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Comparative Structural Analysis of G+24 Building with Various Geometrical Plan and Elevations, by using Staad Pro V8i Software

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ABSTRACT:

Effect of earthquake and wind has dependably been a risk to human progress, destroying human lives, property and man-made structures. Subsequently there is continuous research works going ahead around the world, revolving around improvement of new and better methods that can be used in structures for better earthquake and wind performance. Most commonly used systems that can be used for strengthening buildings for earthquakes and wind load effect are horizontal structural systems like (diaphragms and trussing) and vertical structural systems like (braced frames, moment resisting frames and shear walls). Roofs and floors, called "diaphragms", are relatively thin but stiff horizontal or nearly horizontal structural systems which transmit in plane lateral forces to, or between, vertical lateral force resisting structural elements. In addition to primary role of distributing lateral forces to vertical structural elements, the diaphragms tie a whole structural system together.

In this dissertation, comparative structural analyses of three-dimensional (3-D) high rise buildings with floor diaphragm have been considered. The three different building plans square, Hexagonal and Octagonal are considered. The buildings are also considered with different elevation floors that are 6 floors, 12 floors, 18 floors and 24 floors. Under this study, the building is analyzed for Delhi City defining seismic zone IV as per IS 1893-2002 and for one wind zone (zone II) as per IS 875-1987. In this way total 12 buildings are analyzed with 22 load combinations. The structural analyses are carried out using STAAD-Pro software. The buildings are critically analyzed for both seismic and wind lateral loads to quantify the effects of various parameters for study of results in terms of maximum and minimum bending moment, shear force in beams, maximum and minimum axial force in columns and maximum and minimum displacement in X- and Z-transmissions are carried for buildings with rigid diaphragm.

1. INTRODUCTION

1.1 GENERAL

In Today's Scenario, with the increase in population day by day, the surrounding is getting filled with Concrete Forest. However, it is not enough to fulfil the requirement of occupants on land, even for Shelter. Earlier with less residents, people used to stay in horizontal system (due to bigger land area available per head). Leading towards the solution of current era's problem, brings us to adopt vertical system (Higher count of floors on limited land area). From Structural perspective, in High-Rise Buildings, all the vertical as well as horizontal forces are taken into account for calculation. For an effective High-Rise Building, it is essential that it's Load Bearing and Load Transferring Structures like beam, column, foundation and reinforcement should be adequate enough to resist all the external and internal forces.Earthquake, always been one of the major threats for human development from beginning devastating humanity, worldly goods and manufactured structures. Recently, an earthquake that confronted in Haiti, a nation on one of the four major Caribbean Sea Islands, on 14th of August 2021 has again represented nature's rage with defacement or demolition of about 1,36,800 buildings. Learning from such an unpredictable calamity, leading us to research for advanced and superior technique that can be adopted in structural designing of buildings to achieve better seismic performance. Certainly, Structures that are planned and designed with particular process to overcome this tremorous movement leads to inflated budget for development in comparison to typical structures, still, to overcome the failures resulting due to seismic forces, it is necessary.

1.1.1 DIAPHRAGM SYSTEM

Under Structural Engineering, any structural component which is capable of transferring the horizontal loads to the adjoining vertical opposing segments of the structure (like shear walls), are termed as Diaphragm. These are generally horizonal, however it can be slanted as it is done in ramp in a garage for vehicle parking.

Diaphragms are generally build-up of plywood or aligned strand board in wood work; metal hang or composite metal hang in steel jobs; or a concrete slab in concrete construction. Diaphragm of a structure consists of mostly three components-

a) **The Membrane,** play role as a shear panel to transfer in-plane shear

b) **The Drag Strut Member,** engage in transporting the loads up to shear walls or frames

c) **The Chord**, stands to combat the tension and compression that blooms in diaphragm, as the membrane is unable of carrying these loads alone.

1.2 TYPES OF DIAPHRAGMS

1.2.1 RIGID DIAPHRAGMS

A diaphragm that can diverge the horizontal forces to the vertical lateral load carrying elements in fraction to their relative stiffness. For rigid diaphragms, on comparing the diaphragm deflection to that of upstanding lateral load resisting elements will be inconsequential. A diaphragm can be defined rigid when its displacement under horizontal load at midpoint is not so much as double the mean displacements at its ends. The dispensation of the lateral forces to the vertical repelling elements is directly equivalent to the relevant rigidities. It is grounded on the speculation that the diaphragm doesn't warp by its own and will resulting each vertical element to divert the same amount. Rigid diaphragms competent of passing on shear and torsional deflections and forces are also built on the speculation that the diaphragm with shear walls go through rigid body gyration which develops secondary shear forces at the shear wall. Rigid diaphragms comprise of precast concrete diaphragms, reinforced concrete diaphragms, and fused steel deck.

1.2.2 FLEXIBLE DIAPHRAGMS

The diaphragm is said to be flexible, when the diversion of lateral forces to the vertical bearing elements is unconstrained of their relative stiffness. For flexible diaphragm, unlike rigid diaphragms, the diaphragm deflection to that of upstanding lateral load resisting elements will be comparatively large. A diaphragm can be defined flexible when its maximum displacement under horizontal load is comparatively more than the twice of mean story float of the corresponding story. It may be calculated by comparing the evaluated midpoint in-plane deviation of the diaphragm on its own under horizontal load with the pile up to adjacent vertical elements under influent lateral load.

1.3 MOTIVATION BEHIND THIS STUDY

Consequences of seismic and wind has deliberately been a peril to human progress, destroying human lives, property and man-made structures. Afterwards, there is ramification research work going ahead in this world, spinning around improvement of new and better methods that can be placed in structures for finer seismic and wind performance. Generally used method to strengthen buildings for seismic and wind load effect are lateral structural systems like diaphragms. Rigid diaphragm is increasingly used for high rise structures.

1.4 OBJECTIVES

Our intentions of the current study are as follows:

1. To examine the out-turn of rigid diaphragm on 3D RC building having several geometrical plans such as square, hexagonal and octagonal.
2. To study the outcome of rigid diaphragm on the above buildings with different elevations floors, 6th floors, 12th floors, 18th floors and 24th floors.
3. To scrutinize the effects of earthquake and wind horizontal forces on these building. The structure is analysed for Deli City seismic zones (zone II, III, IV and V) as per IS 1893-2002 and for one wind zone (zone II) as per IS 875-1987. Through this way, total 120 buildings are inspected with 27 load combinations.
4. The several parameters such as topmost axial forces, bending moment and shear force in beams, earthquake forces and floor displacements on structures. The analysis of buildings are carried out using STAAD-Pro software (User manual 2012).

2. LITERATURE REVIEW:

1.Moon and Lee (1994) presented economical model for sky high pile counting in plane floor slab pliability unaccompanied by turning down the fidelity of the inspection, and also lodge a floor flexibility index whose knock are researched through criterion cramming in terms of seismic base shear and its dispensation, and displacement at the roof. The outcome depicts that it is prudent to include the in-plane wrenching of floor slabs in the seismic analysis of structures for reasonable and timid design when the in-plane deformation of floor slabs is anticipated to be massive.

2. Kim et al. (2003) modelled the building structures without the floor slabs assuming that they would have negligible effects on the response of a structure. Tier slabs are unambiguously put back by taut floor valve for the coherence in the analysis. Beams and floor slabs are split up into several component hence spare time is required for the investigation policy and set on the mix-up, efficient analytical modelling methods employing the sub structuring procedure, super-strand, and stiff diaphragms are adapted. The methodical consequences of time antiquity perusal and the algorithmic time of several studies for instance anatomy are collate to look over the cogency of the modelling strategy lodge in this survey. The preferred model does provide earthquake response of the said structures in outstanding reduced algorithmic times while the accuracies in the analysis results are very close to those obtained from the refined model. The efficiency and accuracy of the proposed systematic models are verified and the conclusions can be obtained.

