Comparative Seismic Analysis of RC frame Structures with and without Shear Wall at Different Positions as per IS 1893(part I):2002 and IS 1893(part I):2016

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Abstract - *High rise building structures are mostly affected by lateral loads and vulnerable to seismic forces. In this study, the response of (G+25) storey building model for seismic zone II, III, IV, V are evaluated for soil type II. The analytical methods used in this work are Equivalent Static Method and Response Spectrum Method. The seismic parameters for earthquake load and functions are set as per IS 1893(part I):2002, IS 1893(part I):2016 and IS 16700:2017. The finite element analysis software ETABS v18 is used for analysis. Also, the presence of shear wall and the behavior of structure by its inclusion is studied. For the study, frame structure with and without shear wall at different positions using above mentioned methods are considered with IS 1893(part I):2002 and IS 1893(part I):2016. In this work various parameters like Storey Displacement, Storey Drift, Base Shear, Modal mass participation ratio are obtained for all the models considered and have been compared. P-Delta effect is also considered with this seismic analysis.*

Key Words: Equivalent Static Method, Response spectrum Method, Shear Wall, IS 1893(part I):2002, IS 1893(part I):2016, IS 16700:2017, ETABS v18

1.INTRODUCTION

With the increase in population and urbanization; it is necessary to provide high rise building structures in comparatively small ground area provided for construction. As earthquake has been most devastating and unavoidable natural disaster which causes severe losses to both life and property. Therefore comparative analysis of change in codal provisions of IS 1893(part I):2002 and IS 1893(part I):2016 and its effect and precautionary measurement on high rise building structure are required.

To perform well in an earthquake, a building should possess four main attributes namely simple and regular configuration, adequate lateral strength, stiffness and ductility.

Various new amendments and guidelines were introduced in IS 1893(part I):2016 as compared to IS 1893(part I):2002. Major amendments related to our concern for analysis are as follows:

(A) As per the clause 6.3.3.1, the structures located in seismic zone IV or V, structures which has plan or vertical irregularity, structures founded on soft soil, bridges, structures with long spans or with large lateral overhangs of structural members are required to consider the effects due to vertical earthquake shaking in load combinations. the load combinations for three directional earthquake ground shaking are mentioned in clause 6.3.4.

(B) 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 and 35% of gross moment of inertia of beams in case for RC and masonry structures.

(C) In IS 1893(part I):2016, Table 8 enlists the values of importance factor depending upon the use, occupancy and service provided by the structures. The importance factor value 1.2 is introduced for residential or commercial buildings with occupancy more than 200 people.

(D) The code expects to ensure that the first 3 modes together contribute at least 65% mass participation factor in each principal plan direction.

(E) The clause 7.7.1 expects to perform linear dynamic analysis to obtain design seismic base shear and its distribution at different levels along height of building, for all buildings other than regular buildings lower than 15 m in seismic zone II.

2. LITERATURE REVIEW

[Agrawal and Charkha (2012)] studied the effect of change in shear wall location on storey drift of multi-storey building subjected to lateral loads. They concluded that the significant effects on deflection in orthogonal direction by shifting the shear wall location; placing the shear wall away from the centre of gravity resulted in increase in most of member forces. They also suggested that lift core should be placed at appropriate location govern by seismic analysis.

[Kumar et al., (2013)] studied the Seismic vulnerability assessment of reinforced concrete building with shear wall. In this study, they concluded that maximum storey displacement was less when shear wall was placed mid of the outer periphery in x-direction comparative to other locations. They concluded that scale-up factor in x & y-direction was high when no shear wall provided, also it was decreased slightly after providing wall at different locations. They also concluded that shear wall is advisable to vary the maximum storey drift with different positions.

[Santhosh and Pradeep (2014)] studied the seismic analysis and design of multi-storey building with non-parallel shear wall system. They studied (G+4) storeyed bare frame structure with three different conditions as building without shear wall(WSW),building with parallel shear wall(PSW) and building with non-parallel shear wall(NPSW).They concluded that the lateral displacement and storey drift for the structure with PSW was less as compared to other two structures. Base shear was less for PSW as compared to NPSW.Therefore,they concluded that PSW structure be much efficient than the other two structures i.e. NPSW and WSW during lateral forces.

[Gupta B. (2015)] studied different shear wall locations on seismic performance of reinforced cement concrete framed buildings. In this study,Gupta adopted different models of different locations and configurations of shear wall using ETABS 2013 software as per IS 1893(part I):2002 and gave the most efficient location and configuration to be provided at centre as '+' shape, considered different parameters as storey displacement and storey drift.

