Analysis and Design of RC buildings by using latest IS codes for earthquake (IS 1893 Part 1: 2016) and wind (875 Part 3:2015)

Miss. Divya S. Gupta[1], Dr. P. S. Pajgade[2]

[1]P.G. Student (Structural Engineering) Civil Engineering Department, PRMIT&R, Amravati, India
[2]Head of Civil Engineering Department, PRMIT&R, Amravati, India

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Abstract - The aim of this project is to present a study results of RC building modeling by using latest IS codes of earthquake and wind (IS 1893 part 1 2016 and IS 875 part 3 2015 respectively) and comparing the results with old code of earthquake and wind i.e. (IS 1893 part 1 2002 and IS 875 part 3 1987 respectively) on an institutional building design by performing Response spectrum analysis method (Dynamic analysis method) using ETABS 19 software.

***Key Words*: Response spectrum analysis, ETABS 19 software**

1. INTRODUCTION

Wind load is one of the important design loads for civil engineering structures; it controls the structural design of the high-rise structures. Therefore knowledge of the effect of wind on high - rise structure becomes a requirement in engineering design and in academic study.

Earthquakes and cyclones are unexpected events which cannot be predicted. The only way to survive through this disaster is by taking careful considerations while planning and designing buildings in urban areas. A structure because of its height is affected by lateral forces due to wind or earthquake actions to an extent that they play an important role in the structural design. A high rise building has to resist to overturning moment and lateral deflection caused by lateral forces like earthquake and wind forces.

The Indian Standard codes for civil engineering practices are being revised by the BIS as per basic design and engineering requirements, new inventions, latest design concepts, improved materials and environmental happenings. Hence it is pertinent to spell out the major changes that are reflecting in the revised or latest codes with respect to the previous ones. The modifications, additions, eliminations and revisions in IS codes definitely reflect the modified requirements for existing structures and revisions to be admissible for designing new structures. The design and construction of all the structures must comply with the latest relevant codes. In the fitness of the context, a comparative study has been made between IS: 1893 – 2002 and 2016 (Code of Practice – Criteria for Earthquake Resistant Design of Structures), and IS: 875 – 1987 and 2015 (Code of Practice–Design loads [Other than earthquake] Wind load for buildings and structures).

Revisions in IS 1893 (Part 1) 2016:

a) Importance Factor (I): Table 8 enlists the values of Importance factor depending upon the use, occupancy & service provided by the structures. For Residential or commercial Buildings, with occupancy more than 200 persons importance factor 1.2 has been assigned.

b) Moment of Inertia (I): As per the clause 6.4.3.1, for structural analysis, the moment of inertia shall be taken as 70% of gross moment of inertia of columns & 35% of gross moment of inertia of beams in case for RC & masonry structures. The gross moment of inertia can be considered for columns & beams in case of steel structures.

Revisions in IS 875 (Part 3) 2015:

a) The preceding type of structures into B class & C class has been deleted and for that reason the k1 is renamed as terrain roughness and height aspect.
b) The values of k_2 factor similar to preceding class A type structure are retained in this code.
c) An additional factor, termed as importance factor has been introduced for cyclonic area (k4).

Objectives:

To highlight the revised clauses in IS 875 (Part3): 2015 & IS 1893 (Part1) 2016 which will help designers to understand new code in simple & quick manner.

2. METHOD OF ANALYSIS

Analysis of building is done by two methods i.e. by, Equivalent Static Analysis and Dynamic Analysis. Seismic codes are unique to a particular region or country, In India, Indian Standard Criteria for Earthquake Resistant Design of Structures IS 1893 (Part-1) : 2016 is the main code that provides outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests and its ductility. The code recommends following methods of analysis.

i. Equivalent Static Analysis
ii. Dynamic Analysis
   a. Response Spectrum Analysis
   b. Time History Analysis

In this Study Dynamic analysis i.e. Response spectrum analysis method is used for design of building.

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Response Spectrum Analysis:

Response Spectrum analysis allows the users to analyze the structure for seismic loading. For any supplied response spectrum (either acceleration v/s period or displacement v/s period) joint displacement, member forces and support reaction may be calculated. Model response may be combined either Square Root of Sum of Square (SRSS) or complete quadratic combination (CQC) method to obtain the resultant response, as given in clause 7.7.5 of code IS1893 (Part 1) : 2016.