3. Basu and Jain (2004) declare the median of rigidity for rigid floor diaphragm structure that has been lengthen to askew structures with ductile floors. They lodge a stratagem which clinch that the corollary member force is close to that of rigid floor structures as the floor flange rigidity escalate. A superposition-based methodology was proposed to execute code- itemized dihedral purveying for buildings with flexible floor diaphragms. The analysis showed that outcome member force is close to that of rigid floor diaphragm structure as the floor diaphragm rigidity escalate and also it was noticed that medicate the diaphragms of building as rigid for torsional analysis may genesis considerable error.

3. METHODOLOGY :

Under this heading, the seismic and wind analysis of structure is carried out with the help of STAAD-PRO software. This chapter covers comparative study of behaviour of high-rise structure considering different geometrical configurations and diaphragm constraints under seismic and wind forces. A comparative analysis of results in terms of lowest and highest moments in columns and beams, horizontal loads and displacements has been examined.

3.1 SOFTWARE USED FOR ANALYSIS

STAAD Pro stands for Structural Analysis and Designing Program. STAAD Pro is computer program used for structural analysis & design that was being developed at Yorba Linda, California in 1997 by Research Engineers International (REL).

In Present Era, STAAD Pro is one of the most popular and globally used software for structural analysis and design by Civil Engineers. It examines the structure with reference to all types of various steel, concrete, and timber design codes.

Generally, in high-rise structures, STAAD-PRO software is used to calculate the seismic and wind load. Manually, the calculation for a high-rise building requires much time and chances of human errors are also high, so the use of computational software make it easy. It provides more accurate and precise results than the manual techniques. STAAD-PRO can solve typical problem like static analysis and dynamic analysis.

The step-by-step procedure that is involved in analyses using STAAD-PRO software are discussed below-

- Prepare the input file
- Analyse the input data
- Summarise the Result

➢ Prepare the input file Initially, the geometry, the materials, its cross sections, the support situations of the structure are drawn.

➢ Analyse the input dataAfter the preparation of the input file, all the data are inspected and the analysis system is given as input for analysing the structure, so that a stable structure, else it will show error.

➢ Results Analysing the result is done out in post processing mode.

4. STEPS TAKEN IN STUDY FOR ANALYSIS METHOD

STEP-1

To select the structure geometry and number of storeys. In the current study, 3 types of geometry plans are selected:

a) Square building frame Fig. 4.1

b) Hexagon building frame Fig. 4.2

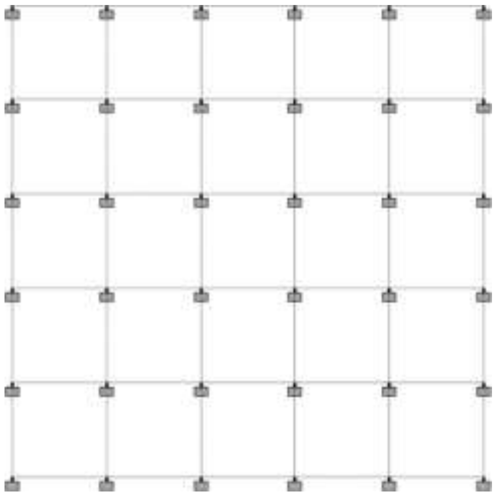
c) Octagon building frame Fig. 4.3

Type 1. Regular building frame of 24 floors as shown in Fig.4.4 for square building, Fig 4.8 for hexagonal building and 4.12 for octagonal building.

Type 2. Regular building frame having section cut from 6th floor up to 24th floor as shown in Fig 4.5 for square building, Fig 4.9 for hexagonal building and 4.13 for octagonal building.

Type 3. Regular building frame having section cut from 12th floor up to 24th floor as shown in Fig 4.6 for square building, Fig 4.10 for hexagonal building and 4.14 for octagonal building.

Type 4. Regular building frame having section cut from 18th floor up to 24th floor as shown in Fig 4.7 for square building, Fig 4.11 for hexagonal building and 4.15 for octagonal building.