[Reddy et al., (2015)] studied the seismic analysis of multi-storied building with shear walls using ETABS software. They studied the efficient and ideal location of shear walls in symmetrical high-rise building. They performed static and dynamic analysis for seismic zone II and zone V for soft soil (soil type I) and hard soil (soil type III) as per IS 1893(part I):2002 using ETABS software. They concluded the performance of structure with shear wall is better than structure without shear wall because centre of mass and centre of rigidity became closure. They shown that shear wall reduced the displacement. They concluded that shear wall placed at efficient location(outer periphery of the structure),which they provided from foundation to the roof top, had excellent earthquake resistance in high rise buildings.

[Shaha and Banhatti (2016)] studied the earthquake behaviour of RCC building for various shear wall configurations. In this, they analysed (G+20) multi-storey building situated in zone IV as per IS 1893(part I):2002 using ETABS software. They concluded that the stiffness of building increases due to adding shear wall, hence reducing the damage to the structure from seismic effects. They also shown that efficient position of shear wall was more important as compared to length of shear wall to reduce quantity and cost .They concluded that maximum displacement of structure can be decreased significantly by introducing shear wall at symmetric and peripheral location of the building structure.

[Thakur and Saklecha (2016)] studied the addition of shear walls to enhance the structural stability of medium rise structures. They concluded that Box shape shear wall at centre of the building was more efficient to resist horizontal seismic forces as compared to other models of shear wall at mid of the outer edges and at the corner of the building. Above conclusion was based on seismic response parameters like storey displacement, storey drift and storey base shear of the building.

[Malviya and Pahwa (2017)] studied the seismic analysis of high rise building with IS 1893(part I):2002 and IS 1893(part I):2016.In this study, they studied the response spectrum analysis of regular building as per seismic codes above mentioned using SAP software. They considered (G+50) multi-storey building structure with seismic zone They concluded that maximum deflection with new code had much lower value as compared to older code. Similarly they showed the shear force and bending moment to be much lower value obtained as per IS 1893(part I):2016.Also response spectrum results showed that the acceleration against time is higher in case of revised code.

[Salimath and Rajeeva (2018)] studied the comparative analysis of T-shaped reinforced concrete frame structures with and without shear wall as per IS 1893(part I_):2002 and IS 1893(part I):2016.In this study, they concluded that the model analysed in seismic zone V,as per the codal provisions in IS 1893(part I):2016 had higher values of storey displacement than the models analysed as per IS 1893(part I):2002;the inclusion of shear wall to the structure decreased displacement up to 36%.They studied that model analysed from IS 1893(part I):2016 had more storey drift values as compared to IS 1893(part I):2002 and also inclusion of shear wall decreased the storey drift. Models analysed with shear walls and IS 1893(part I):2016 had greater base shear as compared to models with IS 1893(part I):2002 and without shear wall.

[Afzal and Mishra (2019)] studied the seismic analysis of shear wall optimization for multi-storey building. They performed seismic analysis for 15 storeys building for zone V as per IS 1893(part I):2016 using ETABS software. They studied model without shear wall and model with shear wall at different positions. They concluded that shear wall and model with shear wall at different positions. They concluded that shear wall provided at corner decreased time period by

19%, storey stiffness increased by 42%, base shear increased by 15% as compared to shear wall at the mid of the frame outer periphery provided decrease in the period as 11%, storey stiffness increased by 31% and base shear increased by 7.5%.

[Khan et al., (2019)] studied the analysis of P-Delta effect on high rise building. In this, they studied the P-Delta effect on high rise building. For this, they studied different heights of high rise building as per IS 1893(part I):2002 and using ETABS 2015 software. They concluded that it was essential to consider the P-Delta effect for height more than or equal to 75 meter and this conclusion validated for all the regions and seismic zones of India.

[Kosare and Hazari (2019)] studied the behaviour of multi-storey building with shear walls. In this study, they concluded that the shear wall provided along the periphery of the structure found to be more efficient than all other types of shear wall. Also, high performance shear wall had better ductility than that of conventional shear walls. They concluded that it would be sufficient to raise the shear wall up to mid height of building frames instead of raising up to entire height of the building.

[Shindhalkar et al., (2020)] studied the comparison of conventional high rise building with shear wall building using ETABS software. They concluded that building model with shear wall at all four corners provide optimum storey drifts in all earthquake zones of India.Also,above types of model provided 40% to 50% restriction to lateral movement as compared to conventional structure. They concluded that shear wall must be provided for high rise building and also it should be provided at all corners only; so it became more economical also.

