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Comparative Structural Analysis of Tall Building having Different Geometrical Plan using Floor Diaphragm

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***Abstract:** In this study, comparative structural analyzes of three-dimensional (3-D) G + 20 high-rise with and without rigid floor aperture are considered. The three different construction plans are considered hexagonal, pentagonal and square. The buildings are also considered with different height levels that are 5 floors, 10 floors, 15 floors and 20 floors. The building is analyzed for four different ones Indian seismic zones (zone II, III, IV and V) according to IS 1893-2002. A total of 96 buildings are analyzed with 27 load combinations. The buildings are critically analyzed to quantify the effects of different parameters for maximum axial forces, the bending moment and the shear force in beams, seismic forces, wind forces and displacements of the floor. The results show that the use of a stiff diaphragm is more efficient in reducing above parameters in buildings for lateral forces. Rigid membrane concept is reasonable to build square in plan instead of pentagonal or hexagonal building plan.*
***Keywords:** Bending moment; Displacement; Floor diaphragm, Seismic load, Wind load.*

I. INTRODUCTION

In the 21st century, the number of areas in units because of the enormous population is decreasing by the day. A few decades ago, the populations were not that big, so they stayed in a horizontal system (because of the large available area per person). However, today people prefer a vertical system (high-rise due to scarcity of surface area). In high buildings, it is more about all the forces that affect a building. For external forces acting on the building, the beam, column and reinforcement must be good enough effectively counteract these forces and the ground must be good enough to successfully transfer the load to the foundation. For a loose soil, a deep foundation (pool) is preferred.

Earthquake is reliably a risk to human progress from the day its presence destroys human lives, property and man-made structures. The earthquake that faced in our neighbouring country Nepal has once again shown the fury of nature, which in 2015 has destroyed the nation and its relatives so monstrously. It is such an unpredictable disaster that it is extremely fundamental to survive for the quality of structures against seismic forces. Subsequently, there is ongoing research around the world, revolving around the improvement of new and better methods that can be use in structures for better seismic performance. It is clear that structures that are plan with special methods to resist seismic movements have much higher development costs than typical structures, but it is essential for protection against disturbances under seismic forces.

Earthquakes cause random ground movements, in every direction coming from the epicenter. Vertical movements of the ground are unusual, but an earthquake constantly accompanied by horizontal shaking of the ground. The ground vibrations cause the structures lying on the ground to vibrate, resulting in inertial forces in the structure. As the earthquake changes direction, it can reverse stresses in the structural components, that is, the compression can change into stress and the stress can change into compression. Earthquakes can generate high voltages, which can cause the yield of structures and substantial deformations, making the structure not functional and unusable. There may be a large descent into the building, making the building dangerous for the people to live there (Taranath, 1988).

Reinforced concrete frames are the most widely used building methods in India, with increasing amounts of high structures that mean the scene. There are number of important Indian cities that fall into highly active seismic zones. Such tall building structures, which have developed especially in highly active seismic zones, must be analyzed and designed for ductility and must be planned with an additional lateral stiffening system to improve their seismic performance and reduce damage.

Wind load is also one of the important design loads for civil engineering constructions. For long spans, high buildings and high towers or mast constructions, wind load can considered a critical load (Chopra, 1995). That is why knowledge of the dynamic properties of an important wind load structure becomes a requirement when designing engineers. In the current research project on

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tall buildings, the study of wind-driven requirements has categorized as crosswind and crosswind responses. These requirements has caused by different mechanisms. Moving along the wind has induced due to the effects of turbulence impact, while the perpendicular component has related to the effects of storm. On the other hand, the effect of wind load on high structures has not only distributed over the wider surface, but also has a higher intensity. In all international codes and standards, wind and earthquake loads never apply simultaneously to the structure.

II. METHODOLOGY

The seismic and wind analysis of buildings is carried out using STAADPRO software. This study includes a comparative study of the behavior of tall buildings, taking into account different geometrical configurations and aperture constraints in earthquakes and wind forces. A comparison of results in terms of minimum and maximum moments in columns and beams, lateral forces and displacements has been made. STAAD-PRO software is used for performing seismic and wind analyzes. The calculation for a high-rise building takes more time manually and human error can occur, so using computer software makes it easy. It gives more accurate and precise results than the manual techniques. STAAD-PRO can solve a typical problem such as static analysis and dynamic analysis. The following steps are involved in analyzes using STAAD-PRO software

A. Prepare the input file

First of all the geometry, the materials, cross sections, the support conditions of building are modelled.