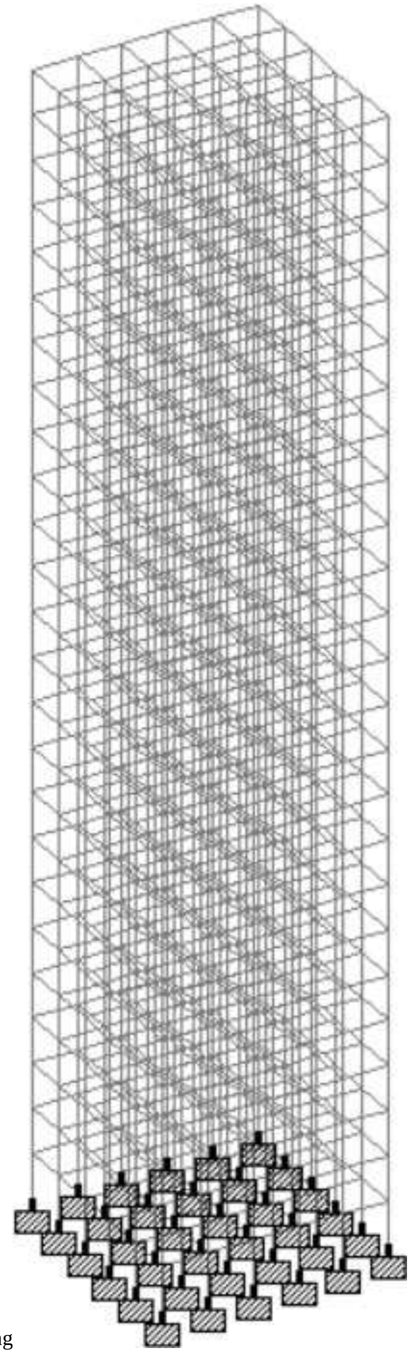


Fig 4.1 Plan and elevation of square building

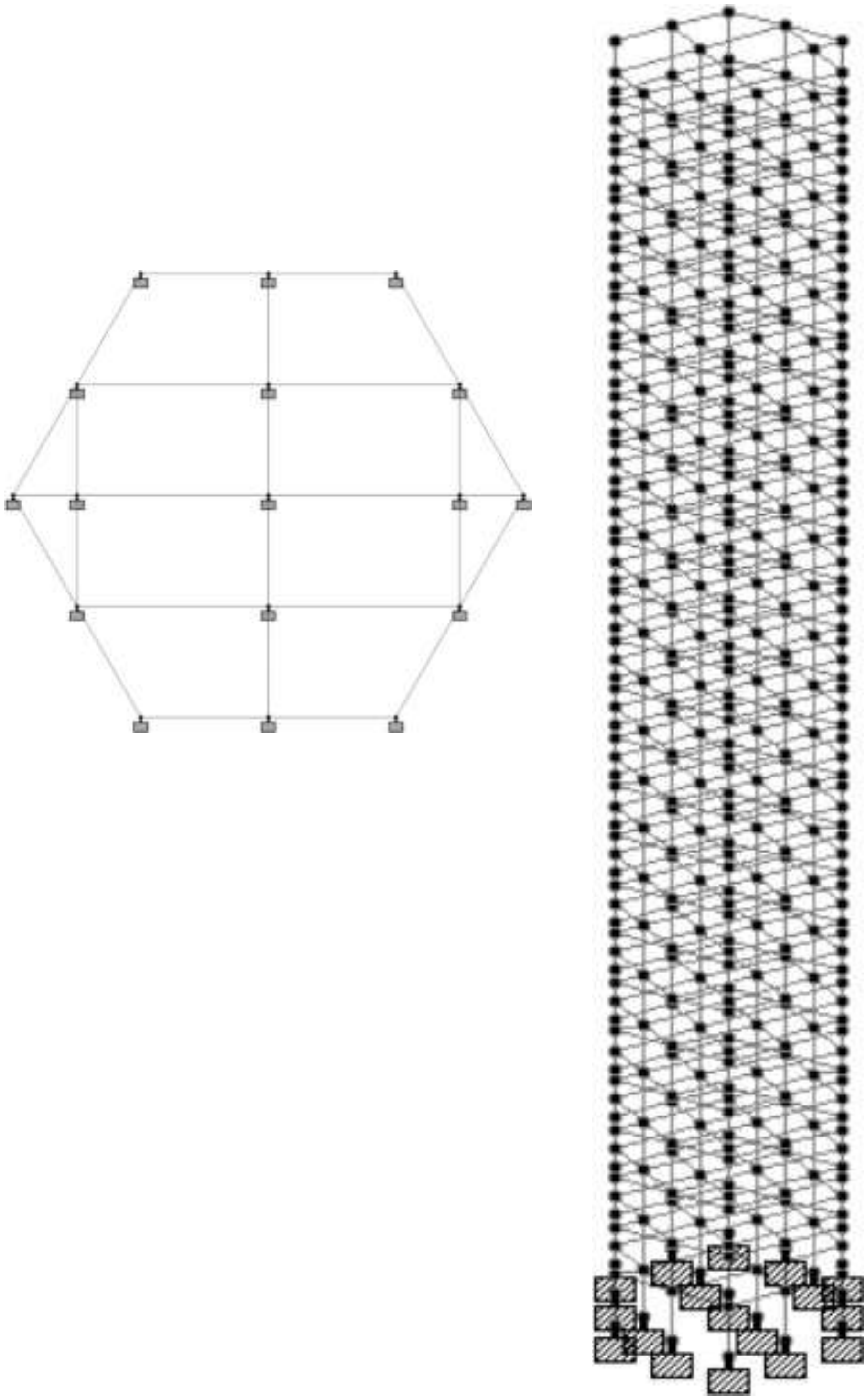


Fig 4.2 Plan and Elevation of Hexagonal Building

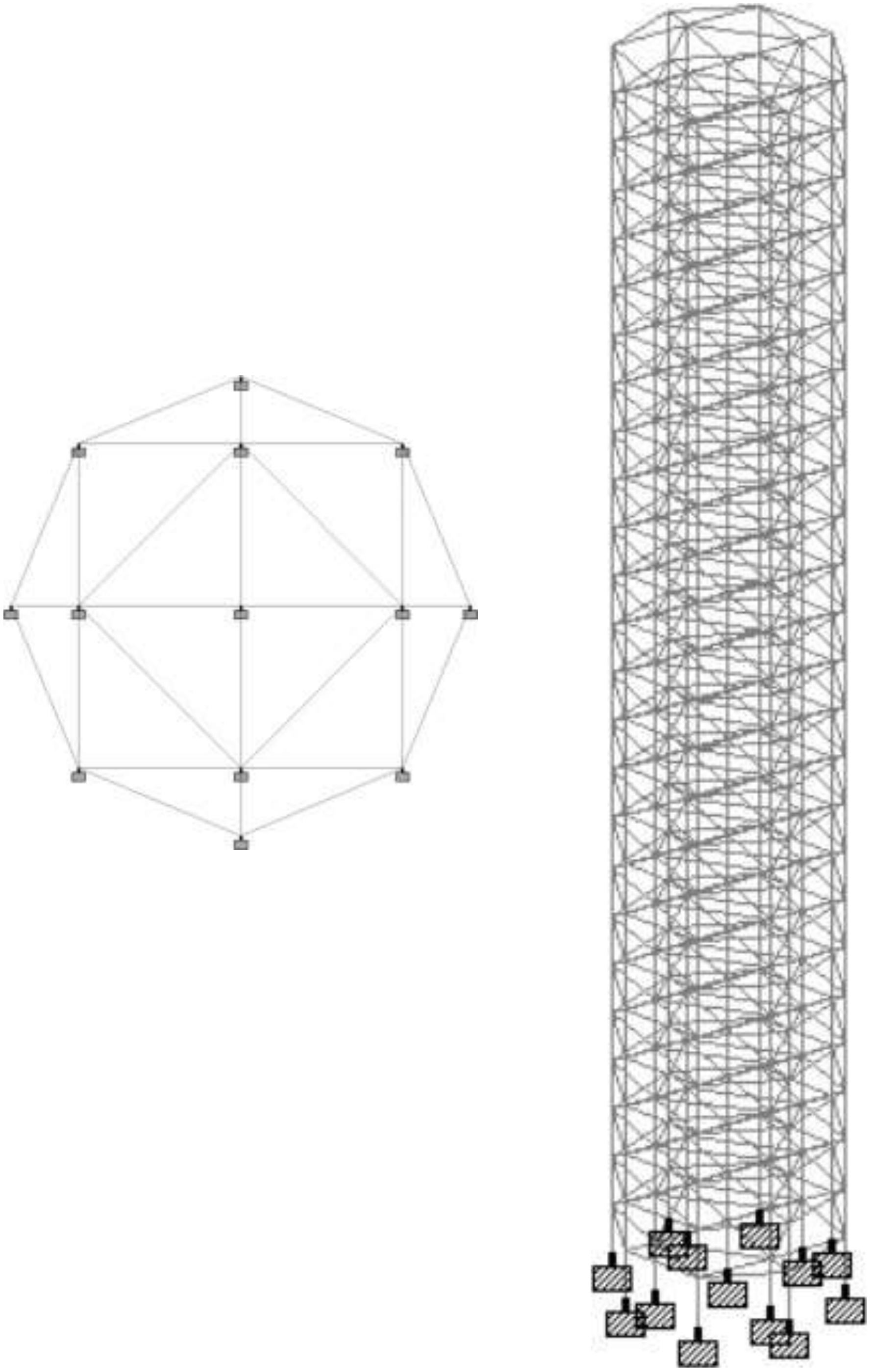
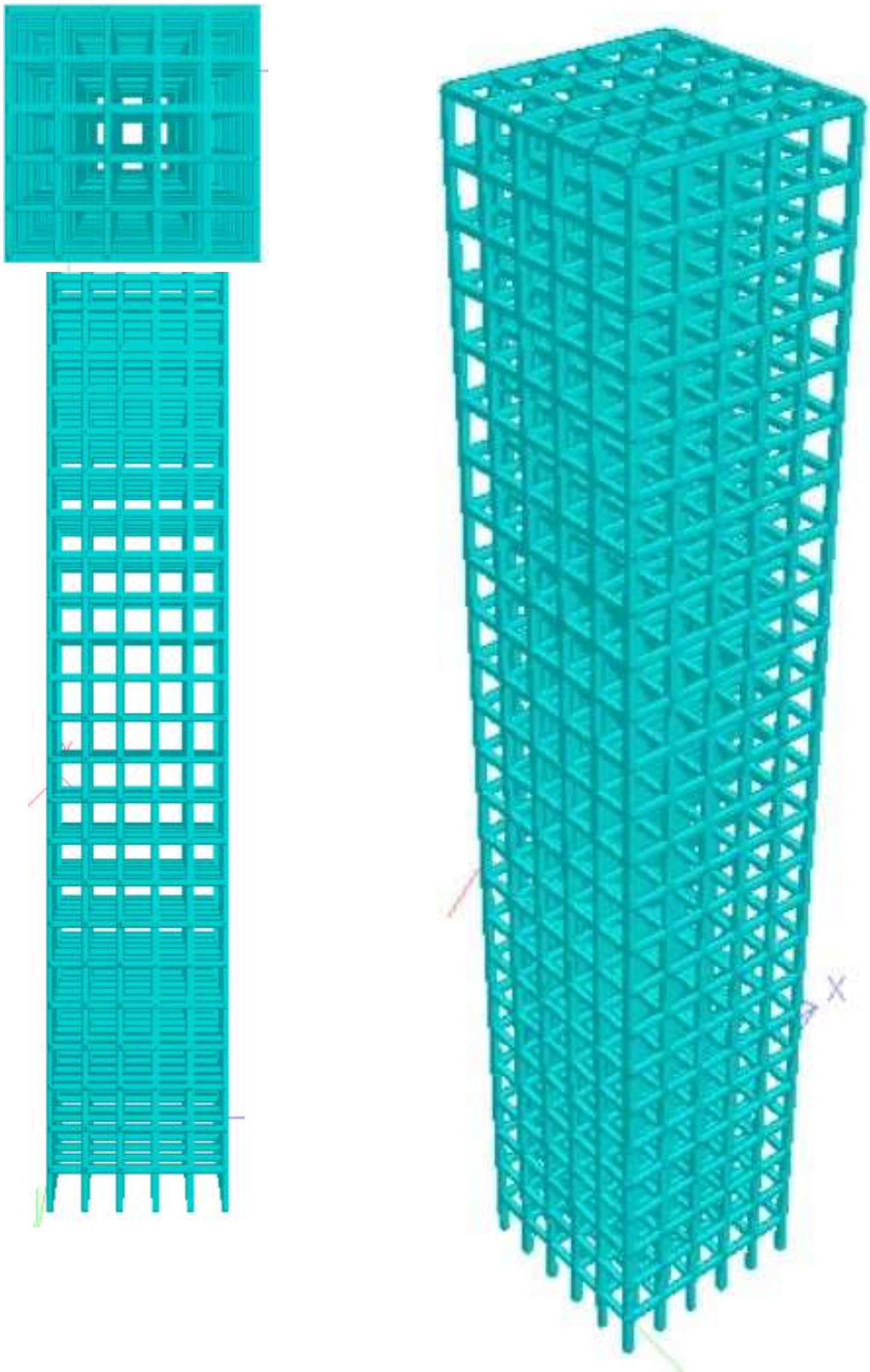