[Shinde B.H. (2020)] studied the seismic analysis of reinforced cement concrete multi-storied building by IS 1893(part I):2016 and its comparison with IS 1893(part I):2002.In this study, Shinde evaluated the performance of RCC buildings with (G+12) and (G+16) storey by both equivalent static analysis and response spectrum analysis method for zone II,III,IV,V using ETABS software. In this study, Shinde concluded that due to introduction of revised due to introduction of revised code IS 1893(part I):2016;there was significant increment in storey shear and base shear by 20% for both building models, decrease in storey displacement of (G+12) storey by 134% and decrease of 170% for (G+16) storey building and increase in storey drift by 156% for (G+12) storey building and 188% increase in (G+16) storey building model as compared to analysis with IS 1893(part I):2002.

3. MODELS CONSIDERED FOR ANALYSIS

Models are modelled with Square shape RC frame structure and analyzed with and without shear wall at different positions as per IS 1893(part I):2002 and IS 1893(part I):2016 considering P-delta effect also.

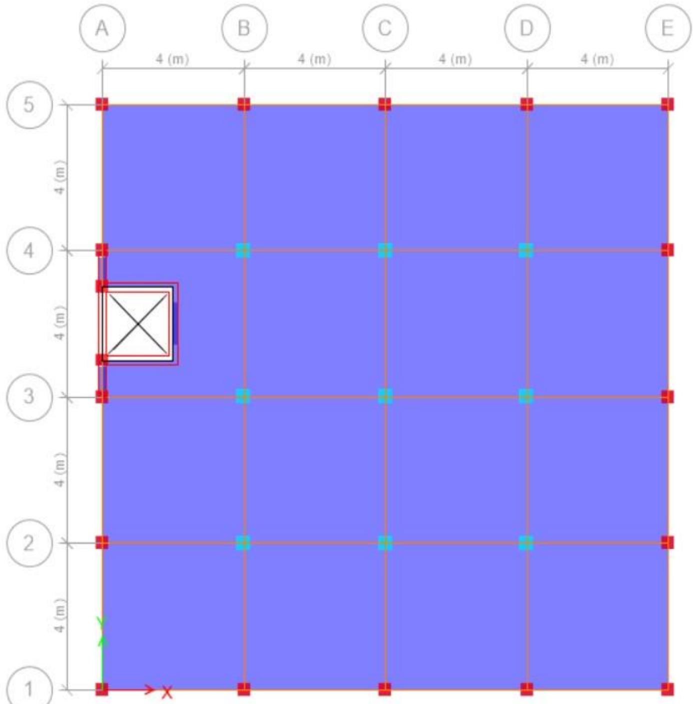

Fig-1: Plan view of RC frame structure without shear wall

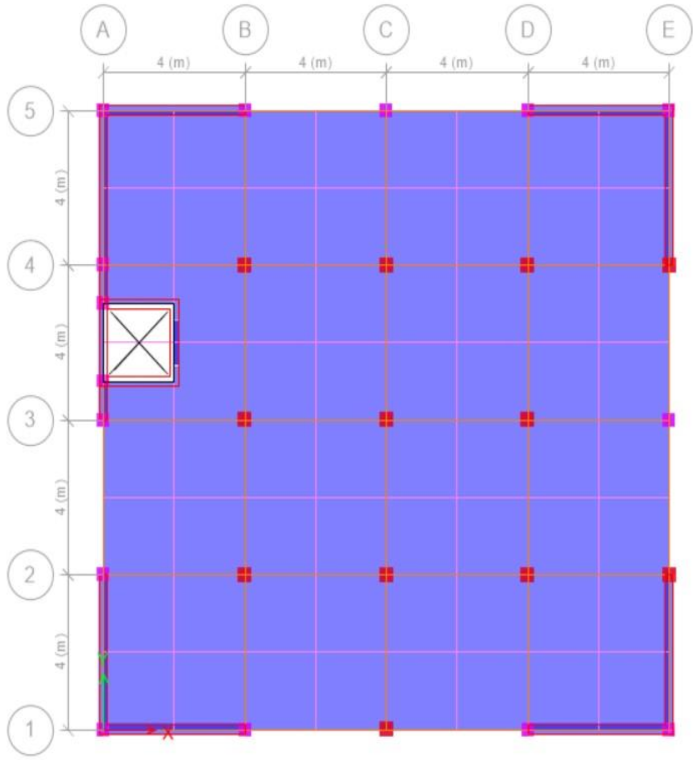

Fig-2: Plan view of RC frame structure with shear wall at corners

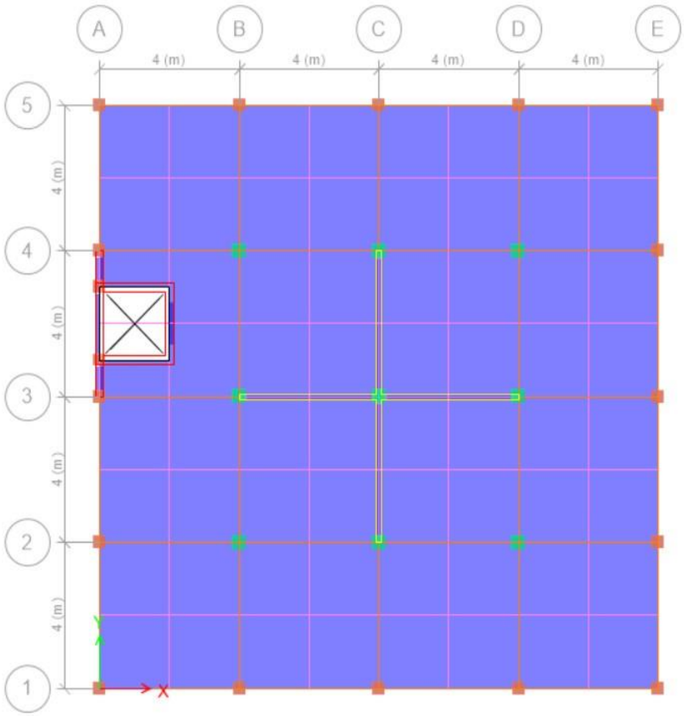

Fig-3: Plan view of RC frame structure with shear wall in '+'shape at centre

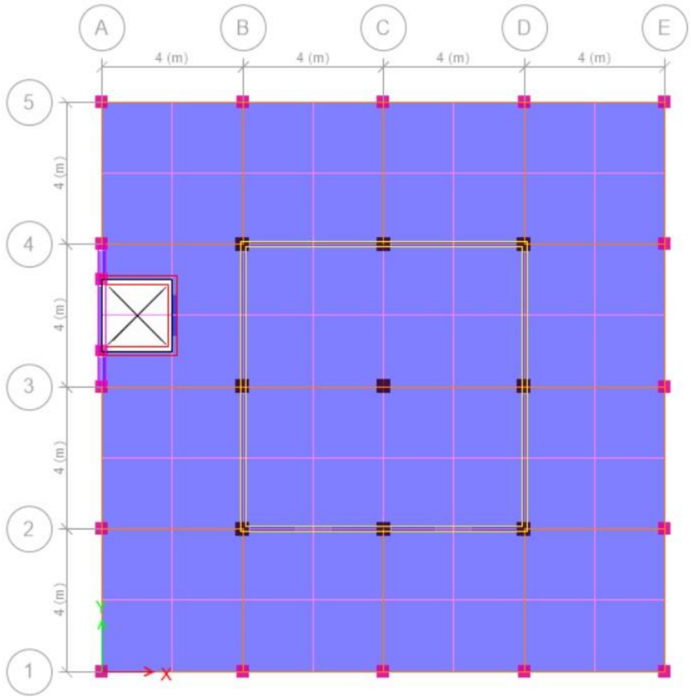

Fig-5: Plan view of RC frame structure with shear wall in box shape at centre(with opening)

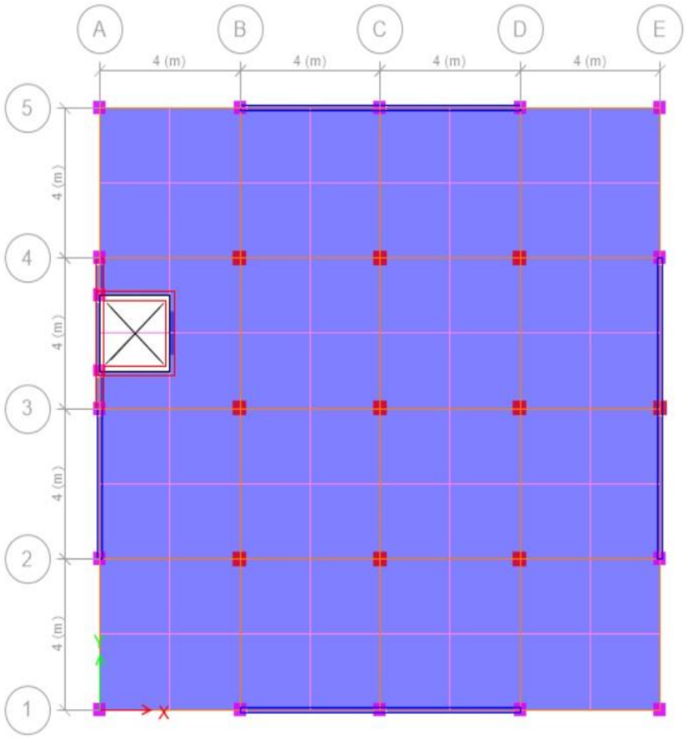

Fig-4: Plan view of RC frame structure with shear wall at mid of the outer periphery of structure

