RESPONSE OF BUILDINGS WITH AND WITHOUT SETBACKS SUBJECTED TO EARTHQUAKE FORCES

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Abstract - *Many buildings lack the required setbacks as per the required norms provided by the authorities. This would be a concern if earthquake occurs. To avoid great Earthquake disaster with its severe consequences, special considerations must be given. In the present study, an attempt has been made to study the structural behavior of 3-D, 3X4 bay ordinary moment resisting RC frames with and without setbacks on all the sides of the building. The detailed investigations are carried out for seismic zone V in India as per IS 1893 (part 1):2002, considering primary loads (dead, live, wall load, floor finish and seismic) and load combinations. A 5 story and a 10-story building, both (with and without setbacks) are subjected to Response Spectrum Method (RSM). The models considered are bare frame. The result for story displacement is analyzed and tabulated for investigation.*

***Key Words*: Setback, Earthquake, Tall Buildings, Response Spectrum analysis, RCC Buildings, Modal Analysis.**

1.INTRODUCTION

A distance from a curb, property line, or structure within which a building is prohibited is known as a setback. Setbacks are building restrictions imposed on property owners. Local governments create setbacks through ordinances and Codes, usually for reasons of public policy such as safety, privacy, and environmental protection. Due to heavy cost of land in urban areas, the standard setbacks are deviated and buildings are constructed without any or less setbacks. This results in ponding of the building in the event of an earthquake. After obtaining approval of the plan from authorities, it is observed that many of the builders do no follow the setbacks are prescribed by the authorities.

1.1 OBJECTIVES

The objectives of this study are as follows
1. To obtain the response of buildings subjected to earthquake forces which are constructed as per existing by laws.
2. To obtain the response of buildings subjected to earthquake forces which are constructed by violating bylaws.
3. To compare the 1 & 2

1.2 PRESENT STUDY

To avoid great earthquake disaster with its severe consequences, special consideration must be given. Engineers have the important responsibility to ensure that the new construction is earthquake resistant and also, they must solve the problem posed by existing weak structures. A problem that an engineer must share with the seismologist/geologist is that of prediction of future occurrence of earthquake, which is not possible in current scenario. Hence, constructing the buildings by taking precautions and following the norms should be adopted. In this research, an effort would be made to analyze the effect of building constructed as per the standard setbacks and the one which are deviated. ETABS is used to create the mathematical models of the buildings considered. Loads considered are taken in accordance with the IS-875(Part1, Part2), IS-1893(2002) code and combinations are according to IS-875(Part5).

Table 1: All around setbacks for building above 11.5m height.

Sl no.	Height of the buildings (m)	Front, rear and side setbacks (Min. in m)
1	Above 11.5 upto 15	5
2	Above 15 upto 18	6
3	Above 18 upto 21	7
4	Above 21 upto 24	8
5	Above 24 upto 27	9
6	Above 27 upto 30	10
7	Above 30 up to 35	11
8	Above 35 upto 40	12
9	Above 40 upto 45	13
10	Above 45 upto 50	14
11	Above 50	16

2. RESPONSE SPECTRUM ANALYSIS

This method is applicable to a building which are not regular structures and to analysis of the dynamic response of structures, which are asymmetrical or have areas of discontinuity or irregularity in their linear range of behaviour.