Fig 4.3 Plan and Elevation of Octagonal Building

Fig 4.4 Plan, Elevation and Isometric view of 24 Storey Square Building



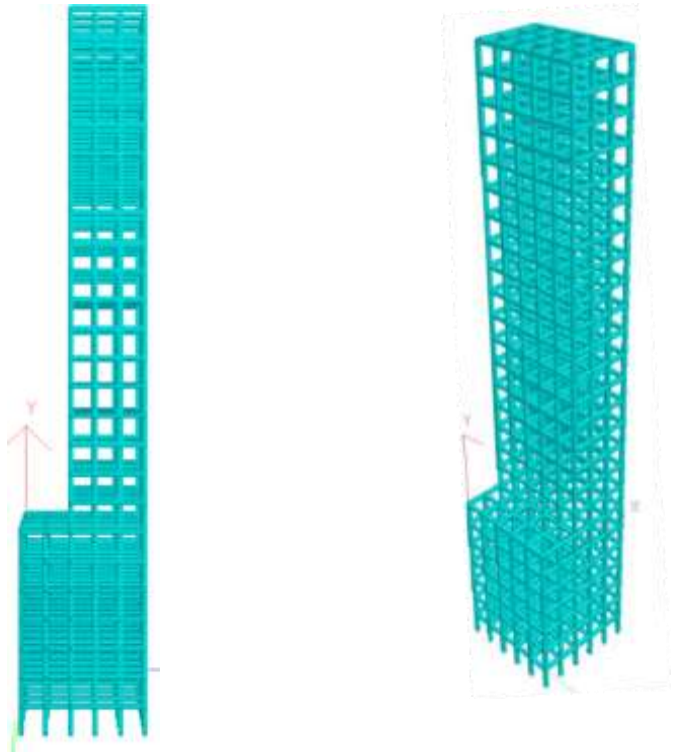


Figure 4.5 Elevation and isometric views of square building having section cut from 6th floor up to 24th floor

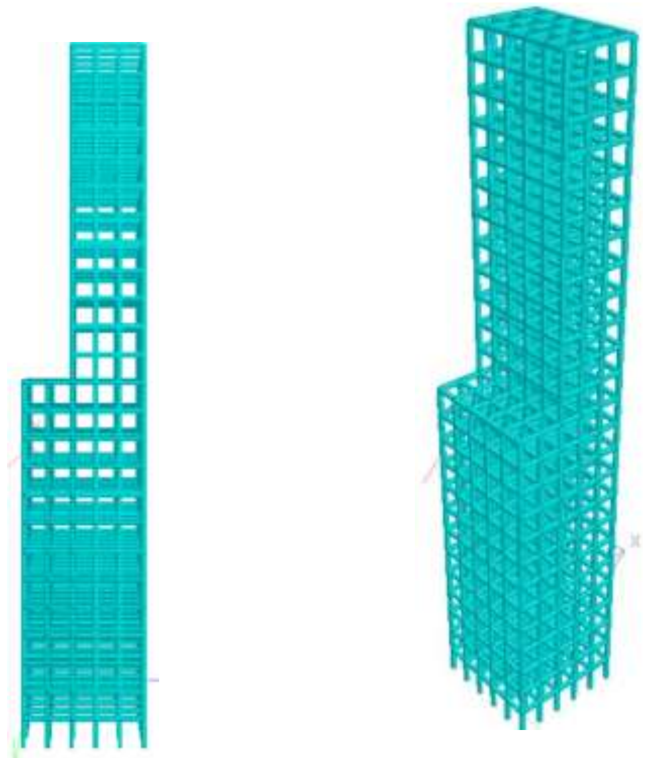


Figure 4.6 Elevation and isometric views of square building having section cut from 12th floor up to 24th floor

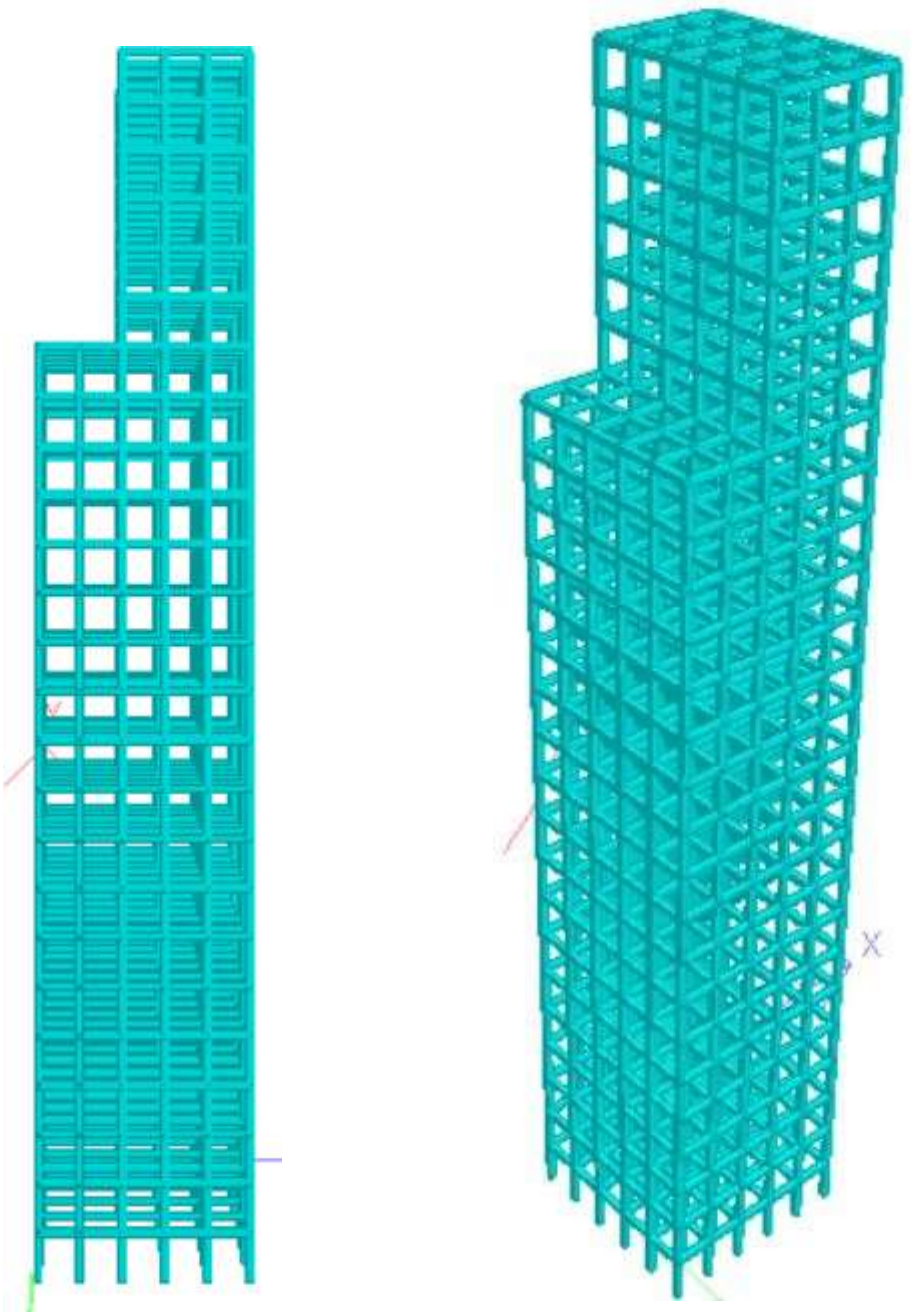


Figure 4.7 Elevation and isometric views of square building having section cut from 18th floor up to 24th floor