Some Important Points about Response Spectrum Method:

- Response Spectrum Analysis (RSA) is an elastic method of analysis and lies in between equivalent force method of analysis and nonlinear analysis methods in terms of complexity.
- RSA is based on the structural dynamics theory and can be derived from the basic principles (e.g. Equation of motion).
- RSA, unlike equivalent force method, considers the influence of several modes on the seismic behavior of the building.
- Damping of the structures is inherently taken into account by using a design (or response) spectrum with a predefined damping level.
- The maximum response of each mode is an exact solution.
- The sole approximation used in RSA is the combination of modal responses.

Criteria:

Those modes shall be considered for which:

- The sum of the modal masses is at least 90 % of the total building mass.
- Response of all modes shall be considered that contribute significantly to the global building response (i.e., important for buildings of a certain height)

3. MODELLING

An Institutional Building structural model is used throughout this project. The building is designed in ETABS 2019. Model is asymmetric with respect to both X and Y axis to demonstrate many of the features expected from multi-story buildings subjected to wind and seismic loading using Dynamic Analysis method [Response Spectrum Analysis Method].

Table -1: Designed data of building

Grade of concrete	M25
Grade of steel	Fe500 & Fe 415
Density of concrete	25kN/m3
Density of AAC Block	7.5kN/m3

Table -2: Earthquake data of building

Seismic Zone	II
Importance factor	1.5
Response reduction factor	5 (SMRF)
Type of soil	TYPE II (Medium)
Damping	5%

Institutional Building Model:

The building is seven storey reinforced concrete moment resisting frame. The building is Institutional Building with plan dimension is 9.82 m X 29.36 m with a height of 32.9 m having 1.9 m cantilever portion as shown in figure. The ground, first and second storey is of hall and other storey having rooms. The building has two different sizes of column & five different sizes of beams. The building is designed in ETABS 2019 Software using Latest IS codes for earthquake and wind Using Dynamic method i.e. Response spectrum analysis method. Shear wall is designed in ETABS Software. Torsion is considered in Building. The table 3 shows the structural data of building.

Table -3: Structural data of building

Plan dimension	9.82 m X 29.36 m
No of storey	7
Ground storey height	4.6 m
Intermediate storey height	4 m
Depth of footing	1.8 m
Slab thickness	140 mm
External wall thickness	230 mm
Internal wall thickness	115 mm
Parapet (1 m height)	230 mm