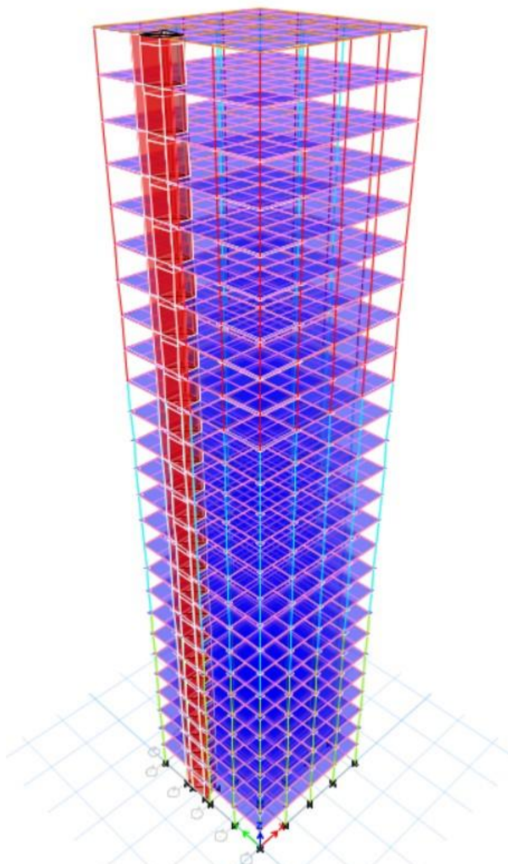

Fig-6: 3D view of RC frame structure without shear wall

4. MODEL DETAILS

Table 1:Model Details

Frames: along X-direction & Y-direction	5 bays at 4m centre to centre each
Plan Dimension	16 m*16 m centre to centre
Type of frames	Special reinforced concrete moment resisting frame (SMRF)
Total height of building	78.2 m ((G+25) storey building)
Height of storey	3.2m (ground storey), 3 m(other storeys)
Height of Parapet Wall	1.2 m
Beam size	300 mm*500 mm
Column size	500mm*500mm,400 mm*400 mm,350 mm*350 mm
Slab thickness	125 mm
Thickness of brick masonry wall	150 mm
Thickness of shear wall	230 mm,175 mm
Thickness of lift core shear wall	230 mm
Number of stories	26 (G+25)
Seismic zone	II,III,IV,V
Type of Soil	Medium soil (Type II)
Response reduction factor	5
Importance factor	1,1.2
Damping factor	1
Super dead load at all floors	1.5 kN/m^2
Live load at all floors	2.5 kN/m^2
Grade of concrete	M35, M50
Grade of steel	HYSD 500
Density of concrete	24.9926 kN/m^3
Poisson's ratio	0.2
Modulus of elasticity of concrete (E_c)	29580.4 N/mm^2 (for M35 grade concrete) 35355.34 N/mm^2 (for M50 grade concrete)
Density of brick masonry wall	18.85 kN/m^3

5. RESULTS AND DISCUSSIONS

The structure with and without shear wall are analyzed as per codal provisions in IS 1893(part I):2002, IS 1893(part I):2016 and IS 16700:2017 using Equivalent Static analysis and Response Spectrum analysis as dynamic analysis. The results are obtained and compared.

5.1 Storey Displacement

The permissible limit for storey displacement is H/500.H is 78.2m for the present model. So, the limit is 156.4 mm.

Case 1:Models without shear wall

M1: RC Frame structure analyzed as per IS 1893(part I):2002 without P-Delta effect considered

M2: RC Frame structure analyzed as per IS 1893(part I):2002 with P-Delta effect considered

M3: RC Frame structure analyzed as per IS 1893(part I):2016 without P-Delta effect considered

M4: RC Frame structure analyzed as per IS 1893(part I):2016 with P-Delta effect considered

Table 2:Maximum storey displacement (in mm) (for case 1)

Models	Zone II	Zone III	Zone IV	Zone V
Model 1	91.33	118.02	145.15	178.40
Model 2	94.51	122.21	149.87	183.67
Model 3	114.03	143.27	188.56	242.27
Model 4	119.98	150.28	191.60	253.51