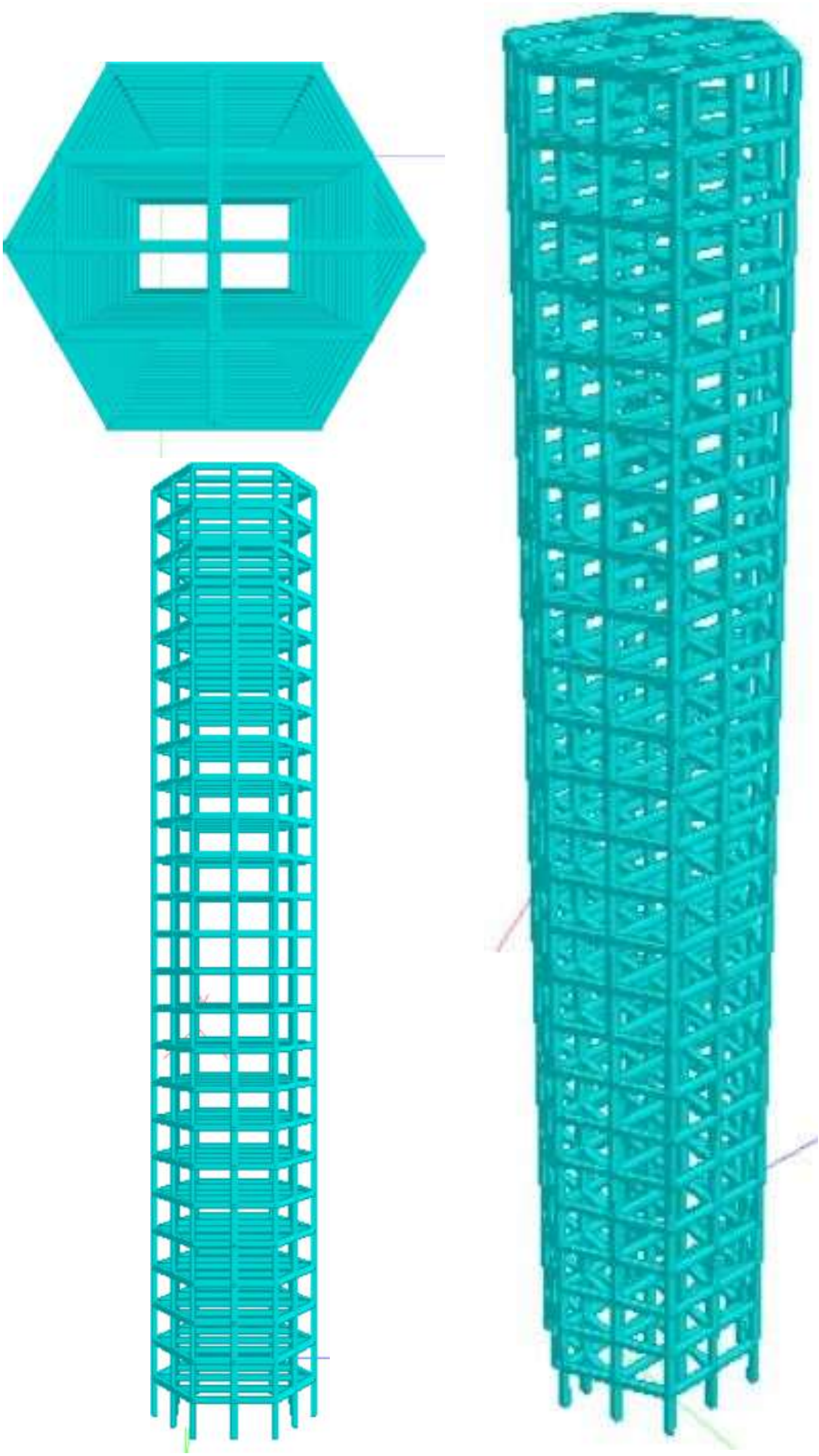


Fig 4.8 Plan, Elevation & Isometric view of 24 Storey Hexagon Building

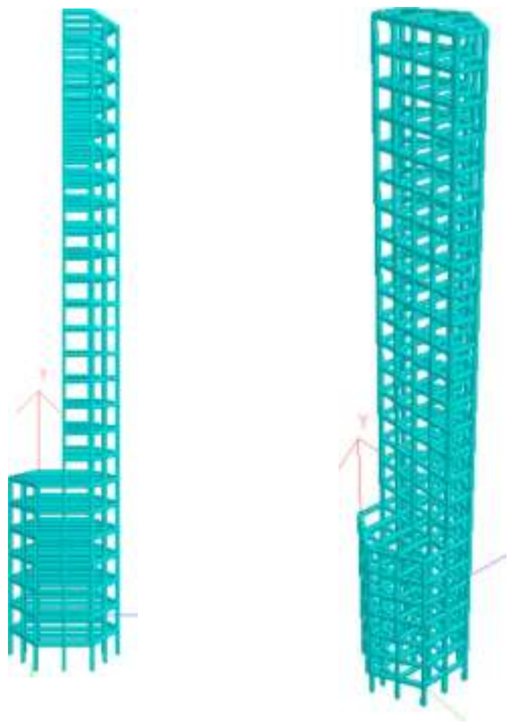


Fig 4.9 Elevation and isometric views of hexagonal building having section cut from 6th floor up to 24th floor

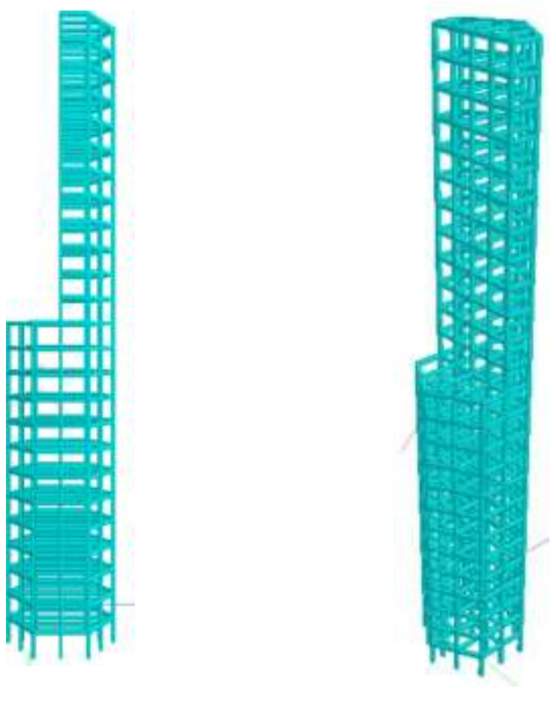


Fig 4.10 Elevation and isometric views of hexagonal building having section cut from 12th floor up to 24th floor