2.1 STRUCTURAL MODEL

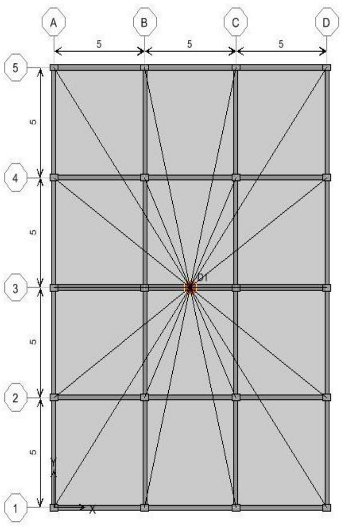


Fig - 2.2 a: Plan of 5-story building

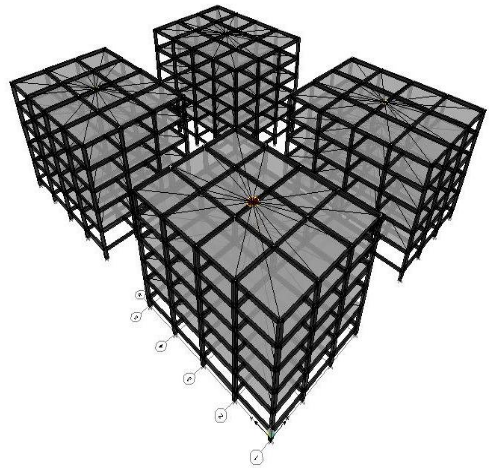


Fig-2.2 b: 3D view of 5-story buildings (with setbacks)

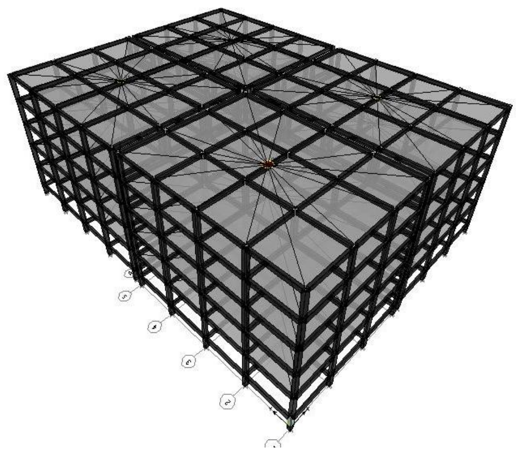


Fig-2.2 c: 3D view of 5-story buildings (without setbacks)

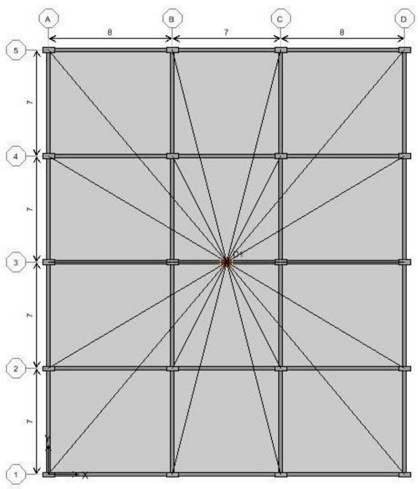


Fig – 2.2 d: Plan of 10-story building

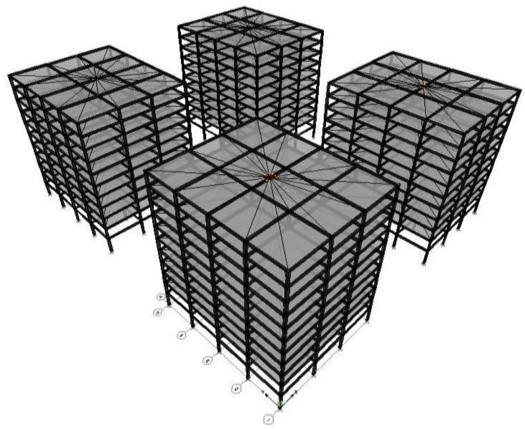


Fig – 2.2 e 3D view of 10-story buildings (with setbacks)

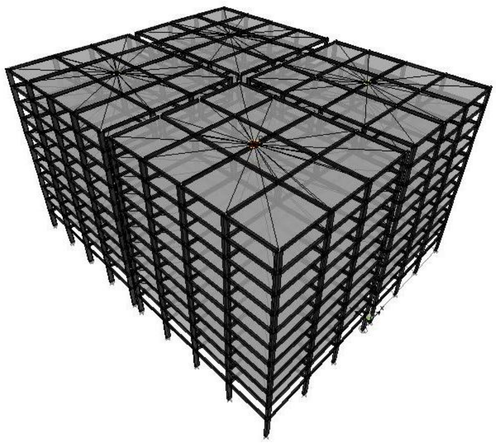


Fig - 2.2 f: 3D view of the buildings (without setbacks)

2.2: INPUT DATA

Table 2.1 : Description of the 5 Storey building.