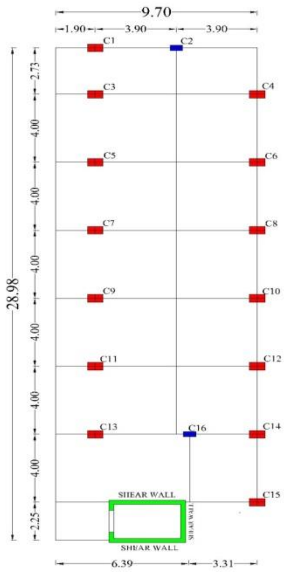

Fig -1: Plan view of Building

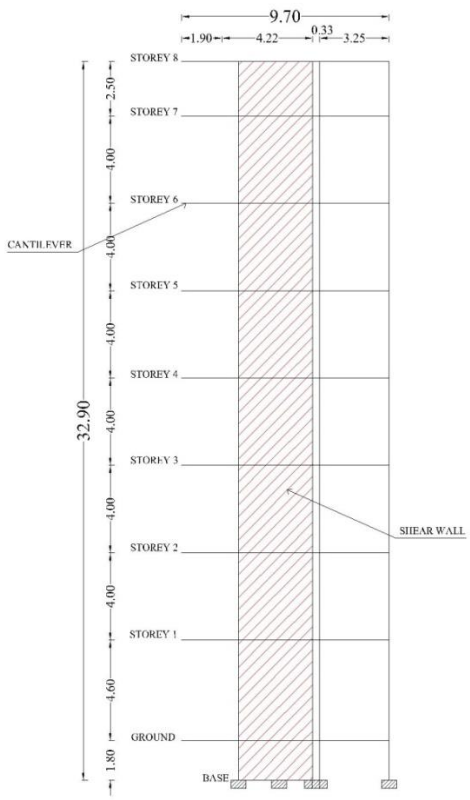

Fig- 2: Front Elevation view of Building

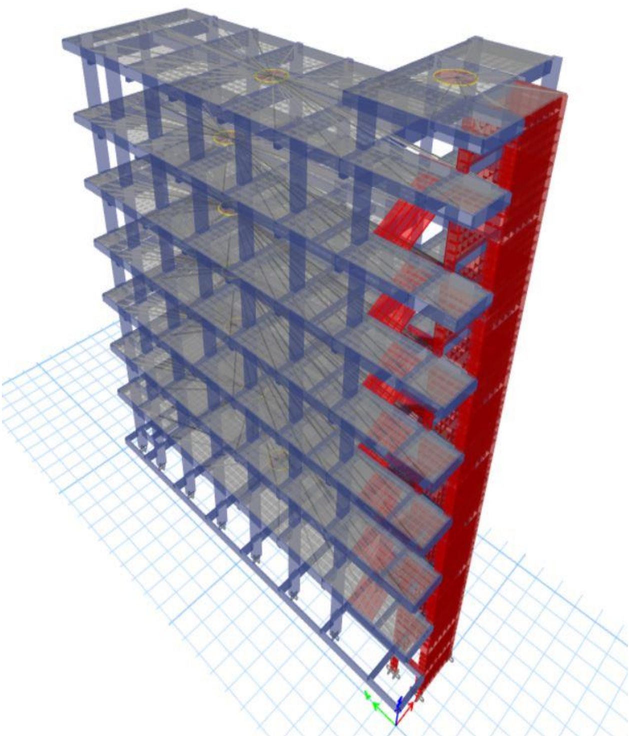

Fig -3: 3D view of Building [ETABS 19 Software]

Response spectrum analysis was carried out employing ETBAS using IS 1893:2016 (part 1) code for earthquake and IS 875 Part 3 2015 for wind analysis. The design is carried out of building using IS 456:2000and IS 13920:1993 codes. The designed forces *i.e.* axial force, moments and shear forces are taken from the ETABS analysis results.

An accidental eccentricity is introduced in IS code. But it is observed in field design these codal provisions are generally not followed which is very dangerous for structure. From this study it is observed that after considering torsion in building with addition of shear wall, exhibits better results.

4. RESULT AND DISCUSSION

Results and discussions of different parameter such as Storey displacement, Storey Drift, Storey shear and storey stiffness are shown with the help of graphs.

Maximum Storey Displacement of Building in X & Y Directions for Seismic load case.

Story displacement is the lateral displacement of the story relative to the base.

Maximum Storey Displacement for seismic load in X Direction:

The height of building is 32.9m. The acceptable lateral displacement limit for seismic load case could be taken as H/250. Hence the maximum storey displacement allowable is 32900/250 i.e. 132 mm. The maximum storey displacement is under the allowable displacement limit in both cases. The values of the displacement are shown in Table 4 & Fig 4.

Table -4: Maximum Storey Displacement for Seismic load in X direction

Maximum Storey Displacement for Seismic load in X - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m	**mm**	**mm**
8TH	32.9	80.911	40.455
7TH	30.4	80.901	39.435
6TH	26.4	76.037	37.068
5TH	22.4	68.253	33.278
4TH	18.4	57.62	28.173
3RD	14.4	44.847	22.107
2ND	10.4	30.741	15.424
1ST	6.4	16.097	8.374
GL	1.8	1.77	0.945

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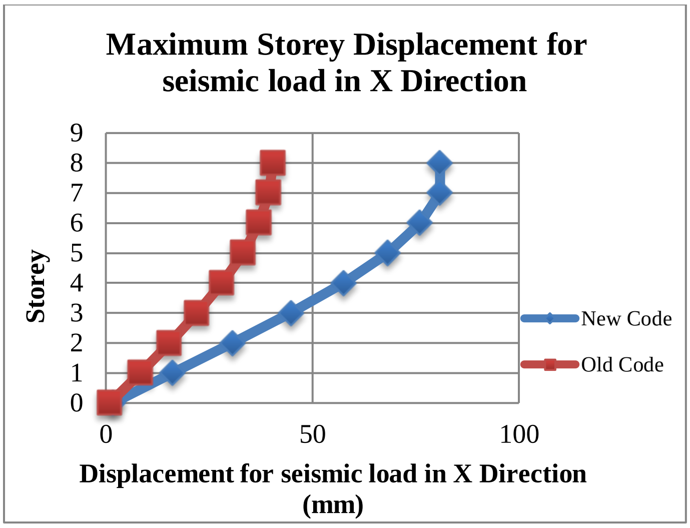