Case 2: Models with shear wall at different places for IS 1893(part I):2002

Model 1: RC frame structure without shear wall

Model 2: RC frame structure with shear wall at corners of structure

Model 3: RC frame structure with shear wall at mid of the outer periphery of structure

Model 4: RC frame structure with shear wall in '+'shape at centre

Model 5: RC frame structure with shear wall in box shape at centre(with opening)

(model definition for both case 2 & 3)

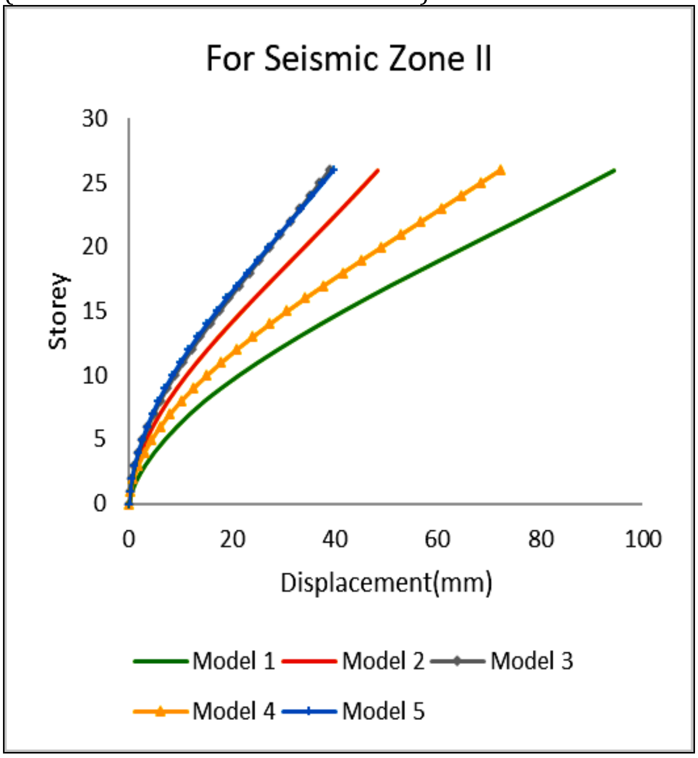

Chart 1: Storey displacement for seismic zone II for IS 1893(part I):2002

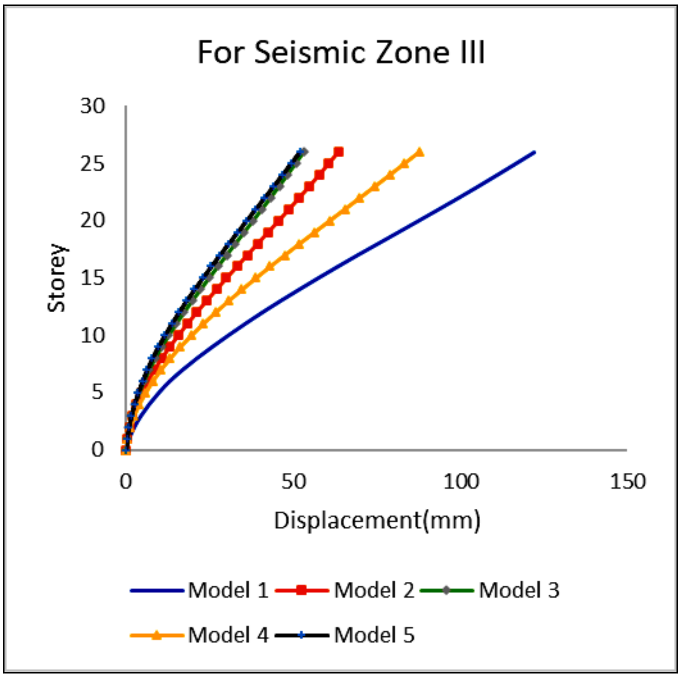

Chart 2: Storey displacement for seismic zone III for IS 1893(part I):2002

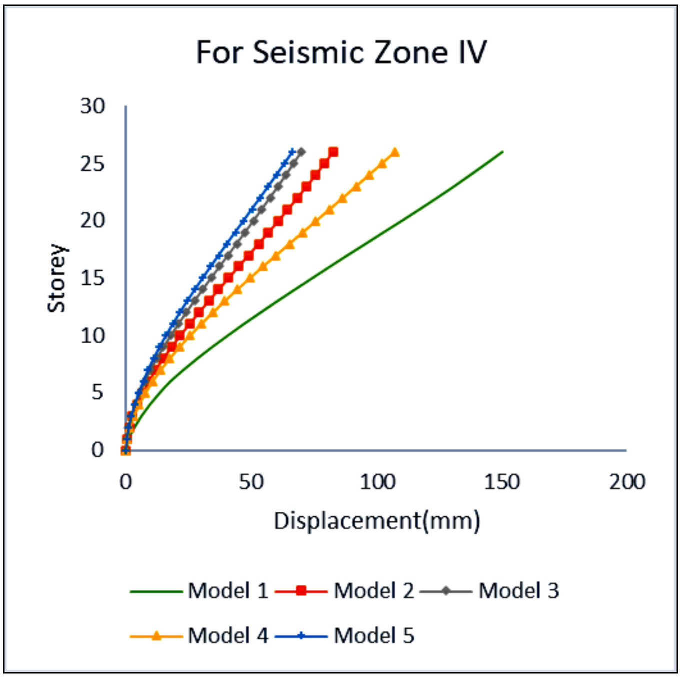

Chart 3: Storey displacement for seismic zone IV for IS 1893(part I):2002

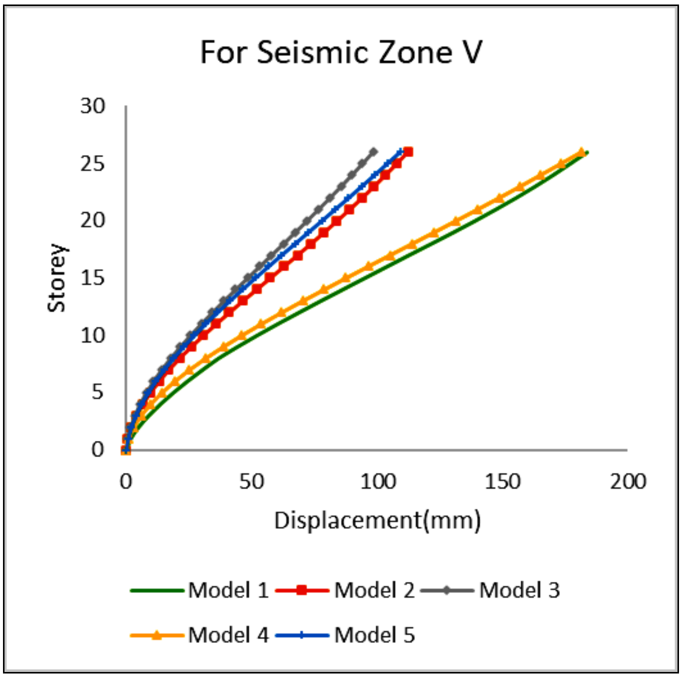

Chart 4: Storey displacement for seismic zone V for IS 1893(part I):2002