Sl no.	PARTICULARS	VALUE
	DIMENSIONS	
1	Plan dimension	15m x 20m
2	Total height of buildings	15m
3	Height of each story	3m
	STRUCTURAL MEMBERS	
1	Size of Beams	230mm x 450mm
2	Size of Columns	300mm x 450mm
3	RCC Slab	150mm
4	Masonry Walls	230mm
5	Supports	Fixed
	OTHER CONSIDERATIONS	
1	Density of RCC	25kN/ m^3
2	Density of reinforcing steel	7850 kg/ m^3
3	Grade of concrete	M25
4	Grade of reinforcing steel	Fe500
5	Density of masonry	22kN/ m^3

Table 2.2 : Description of the 10 Storey building.

Sl no.	PARTICULARS	VALUE
	DIMENSIONS	
1	Plan dimension	23m x 28m
2	Total height of buildings	30m
3	Height of each story	3m
	STRUCTURAL MEMBERS	
1	Size of Beams	230mm x 450mm
2	Size of Columns	300mm x 750mm
3	RCC Slab	150mm
4	Masonry Walls	230mm
5	Supports	Fixed
	OTHER CONSIDERATIONS	
1	Density of RCC	25kN/ m^3
2	Density of reinforcing steel	7850 kg/ m^3
3	Grade of concrete	M40
4	Grade of reinforcing steel	Fe500
5	Density of masonry	22kN/ m^3

2.3 STATIC LOAD ASSIGNMENT

This section provides an overview of building loads and their effect on the structural response of typical framed homes. Depending on the orientation of the structural action or forces the loads induces, building loads can be classified as vertical and horizontal (i.e., lateral) loads. Classifications of loads are described in the following sections. It is to be noted that all the loadings were taken into consideration as per the standard Indian codes of practice. Classifications of loads are described in the following sections. It is to be noted that all the loadings were taken into consideration as per the standard Indian codes of practice.

Dead Load Calculations: Dead loads are the loads that do not change relatively over time such as the Beam, columns and slabs. Calculations of dead loads is done by considering member sizes and material densities ETABS assigns dead load automatically as the user assigns the property of the member during modeling.

Live Load Calculations: Live loads are those which can change over time with respect to a position, such as people or movable objects such as furniture. Live loads are variable as they depend on usage and the type of building. However, design codes can provide equivalent loads for various structures.
The load on the floor is obtained from Table 1 of IS 875 (Part 2) – 1987. The uniformly distributed load on the floor of the building is assumed to be 4.0 kN/m^2 (for assembly areas, corridors, passages, restaurants business and office buildings, retail shops etc).

Super dead loads: Below are certain materials which cannot be modeled and therefore their loads has to be input:
Following will be the loads-

- Floor finish for 55 mm screed + 10 mm thick vitrified tile flooring
  = (0.065+0.01) x 22 =1.65kN/m^2
- Wall Load=22 x 0.23 x 3 (density of the wall x thickness x height)
  = 15.18kN/m
- Parapet wall Load=22 x 0.23x 1.2= 6.072kN/m

Earth Quake Load: Earthquake forces are generated due to structure's dynamic inertial response to cyclic ground movement. Response Spectrum Method has been followed in the project.

Design horizontal acceleration coefficient Design Base Shear,

$$A_h = \frac{Z \times S_a \times I}{2 \times g \times R}$$

- Z=Seismic Zone factors

Table 2.3: Seismic Zone Factors

Seismic Zone	II	III	IV	V
Seismic Zone Factors, Z	0.1	0.16	0.24	0.36

- Soil type II- Medium soils (Assumed) for which the $\frac{S_a}{g}$= 2.5
  clause.6.4.2
- Importance Factor, I =1
  clause.7.2.3
- Response Reduction Factors, R: RC building with OMRF=3.0

Load Combinations: The load combinations is obtained from page no 13, clause 6.3.1.2. of IS 1893-2002

DCON 3= 1.2(DL+LL+ELX)

DCON 5= 1.2(DL+LL+ELY)

3. ANALYSIS AND RESULTS

In result section discussion about displacement of a building subjected to seismic load is done.