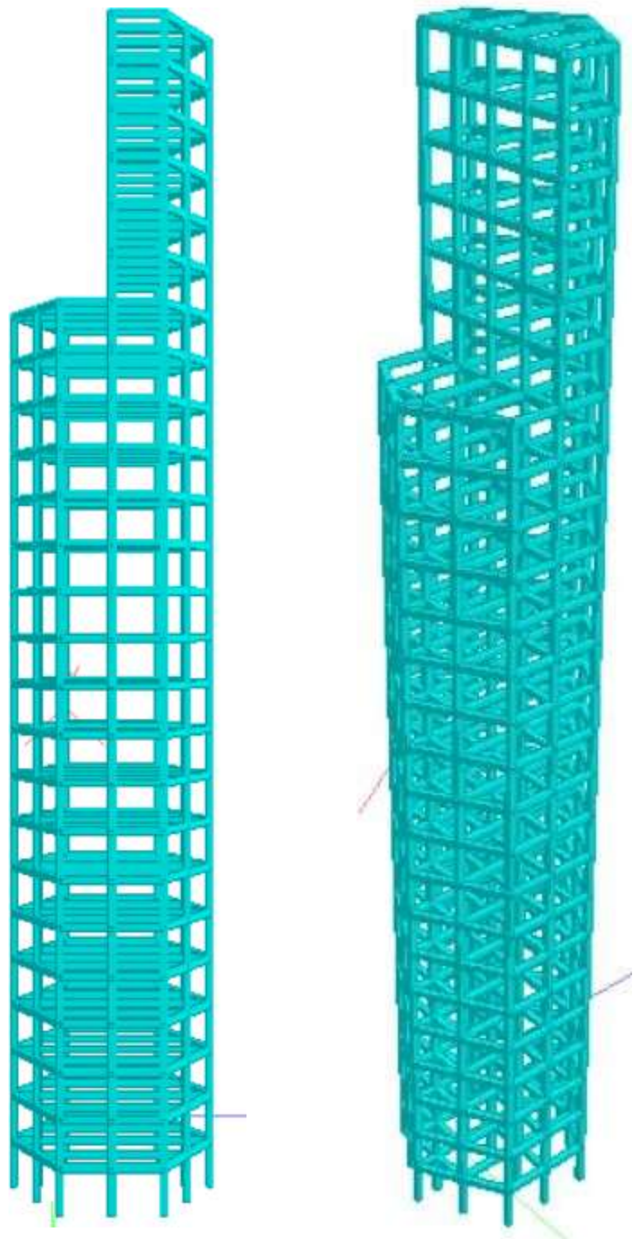


Fig 4.11 Elevation and isometric views of hexagonal building having section cut from 18th floor up to 24th floor

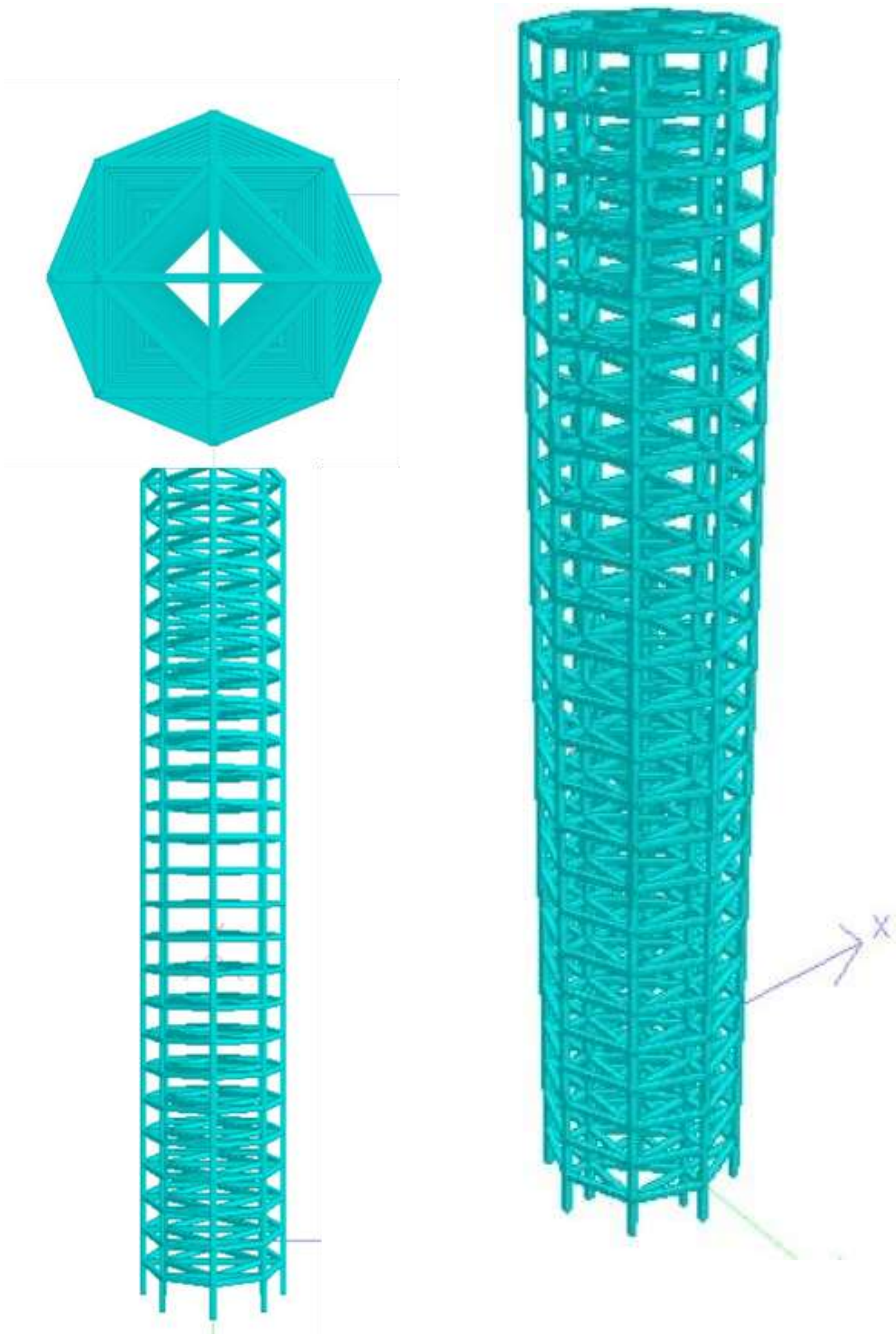


Fig 4.12 Plan, Elevation & Isometric view of 24 Storey Octagon Building

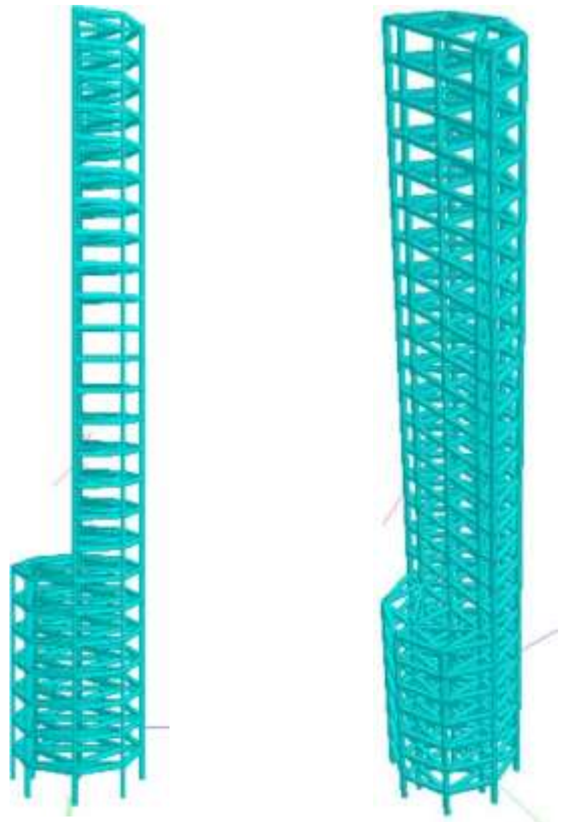


Fig.4.13 Elevation and isometric views of octagonal building having section cut from 6th floor up to 24th floor