B. Analyze The Input File

All the input data are checked and the analysis method is given as input for analyzing the building, so that a stable structure, else it will show error.

C. Results

Reading the result is carried out in post processing mode.

Steps Adopted In Study For Analysis

1) *STEP 1:* To select the building geometry and number of storeys. In the present study 3 type of geometry, plans has selected:
   a) Square building frame Fig. 1
   b) Pentagonal building frame Fig. 2.
   c) Hexagonal building frame Fig 3

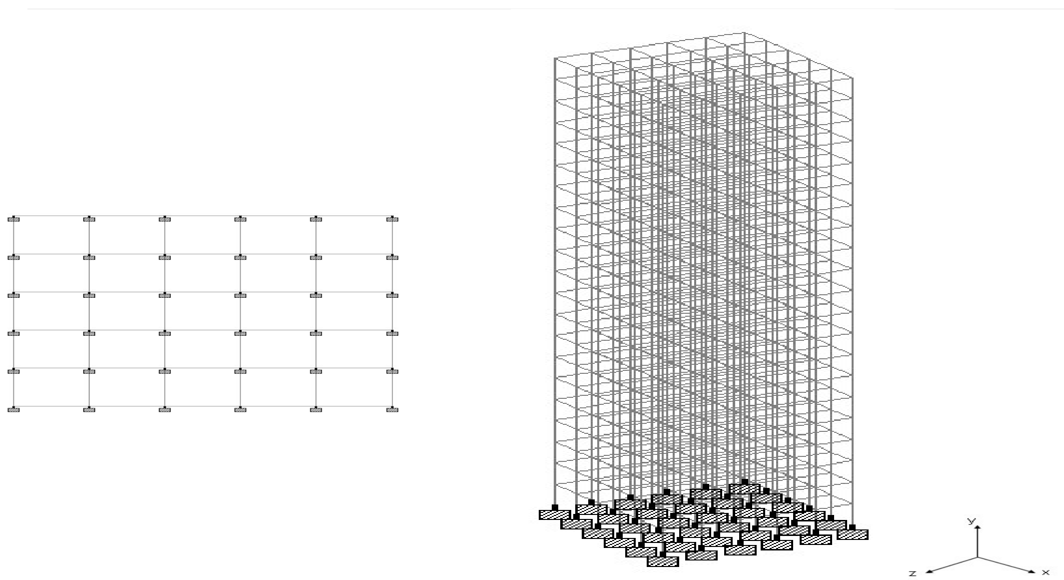

Fig 4.1 Plan And Elevation Of Square Of Square Building

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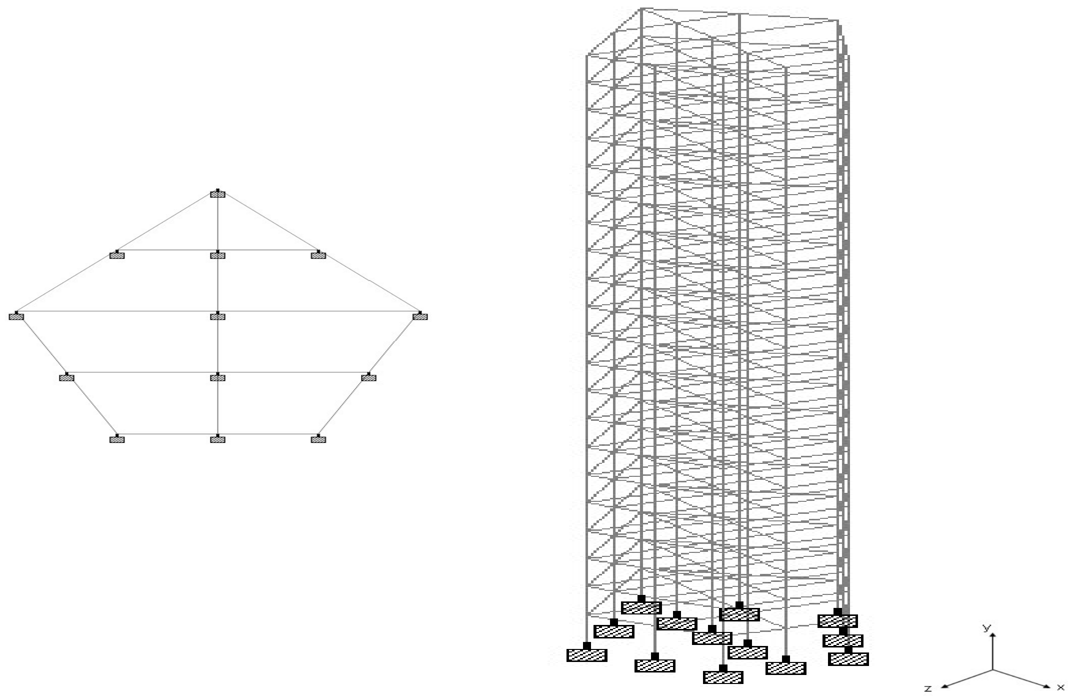