Fig- 4: Maximum Storey Displacement for Seismic load in X direction

Maximum Storey Displacement for seismic load in Y Direction:

The height of building is 32.9m. The maximum storey displacement allowable is 132 mm. The maximum storey displacement is under the allowable displacement limit. The values of the displacement are shown in Table 5

Table- 5: Maximum Storey Displacement for Seismic load in Y direction

Maximum Storey Displacement for Seismic load in Y - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m	**mm**	**mm**
8TH	32.9	35.213	24.841
7TH	30.4	32.418	23.031
6TH	26.4	28.209	20.391
5TH	22.4	23.395	17.171
4TH	18.4	18.245	13.61
3RD	14.4	13.078	9.936
2ND	10.4	8.266	6.417
1ST	6.4	4.177	3.331
GL	1.8	1.054	0.839

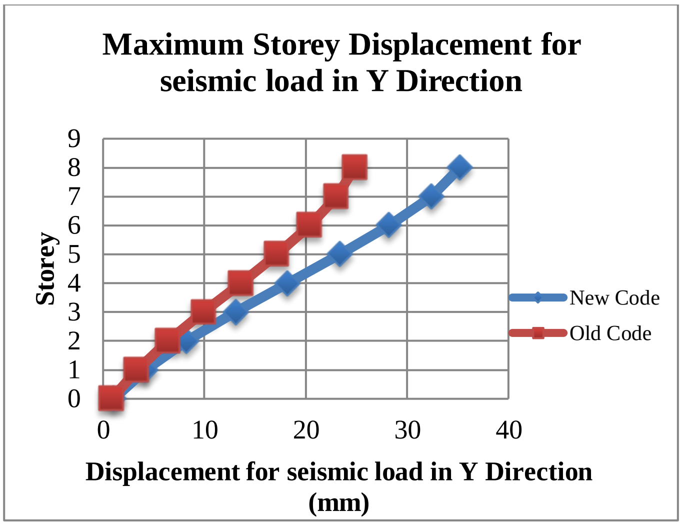

Fig- 5: Maximum Storey Displacement for Seismic load in Y direction

Maximum Storey Drift of Building in X & Y Directions for Seismic load case.

The ratio of displacement of two consecutive storey's to height of that storey is called storey drift.

Storey Drift for seismic load in X Direction:

As per Clause no. 7.11.1 of IS 1893 (part 1):2016, the storey drift in any storey due to specified design lateral force with partial load factor of 1.0, shall not exceed 0.004 times the storey height. The maximum storey drift permitted to all Storey is 13 mm. The values of the drift are under allowable limit as shown in Table 6

Table- 6: Storey Drift for Seismic load in X direction

Storey Drift for Seismic load in X - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m		
8TH	32.9	0.000216	0.00006
7TH	30.4	0.001216	0.000592
6TH	26.4	0.001946	0.000947
5TH	22.4	0.002658	0.001276
4TH	18.4	0.003193	0.001517
3RD	14.4	0.003526	0.001671
2ND	10.4	0.003661	0.001762
1ST	6.4	0.003115	0.001617
GL	1.8	0.000983	0.000524