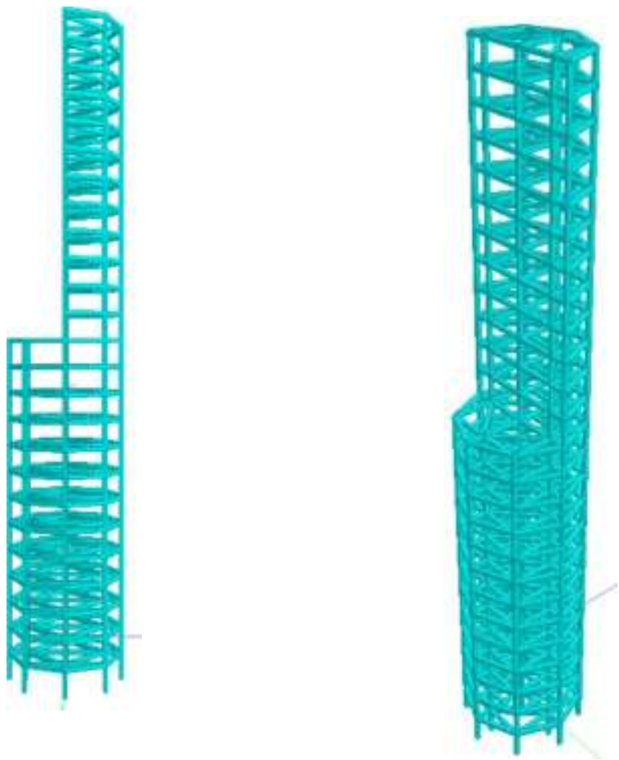


Fig.4.14 Elevation and isometric views of octagonal building having section cut from 12th floor up to 24th floor

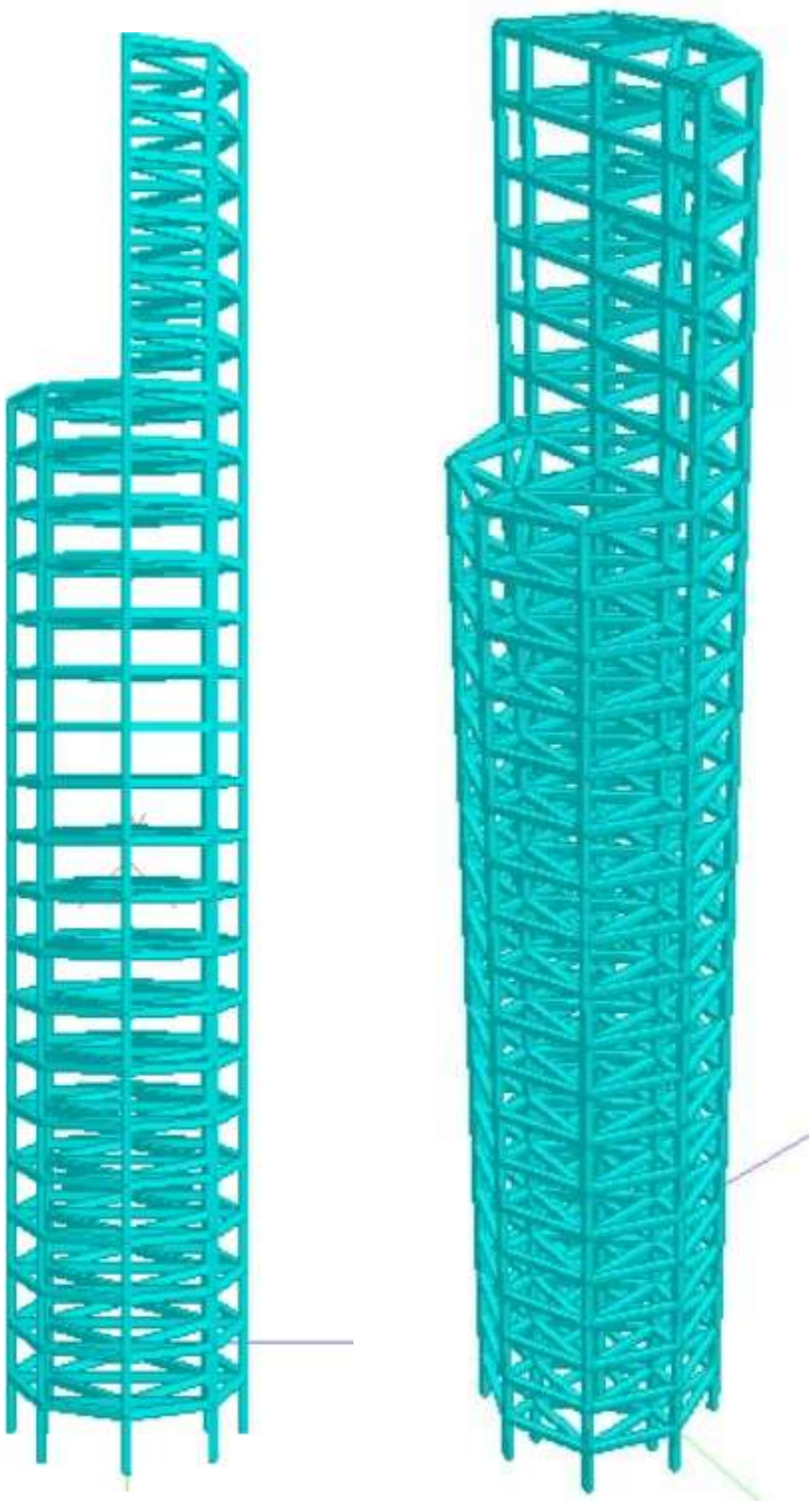


Fig.4.15 Elevation and isometric views of octagonal building having section cut from 18th floor up to 24th floor

5. RESULT ANALYSIS

5.1 RESULTS OF SEISMIC AND WIND ANALYSIS

Seismic Analysis for the Delhi city (Zone IV) of the Square Building is discussed under Table 5.1. The table defines the maximum and minimum axial force in columns and bending moment and shear force in beams and maximum displacement in X- and Z- transmissions for building with floor diaphragm for regular 24 floor, 6th floor cut up to 24th floor, 12th floor cut up to 24th floor, and 18th floor cut up to 24th floor elevation.

Seismic Analysis for the Delhi city (Zone IV) of the Hexagonal Building is discussed under Table 5.2. The table gives the maximum and minimum axial force in columns and bending moment and shear force in beams and maximum displacement in X- and Z- transmissions for building with floor diaphragm for regular 24 floor, 6th floor cut up to 24th floor, 12th floor cut up to 24th floor, and 18th floor cut up to 24th floor elevation.

Seismic Analysis for the Delhi city (Zone IV) of the Octagonal Building is discussed under Table 5.3. The table gives the maximum and minimum axial force in columns and bending moment and shear force in beams and maximum displacement in X- and Z- transmissions for building with floor diaphragm for regular 24 floor, 6th floor cut up to 24th floor, 12th floor cut up to 24th floor, and 18th floor cut up to 24th floor elevation.