Fig 4.2 Plan and elevation of a pentagonal building

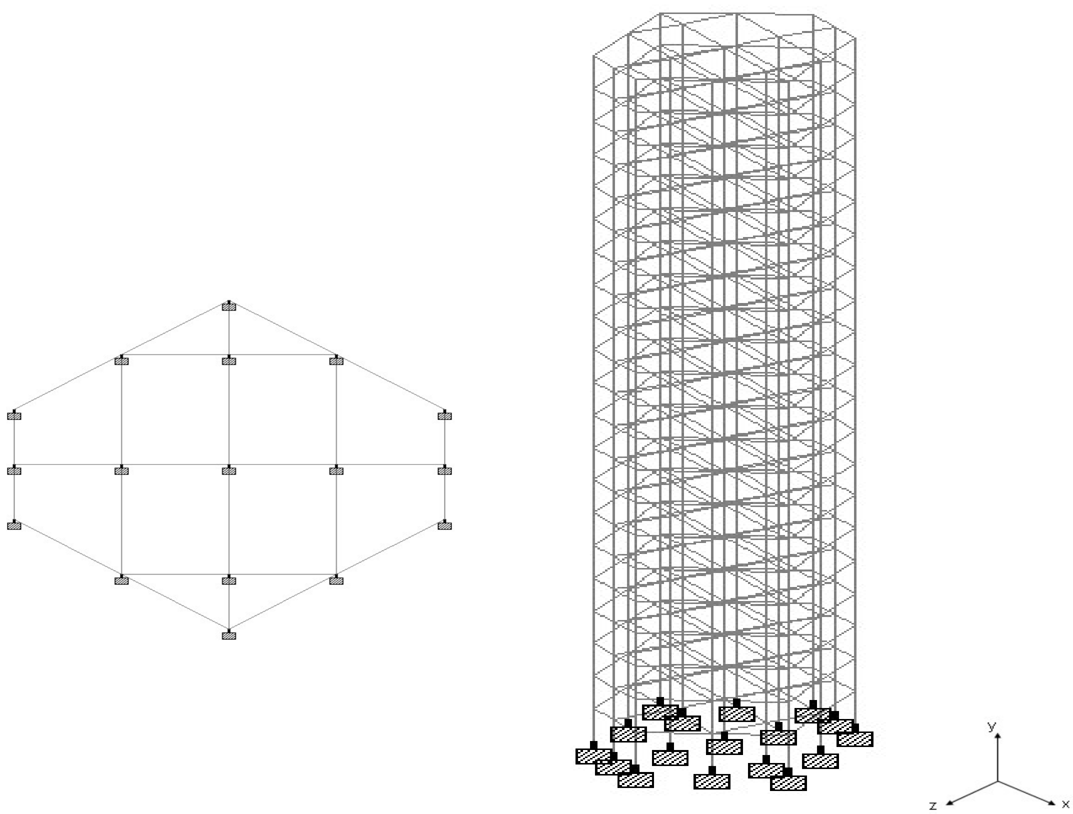

Fig 4.3 Plan and elevation of a hexagonal building

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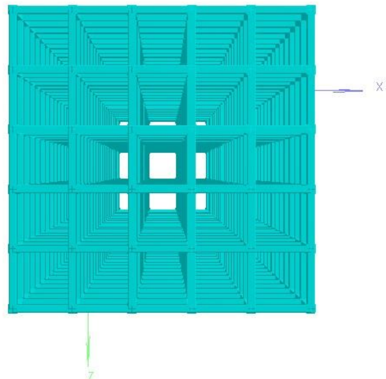
Type 1. Regular building frame of 20 floors as shown in Fig.4.4 for square building , Fig 4.8 for pentagonal building and 4.12 for hexgonal building.

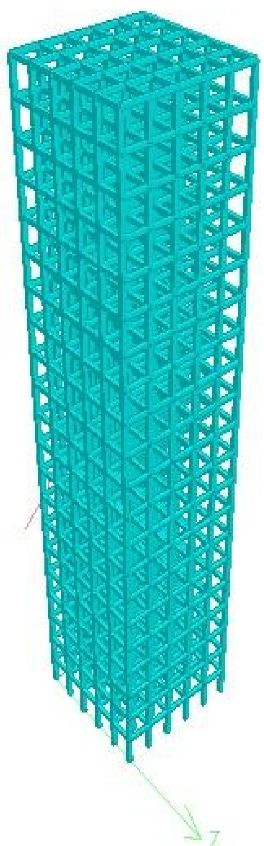
Type 2. Regular building frame having section cut from 5th floor up to 20th floor as shown