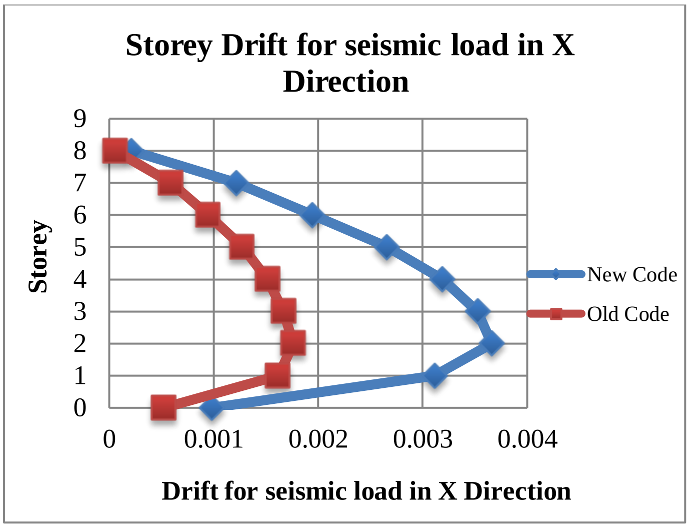

Fig- 6: Maximum Storey Drift for Seismic load in X direction

Storey Drift in for seismic load Y Direction:

The maximum storey drift permitted for all storey's is 13 mm. The values of the drift are under allowable limit as shown in Table 7

Table- 7: Storey Drift for Seismic load in Y direction

Storey Drift for Seismic load in Y - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m		
8TH	32.9	0.00112	0.00073
7TH	30.4	0.001139	0.00073
6TH	26.4	0.001203	0.000805
5TH	22.4	0.001288	0.000891
4TH	18.4	0.001292	0.000918
3RD	14.4	0.001203	0.00088
2ND	10.4	0.001024	0.000772
1ST	6.4	0.000806	0.000644
GL	1.8	0.000348	0.000281

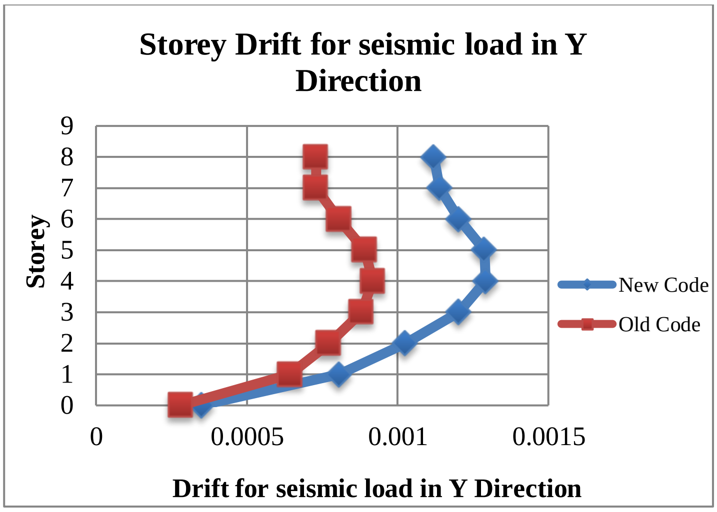

Fig- 7: Maximum Storey Drift for Seismic load in Y direction

Similarly values of storey shear and storey stiffness are also compared with respect to new and old code case.

Maximum Storey Displacement of Building in X & Y Directions for wind load case.

The height of building is 32.9 m. The acceptable lateral displacement limit for wind load case could be taken as H/500. Hence the maximum storey displacement allowable is 32900/500 i.e. 66 mm. The maximum storey displacement is under the allowable displacement limit in both cases. The values of displacement are more in new code model than old code model for wind load case are shown in Table 8 & Fig 8.

Table- 8: Maximum Storey Displacement for Wind load in X direction

Maximum Storey Displacement for Wind load in X - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m	**mm**	**Mm**
8TH	32.9	58.264142	30.195156
7TH	30.4	58.142224	29.851967
6TH	26.4	55.597672	28.604759
5TH	22.4	51.314036	26.469465
4TH	18.4	45.012546	23.350016
3RD	14.4	36.685514	19.254118
2ND	10.4	26.437221	14.189624
1ST	6.4	14.512705	8.120224
GL	1.8	1.647103	0.945174