3.1 DISPLACEMENT (mm)

- Displacement is an essential parameter used for assessing the stiffness and lateral stability of tall buildings.
- Lateral displacement is caused during earthquake, which reduces stability and durability of tall buildings.
- Due to displacement of the building the occupants feel uncomfortable.

3.1.1 10 STOREY BUILDING

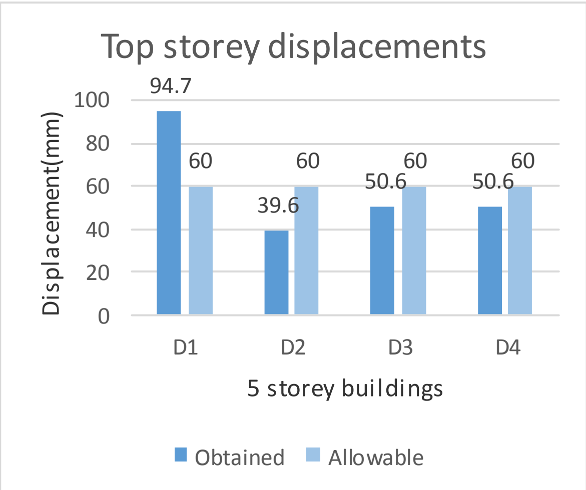
With Setbacks

Table 3.1: Displacement in x-direction

Storey	Diaphragm	Load	UX (mm)
STOREY5	D1	DCON3	94.7
STOREY5	D2	DCON3	39.6
STOREY5	D3	DCON3	50.6
STOREY5	D4	DCON3	50.6

From the above table, it can be observed that all the buildings have different displacement values in x-direction when setbacks are provided.

Fig 3.1 Top storey displacements



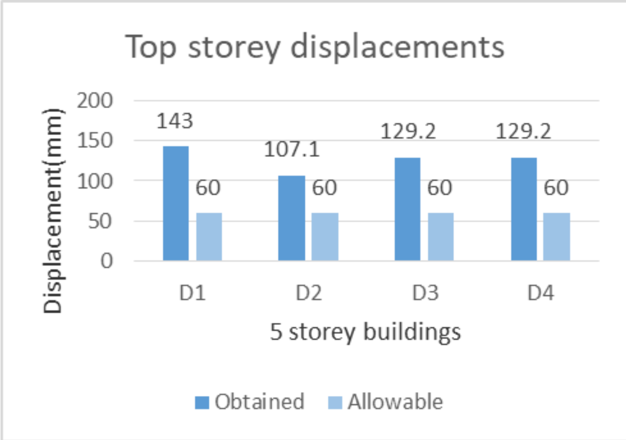
The above graph shows the obtained displacement values compared to the maximum allowable values in x-direction for the 5 storey buildings with setbacks.

Table 3.2: Displacement in y-direction

Storey	Diaphragm	Load	UY(mm)
STOREY5	D1	DCON5	143
STOREY5	D2	DCON5	107.1
STOREY5	D3	DCON5	129.2
STOREY5	D4	DCON5	129.2

From the above table, it can be observed that buildings D3 & D4 have same displacement values while the rest have different displacement values in x-direction when setbacks are provided.

Fig 3.2 Top storey displacements



The above graph shows the obtained displacement values compared to the maximum allowable values in y-direction for the 5 storey buildings with setbacks.

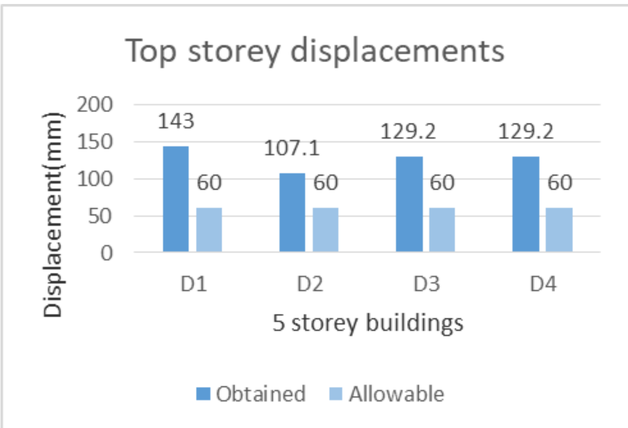
Without Setbacks

Table 4.3 Displacement in x-direction

Storey	Diaphragm	Load	UX (mm)
STOREY5	D1	DCON3	205.7
STOREY5	D2	DCON3	205.7
STOREY5	D3	DCON3	205.7
STOREY5	D4	DCON3	205.7

From the above table, it can be observed that all the 5 storey buildings have same displacement values in x-direction which is the maximum for all the buildings when setbacks are not provided.