in Fig 4.5 for square building, Fig 4.9 for pentagonal building and 4.13 for hexgonal building.

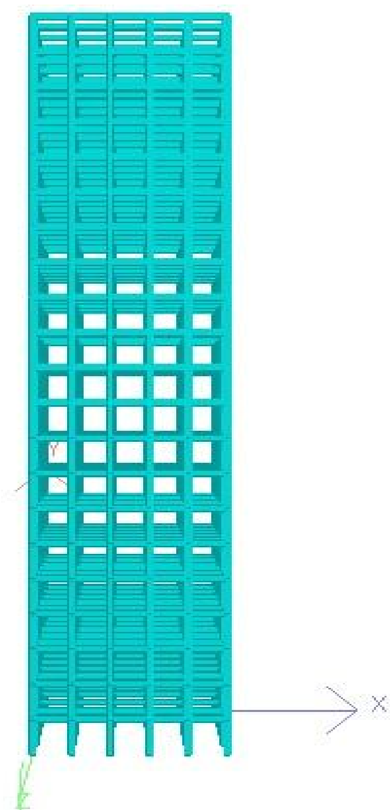
Type 3. Regular building frame having section cut from 10th floor up to 20th floor as shown in Fig 4.6 for square building, Fig 4.10 for pentagonal building and 4.14 for hexgonal building.

Type 4. Regular building frame having section cut from 15th floor up to 20th floor as shown in Fig 4.7 for square building, Fig 4.11 for pentagonal building and 4.15 for hexagonal building