Square			**ZONE IV**			
			Whole	**6th Floor**	**12th Floor**	**18th Floor**
Axial Force	**(Fx) kN**	**Max**	81.198 (38) [1.5(DL+LL+WL-ve)]	108.472 (38) [1.5(DL+LL+WL-ve)]	97.658 (38) [1.5(DL+LL+WL-ve)]	88.044 (38) [1.5(DL+LL+WL-ve)]
		Min	-81.199 (67) [1.5(DL+LL+WL +ve)]	-100.676 (38) [1.5(DL+LL+WL +ve)]	-95.908 (41) [1.5(DL+LL+WL +ve)]	-87.863 (41) [1.5(DL+LL+WL +ve)]
Shear Force	**(Fy) kN**	**Max**	6724.683 (37) [1.5(DL+LL+WL-ve)]	7068.464 (72) [1.5(DL+LL+WL +ve)]	6763.062 (72) [1.5(DL+LL+WL +ve)]	6725.776 (72) [1.5(DL+LL+WL +ve)]
		Min	-1668.517 (37) [1.0(WL +ve)]	-1751.078 (72) [1.0(WL -ve)]	-1520.762 (72) [1.0(WL -ve)]	-1533.758 (72) [1.0(WL -ve)]
Bending Moment	**(Fz) kN**	**Max**	81.198 (43) [1.5(DL+LL+WL-ve)]	69.738 (48) [1.5(DL+LL+WL-ve)]	73.343 (48) [1.5(DL+LL+WL-ve)]	77.435 (48) [1.5(DL+LL+WL-ve)]
		Min	-81.199 (71) [1.5(DL+LL+WL +ve)]	-69.746 (66) [1.5(DL+LL+WL +ve)]	-73.35 (66) [1.5(DL+LL+WL +ve)]	-77.441 (66) [1.5(DL+LL+WL +ve)]
Displacement	**X (mm)**	**Max**	158.997 (43) [1.5(DL+LL+WL-ve)]	136.159 (48) [1.5(DL+LL+WL-ve)]	149.673 (48) [1.5(DL+LL+WL-ve)]	151.243 (48) [1.5(DL+LL+WL-ve)]
	Z (mm)	**Max**	158.998 (67) [1.5(DL+LL+WL +ve)]	199.644 (38) [1.5(DL+LL+WL +ve)]	205.14 (41) [1.5(DL+LL+WL +ve)]	172.993 (41) [1.5(DL+LL+WL +ve)]

Table 5.1 Wind Analysis of Square Building Frame for Zone IV

Hexagon			ZONE IV			
			Whole	**6th Floor**	**12th Floor**	**18th Floor**
Axial Force	**(Fx) kN**	**Max**	173.462 (24) [1.5(DL+LL+WL-ve)]	212.587 (24) [1.5(DL+LL+WL-ve)]	189.457 (24) [1.5(DL+LL+WL-ve)]	174.783 (24) [1.5(DL+LL+WL-ve)]
		Min	-173.149 (24) [1.5(DL+LL+WL +ve)]	-207.685 (24) [1.5(DL+LL+WL +ve)]	-187.947 (24) [1.5(DL+LL+WL +ve)]	-173.149 (24) [1.5(DL+LL+WL +ve)]
Shear Force	**(Fy) kN**	**Max**	9431.682 (20) [1.5(DL+LL+WL +ve)]	9539.643 (20) [1.5(DL+LL+WL +ve)]	9745.737 (20) [1.5(DL+LL+WL +ve)]	9431.682 (20) [1.5(DL+LL+WL +ve)]
		Min	-2355.424 (21) [1.0(WL-ve)]	-3155.184 (20) [1.0(WL-ve)]	-2501.933 (20) [1.0(WL-ve)]	-2355.424 (21) [1.0(WL-ve)]
Bending Moment	**(Fz) kN**	**Max**	192.679 (27) [1.5(DL+LL+WL-ve)]	162.434 (25) [1.5(DL+LL+WL-ve)]	178.078 (27) [1.5(DL+LL+WL-ve)]	192.679 (27) [1.5(DL+LL+WL-ve)]
		Min	-192.931 (27) [1.5(DL+LL+WL +ve)]	-163.16 (25) [1.5(DL+LL+WL +ve)]	-179.264 (27) [1.5(DL+LL+WL +ve)]	-192.931 (27) [1.5(DL+LL+WL +ve)]
Displacement	**X (mm)**	**Max**	358.541 (27) [1.5(DL+LL+WL-ve)]	298.453 (25) [1.5(DL+LL+WL-ve)]	329.285 (27) [1.5(DL+LL+WL-ve)]	358.541 (27) [1.5(DL+LL+WL-ve)]
	Z (mm)	**Max**	347.773 (24) [1.5(DL+LL+WL +ve)]	418.243 (24) [1.5(DL+LL+WL +ve)]	378.716 (24) [1.5(DL+LL+WL +ve)]	347.773 (24) [1.5(DL+LL+WL +ve)]

Table 5.2 Wind Analysis of Hexagon Building Frame for Zone IV

Octagon al			**ZONE IV**			
			Whole	**6th Floor**	**12th Floor**	**18th Floor**
Axial Force	**(Fx) kN**	**Max**	244.592 (25) [1.5(DL+LL+WL-ve)]	266.167 (24) [1.5(DL+LL+WL-ve)]	253.894 (21) [1.5(DL+LL+WL-ve)]	244.687 (25) [1.5(DL+LL+WL-ve)]
		Min	-244.594 (23) [1.5(DL+LL+WL +ve)]	-267.54 (24) [1.5(DL+LL+WL +ve)]	-252.829 (24) [1.5(DL+LL+WL +ve)]	-245.163 (23) [1.5(DL+LL+WL +ve)]
Shear Force	**(Fy) kN**	**Max**	14341.924 (19) [1.5(DL+LL+WL-ve)]	14821.703 (20) [1.5(DL+LL+WL-ve)]	13652.769 (20) [1.5(DL+LL+WL-ve)]	13650.622 (19) [1.5(DL+LL+WL-ve)]
		Min	-3644.036 (19) [1.0(WL +ve)]	-4141.106 (20) [1.0(WL +ve)]	-3267.267 (20) [1.0(WL +ve)]	-3247.495 (19) [1.0(WL +ve)]
Bending Moment	**(Fz) kN**	**Max**	243.866 (22) [1.5(DL+LL+WL-ve)]	171.03 (21) [1.5(DL+LL+WL-ve)]	185.564 (21) [1.5(DL+LL+WL-ve)]	206.843 (22) [1.5(DL+LL+WL-ve)]
		Min	-243.868 (24) [1.5(DL+LL+WL +ve)]	-183.76 (21) [1.5(DL+LL+WL +ve)]	-199.169 (21) [1.5(DL+LL+WL +ve)]	-215.046 (21) [1.5(DL+LL+WL +ve)]
Displacement	**X (mm)**	**Max**	474.295 (22) [1.5(DL+LL+WL-ve)]	341.749 (20) [1.5(DL+LL+WL-ve)]	371.906 (21) [1.5(DL+LL+WL-ve)]	409.195 (25) [1.5(DL+LL+WL-ve)]
	Z (mm)	**Max**	475.153 (23) [1.5(DL+LL+WL +ve)]	528.866 (24) [1.5(DL+LL+WL +ve)]	503.377 (24) [1.5(DL+LL+WL +ve)]	477.378 (24) [1.5(DL+LL+WL +ve)]

Table 5.3 Wind Analysis of Octagonal Building Frame for zone IV

5.CONCLUSIONS

The effect of Seismic & Wind load on building having different geometrical plans such as square, pentagonal and hexagonal is carried out in the present study. Also, the effect of same on the above buildings with different elevations floors that are 6 floors, 12 floors, 18 floors and 24 floors are investigated. The buildings are analysed for seismic zone IV as per IS 1893-2002 for Delhi City, India and for one wind zone (zone II) as per IS 875-1987. In this way total 12 buildings are analysed with 22 load combinations. The various parameters such as maximum axial forces, bending moment and shear force in beams, seismic forces, wind forces and floor displacements on buildings are studied. The following are the conclusions made from the present study

1. Under this study, Square shaped Building is safest in comparative to Hexagonal and Octagonal for Axial Forces, as it has minimum effect.
2. Similarly, Square shaped Building is safest in comparative to Hexagonal and Octagonal for Shear Force, as it has minimum effect.
3. Also, Square shaped Building is safest in comparative to Hexagonal and Octagonal for Bending Moment, as it has minimum effect.
4. Square shaped Building is safest in comparative to Hexagonal and Octagonal for Deflection in X Direction, as it has minimum effect.
5. Square shaped Building is safest in comparative to Hexagonal and Octagonal for Deflection in Z Direction, as it has minimum effect.
6. Thus, The Square Building Shape is more efficient for reducing moment, shear force, axial force and displacement than Hexagon and Octagon Building.
7. Cut at higher level i.e., with less height of cut or not cut is safer and more durable for any shape of building.

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