Fig 3.3 Top storey displacements



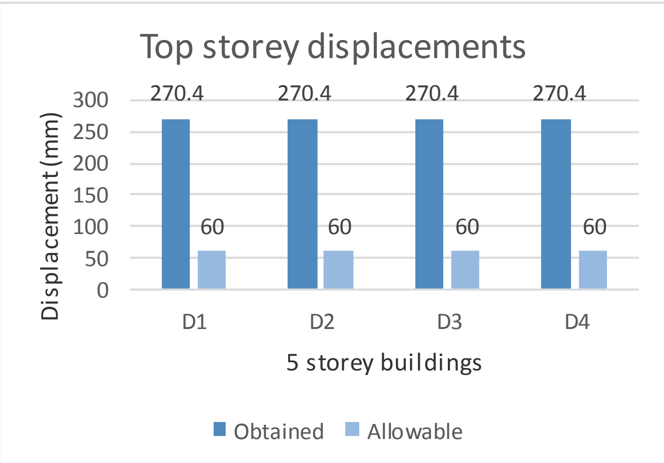
The above graph shows the obtained displacement values compared to the maximum allowable values in x-direction for the 5 storey buildings without setbacks.

Table 3.4 Displacement in y-direction

Storey	Diaphragm	Load	UY (mm)
STOREY5	D1	DCON5	270.4
STOREY5	D2	DCON5	270.4
STOREY5	D3	DCON5	270.4
STOREY5	D4	DCON5	270.4

From the above table, it can be observed that all the 5 storey buildings have same displacement values in y-direction which is the maximum for all the buildings when setbacks are not provided.

Fig 3.4 Top storey displacements



The above graph shows the obtained displacement values compared to the maximum allowable values in y-direction for the 5 storey buildings without setbacks.

3.1.2 10 STOREY BUILDING

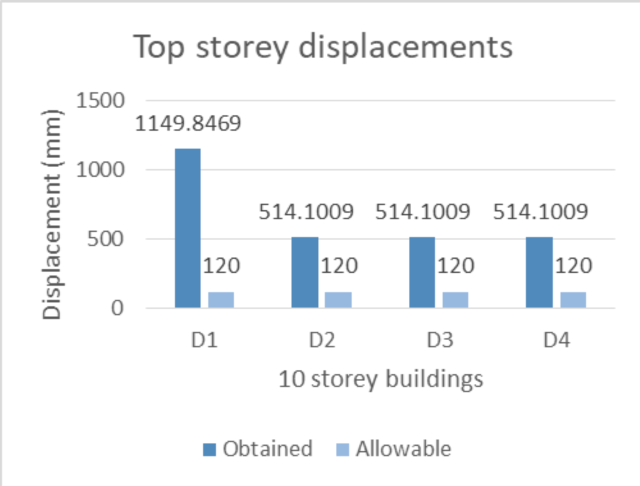
With Setbacks

Table 3.5 Displacement in x-direction

Storey	Diaphragm	Load	UX(mm)
STOREY10	D1	DCON3	1149.847
STOREY10	D2	DCON3	514.1009
STOREY10	D3	DCON3	514.1009
STOREY10	D4	DCON3	514.1009

From the above table, it can be observed that buildings D2, D3 & D4 have same displacement values while D1 has different displacement value in x-direction when setbacks are provided.