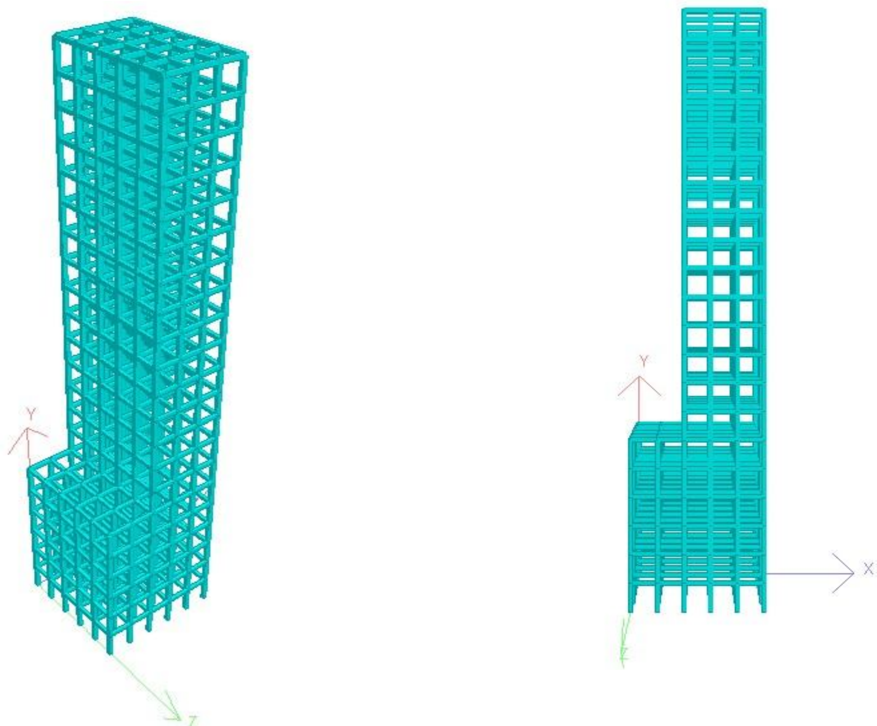
Plan





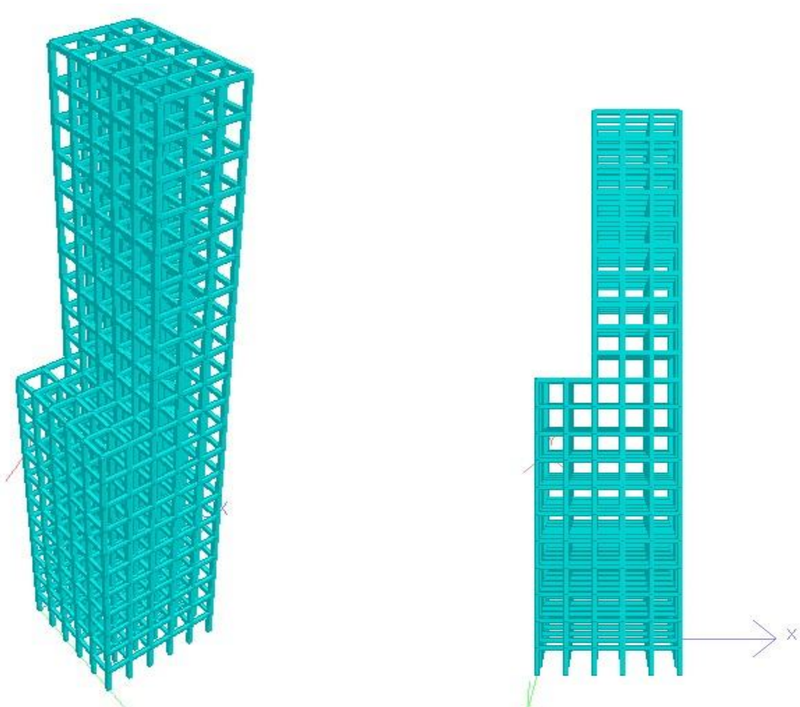
Isometric view Elevation

Fig 4. Plan, elevation and isometric views of 20 floor square building



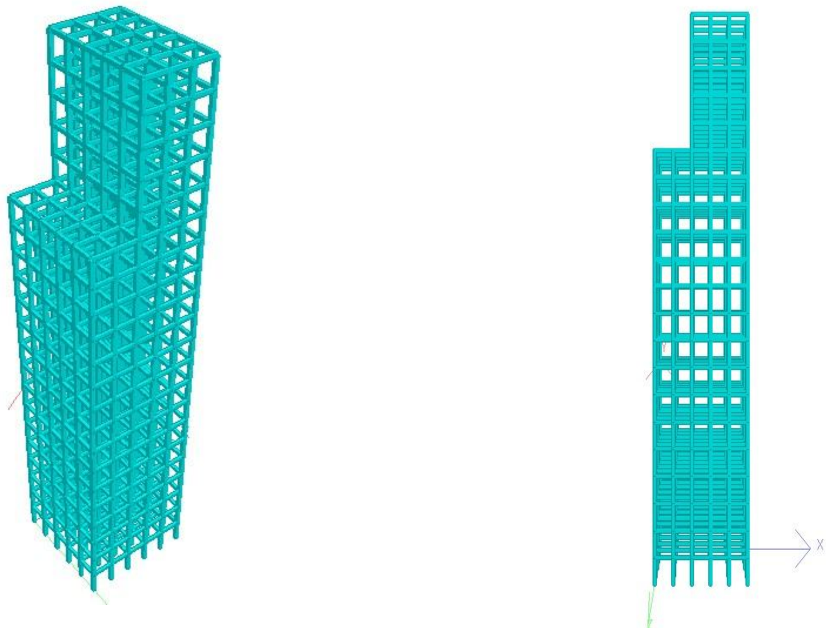
Isometric view Elevation

Fig 5 Elevation and isometric views of square building having section cut from 5th floor up to 20th floor



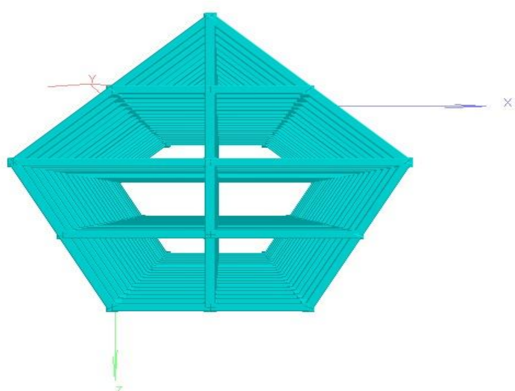
Isometric view Elevation

Fig 6 Elevation and isometric views of square building having section cut from 10th floor up to 20th floor



Isometric view Elevation

Fig 7 Elevation and isometric views of square building having section cut from 15th floor up to 20th floor



Plan

Isometric view Elevation

2) *STEP 2.* Selection of diaphragm models

In this study, 2 types of building models are taken.

a) Building with rigid floor diaphragm.

b) Building without rigid floor diaphragm.

3) *STEP 3.* Selection of seismic zones and wind zones

The building with and without rigid diaphragms are analysed for all 4 different seismic zones (II, III, IV, V) as shown in Fig. 4.4

In this study the structures are analyzed based on wind speed 33 m / s (zone II) according to IS 875 (part 3) -1987 as shown in FIG. 4.6. Basic wind speed map of India, applicable at 10 m altitude above average ground level for different zones of the country. The base speed of the wind is based on the peak fly speed, averaged