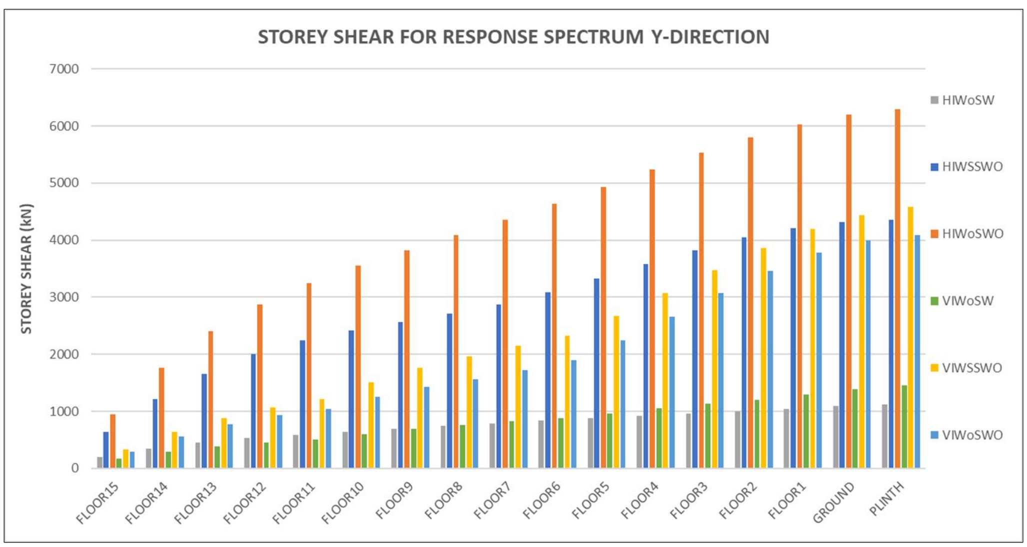

Fig. 4.22 Graph of Response for storey displacement of structure in y-direction

Chapter 5

CONCLUSIONS

The above study shows that how the building performs when the building has combination of irregularity and staggered shear opening as various study has been done on irregular building with shear wall. The performance of the building is measured on the parameters like higher stiffness, low drift and displacement values. To investigate the various parameters response spectrum analysis has been performed using ETABS 20 software. From the above result it can be concluded the VIWSSWO (vertical irregularity with staggered shear wall opening) model performs better than the other models due to higher stiffness, lower shear, drift and displacement values.

- The overall performance of the building was increased to greater extent when compared with building having shear wall without opening.
- The stiffness of the structure was increased by about 20.5% in case of vertical irregularity with staggered shear wall opening.
- The overall drift and displacement values was reduced by about 13-15% in case of staggered shear wall opening which increases the stiffness of the building to withstand the seismic forces.
- The shear values that are coming to the building was reduced by about 10% which will help to reduce the member size requirement of the building.
- Because of the reduction in the various parameters helps to make the building more economical when compared to building having shear wall without opening.

FUTURE SCOPE OF WORK

For future work, the author can work for other types of irregularity with staggered shear wall opening and check for the parameters. Also the study can be extended to different seismic zones to check for the behaviour of the building.

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