Fig 3.5 Top storey displacements



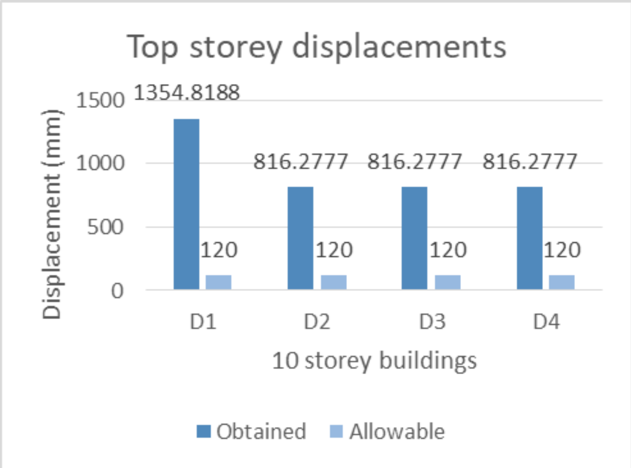
The above graph shows the obtained displacement values compared to the maximum allowable values in x-direction for the 10 storey buildings without setbacks.

Table 3.6 Displacement in y-direction

Storey	Diaphragm	Load	UY(mm)
STOREY10	D1	DCON5	1354.819
STOREY10	D2	DCON5	816.2777
STOREY10	D3	DCON5	816.2777
STOREY10	D4	DCON5	816.2777

From the above table, it can be observed that buildings D2, D3 & D4 have same displacement values while D1 has different displacement value in y-direction when setbacks are provided.

Fig 3.6 Top storey displacements



The above graph shows the obtained displacement values compared to the maximum allowable values in y-direction for the 10 storey buildings with setbacks.

Without Setbacks

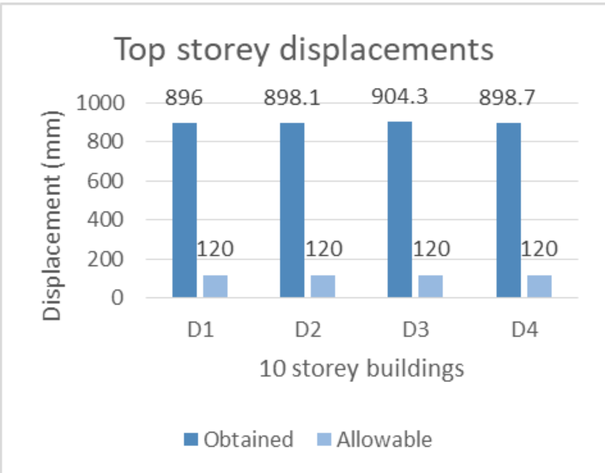
Table 3.7 Displacement in x-direction

Storey	Diaphragm	Load	UX (mm)
STOREY10	D1	DCON3	896
STOREY10	D2	DCON3	898.1
STOREY10	D3	DCON3	904.3
STOREY10	D4	DCON3	898.7

From the above table, it can be observed that all the 10 storey buildings have almost same displacement values in x-direction for all the buildings when setbacks are not provided.

Note: (The difference in values is negligible)

Fig 3.7 Top storey displacements



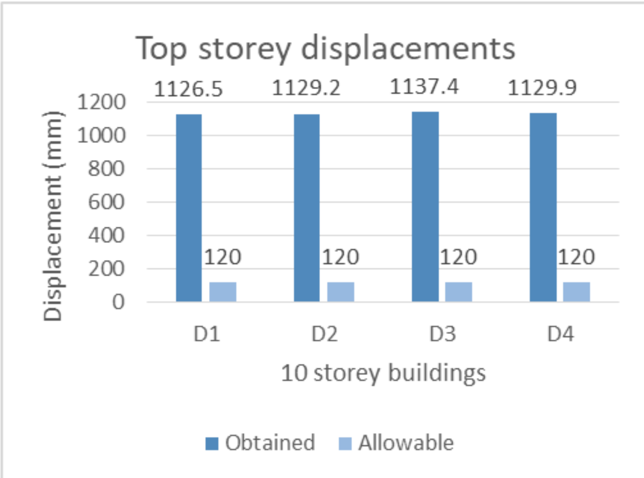
The above graph shows the obtained displacement values compared to the maximum allowable values in x-direction for the 10 storey buildings without setbacks.