over a short time interval of about 3 seconds, and corresponds to average heights above ground level on open ground (category 2). The basic speeds in figure 4.5 have been worked out for a return period of 50 years.

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4) *STEP 4.* Formation of load combination

The Table 4.1 shows the load combinations considered for seismic and wind analyses of the building. In all 27 combinations are considered in the present study. The terms DL, IL, WL and EL stand for the response quantities due to dead load, imposed load, designed wind load and designed earthquake load, respectively

In the limit state design of reinforced concrete buildings, the following load combinations

Table 1: Different load combinations for analysis

Load case no.	Load case detail
1.	EQ/W IN X DIR.
2.	EQ/W IN Z DIR.
3.	DEAD LOAD
4.	LIVE LOAD
5.	1.5 (DL + LL)
6.	1.5 (DL + EQX/WX)
7.	1.5 (DL – EQX/WX)
8.	1.5 (DL + EQZ/WZ)
9.	1.5 (DL – EQZ/WZ)
10.	1.2 (DL + LL + EQX/WX)
11.	1.2 (DL + LL – EQX/WX)
12.	1.2 (DL + LL + EQZ/WZ)
13.	1.2 (DL + LL – EQZ/WZ)
14.	0.9DL + 1.5EQX/WX
15.	0.9DL - 1.5EQX/WX
16.	0.9DL + 1.5EQZ/WZ
17.	0.9DL - 1.5EQZ/WZ
18.	1.0 (DL + LL)
19.	1.0 (DL + EQX/WX)
20.	1.0 (DL – EQX/WX)
21.	1.0 (DL + EQZ/WZ)
22.	1.0 (DL – EQZ/WZ)
23.	0.8 (DL + LL + EQX/WX)
24.	0.8 (DL + LL – EQX/WX)
25.	0.8 (DL + LL + EQZ/WZ)
26.	0.8 (DL + LL – EQZ/WZ)
27.	LOAD FOR CHECK