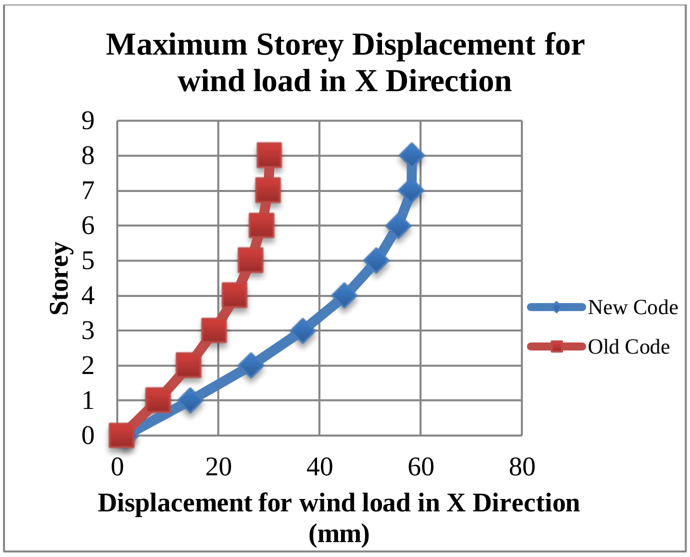

Fig- 8: Maximum Storey Displacement for Wind load in X direction

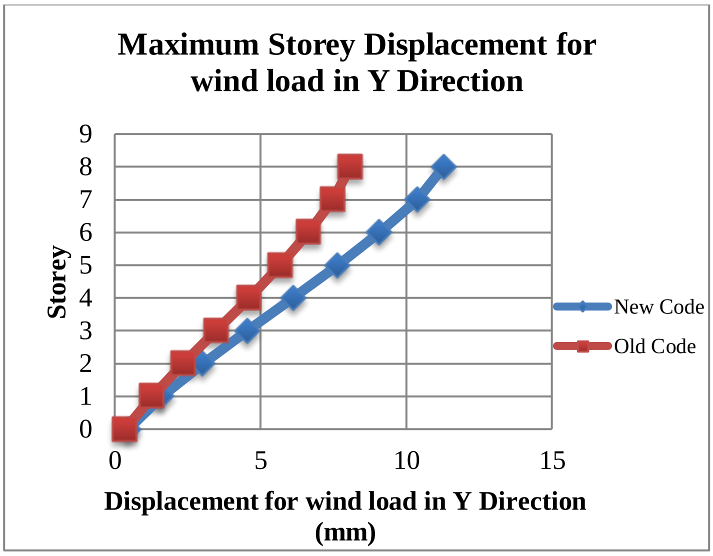

Fig- 9: Maximum Storey Displacement for Wind load in Y direction

Table- 9: Maximum Storey Displacement for Wind load in Y direction

Maximum Storey Displacement for Wind load Y - Direction (mm)			
Story	**Elevation**	**New Code**	**Old Code**
	m	**mm**	**mm**
8TH	32.9	11.288256	8.086494
7TH	30.4	10.388355	7.486996
6TH	26.4	9.083011	6.652202
5TH	22.4	7.655201	5.685848
4TH	18.4	6.130371	4.62079
3RD	14.4	4.554563	3.487999
2ND	10.4	3.015516	2.349054
1ST	6.4	1.613119	1.281922
GL	1.8	0.466837	0.36206

From the results of seismic load case and wind load case it is observed that the values of storey displacement, storey drifts are more in new code model as compared to old code model and storey shear values are similar in both cases from first to top floor of building in new code model and storey stiffness values are observed more in old code model as compared to new code model.

5. CONCLUSION

From the study of latest and old IS code provisions for earthquake and wind, the obtained results, the following conclusions are drawn.

1. In both model as per latest and old code model considering Response spectrum analysis with shear wall the storey displacement is under permissible limits, which is restricted by providing shear wall.
2. It is found that storey displacement and storey drift is more in the model designed by using latest IS code and less in old code model for both wind and seismic load cases.
3. The clause 6.4.3.1 of IS 1893 Part 1 :2016 i.e. The moment of inertia for structural analysis shall be taken as: In RC and Masonry Structures : Ieq = 70% for columns Ieq = 35% for beams, due to this new clause of moment of inertia, the storey displacement and storey drift values are more in new code as compared to old code.
4. Storey stiffness values are observed more in old code model as compared to new code model.
5. In both models due to shear walls are provided the storey drift is within limit.
6. As structural models are designed by using both latest and old IS code provision for earthquake and wind all storey & building checks are under their permissible limits.

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