Table 3.8 Displacement in y-direction

Storey	Diaphragm	Load	UY(mm)
STOREY10	D1	DCON5	1126.5
STOREY10	D2	DCON5	1129.2
STOREY10	D3	DCON5	1137.4
STOREY10	D4	DCON5	1129.9

From the above table, it can be observed that all the 10 storey buildings have almost same displacement values in y-direction for all the buildings when setbacks are not provided.

Fig 3.8 Top storey displacements

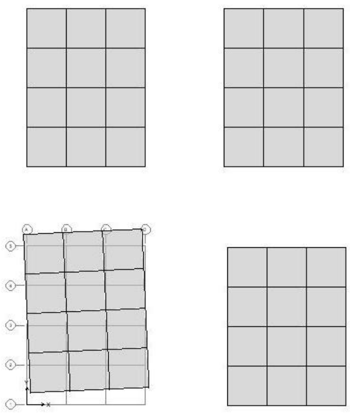


The above graph shows the obtained displacement values compared to the maximum allowable values in y-direction for the 10 storey buildings without setbacks.

3.2 TOP STOREY DEFORMATIONS

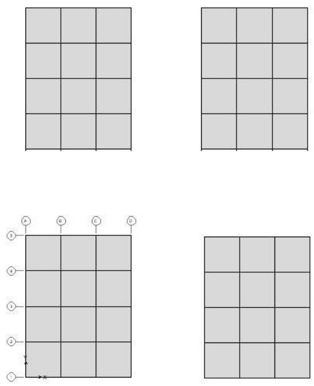
3.2.1 5 Storey buildings.

With setbacks



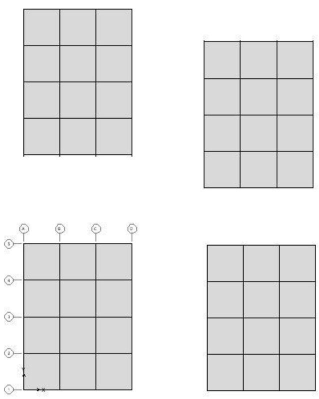
1. **(1st mode)**

D1 shows translation deformation in +y direction.



2. **(2nd mode)**

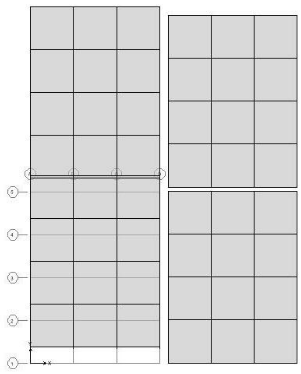
D1 regains its original position.



3. **(3rd mode)**

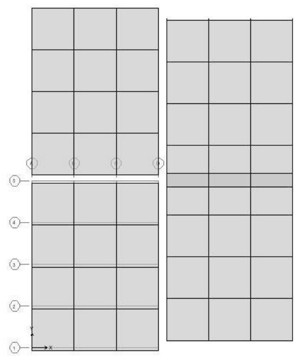
D4 displaces in +y direction.

Without Setbacks



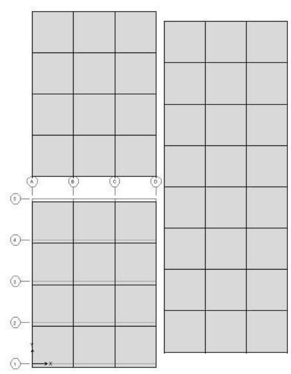
1. **(1st mode)**

D1 shows translation deformation in +x direction.



2. **(2nd mode)**

D2 & D3 shows deformation in +y & -y direction respectively.

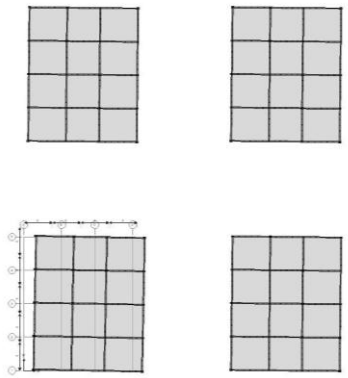


3. **(3rd mode)**

D2 & D3 shows deformation in +y & -y direction respectively.