5) *STEP 5.*Support condition are considered fixed at the base of each column.
6) *STEP 6* In this study there are 3 different geometry in plan and 4 different geometry in elevation, 2 diaphragm models (with and without) and 4 seismic zones and one wind zone. In all 120 buildings are analysed in the present study.
7) *STEP 7* Comparative analyses for both seismic and wind lateral loads to quantify the effects of various parameters in terms of maximum and minimum bending moments, 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 and without rigid diaphragm.

III. STRUCTURAL MODELLING AND INPUT DATA

A. Modelling Of Buildings

Buildings with the following three geometrical configurations are considered for analysis and Table 4.2 gives the number of beams and columns for different buildings:

1) *CASE-1:* Square building frame 15 m × 15 m in plan area and 20 storeys.
2) *CASE-2:* Pentagonal building frame inscribed in 15 m × 15 m plan area and 20 storeys.
3) *CASE-3:* Hexagonal building frame inscribed in 15 m × 15 m plan area and 20 storeys.

Table 4.2: Number of beams and columns

Members	Square building	Pentagonal building	Hexagonal building
Columns	756	273	357
Beams	1260	420	588

The following two types of diaphragm conditions have been considered for analysis-
Type-A : Model without diaphragm constraint.
Type-B : Model with rigid diaphragm constraint.

B. Material and Geometrical Properties

Following material properties have been considered in the modelling -
Density of RCC: 25 kN/m^3
Density of masonry: 20 kN/m^3
Young's modulus of concrete: 2.17185×10^{16} N/m^2
Poisson ratio: 0.17
The foundation depth is considered at 3.5 m below ground level and the typical storey height is 3.5 m. The column size is 450 mm × 450 mm, and the beam size is 350 mm × 500 mm.

C. Different Loading conditions

Following loading are conducted for analysis - 1) Dead loads:

1) Self weight of slab considering 150 mm thick. Slab = 0.15 × 25 = 3.75 kN/m^2
2) Floor finish load = 1 kN/m^2
3) Masonry wall load = 0.20 × 2.55 × 20 = 10.2 kN/m 2) Live loads:

Live load on typical floors = 2 kN/m^2 3) Earthquake Loads:
All the building frames are analyzed for 4 seismic zones
The earthquake loads are derived for following seismic parameters as per IS: 1893 (2002)

a) Earthquake zone-II, III, IV, V
b) Response reduction factor: 5
c) Importance factor: 1
d) Damping: 5 %
e) Soil Type: medium soil

IV. CONCLUSION

The effect of rigid diaphragm on 3D RC building with different geometrical drawings such as square, pentagonal and hexagonal has performed in the current study. The effect of stiff diaphragm on the aforementioned buildings with various raised floors that are 5 storeys, 10 storeys, 15 storeys and 20 storeys has also been investigated. The building is analyzed for four different seismic zones in India (zone II, III, IV and V) according to IS 1893-2002 and for one wind zone (zone II) according to IS 875-1987. In this way, buildings are analyzed with 27 load combinations. The various parameters such as maximum axial forces, bending moment and shear force in beams, seismic forces, wind forces and displacements of the floor on buildings with and without rigid diaphragms are studied. The conclusions from the current study has given below

A. The rigid diaphragm is more efficient in reducing moment, shear force, axial force and displacement than without diaphragms.
B. Rigid diaphragm concept is reasonable for building square in plan rather than pentagonal or hexagonal building plan.
C. In reality, the diaphragm can neither be perfectly rigid nor be perfectly flexible. However, in order to simplify the analysis with reasonable assumptions, the semi rigid diaphragm can be adapted as to a diaphragm's rigidity or flexibility.

V. FUTURE WORK

The following are the future scope of the present work

A. The study can carried out for different types of diaphragm.
B. Instead of using concrete diaphragm, wooden diaphragm can used for analysis.
C. Experimental work can carried of the present study to check the practical application floor diaphragm.

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