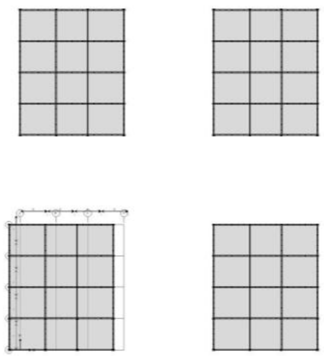
3.2.2 10 Storey buildings

With Setbacks



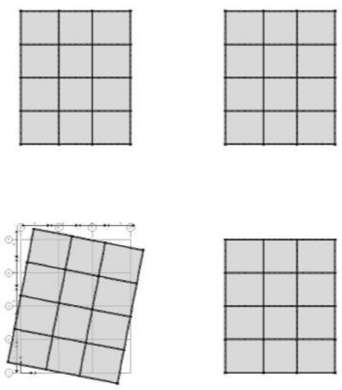
1. (1st mode)

D4 displaces in –x direction.



2. (2nd mode)

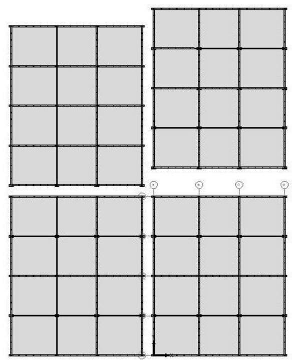
D1 displaces in –x direction.



3. (3rd mode)

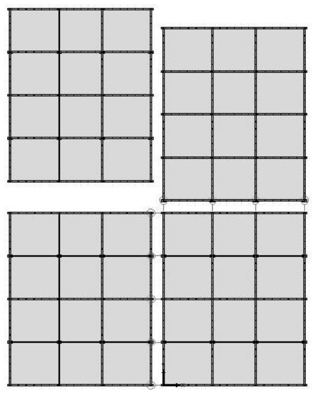
D1 shows torsional deformation in clockwise direction.

Without Setbacks



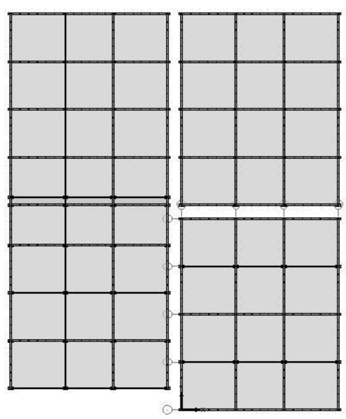
1. (1st mode)

D3 displaces in +y direction.



2. (2nd mode)

D4 displaces in +y direction.



3. (3rd mode)

D1 displaces in +y direction

3.3 DISCUSSIONS

It is observed that

- The maximum displacement occurs in the top storeys in both five and ten storeys buildings.
- The displacement values obtained for both 5 & 10 storey buildings with setbacks occurred in both x-direction and y-direction are different.
- The displacement values obtained for both 5 & 10 storey buildings without setbacks occurred in both x-direction and y-direction are almost similar.
- The maximum displacement values obtained for both 5 & 10 storey buildings with setbacks occurred in both x-direction and y-direction are much more less than that of buildings without setbacks.
- The obtained values exceeds the values permitted in IS Code.
- For 5 Storey buildings, the displacement values obtained for buildings without setbacks is 3.42 times the displacement values obtained for building with setbacks.
- For 10 Storey buildings, the displacement values obtained for buildings without setbacks is 1.34 times the displacement values obtained for building with setbacks.
- The building which are already constructed without setbacks are not safe. These buildings require strengthening. Hence Lateral Load Resisting System should be applied.

4.CONCLUSION

Altogether four models were analysed in ETABS for the seismic zone V. Of these two were modelled with setbacks and two without setbacks for the respective seismic zone. The conclusions were drawn from the project:

- All the Buildings have same deflections along x & y directions.
- There is no pounding between the buildings constructed by following the by-laws. The setbacks provided to the buildings, prevent them from collision with each other.
- There is pounding between the buildings constructed by violating the by-laws. If no proper setbacks are provided, the buildings have very high chances of colliding with each other.
- The overlapping of the buildings do not occur only because of earthquake but also due to the man made errors i.e. not providing the setbacks.

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