Case 3: Models with shear wall at different places for IS 1893(part I):2016

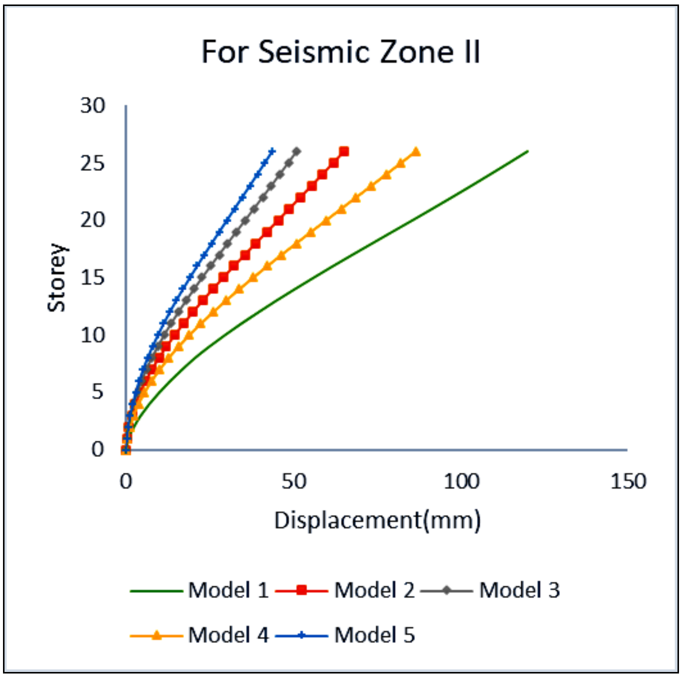

Chart 5: Storey displacement for seismic zone II for IS 1893(part I):2016

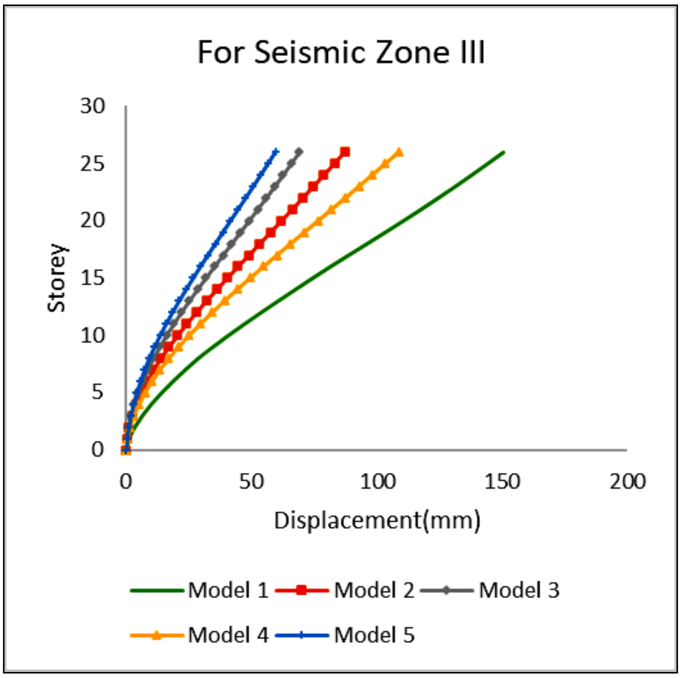

Chart 6: Storey displacement for seismic zone III for IS 1893(part I):2016

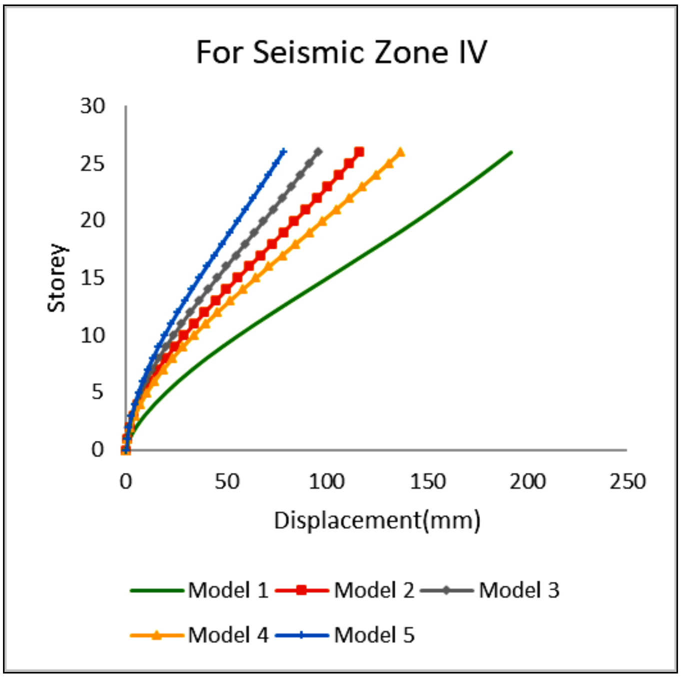

Chart 7: Storey displacement for seismic zone IV for IS 1893(part I):2016

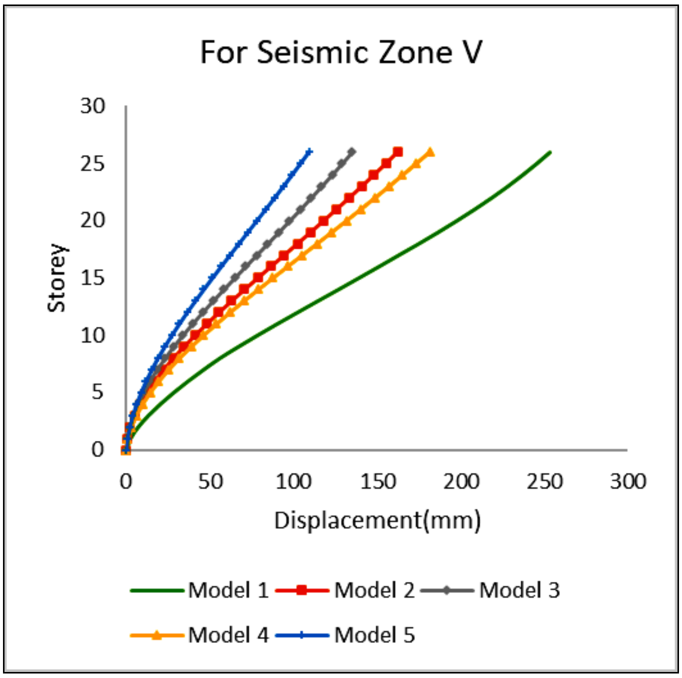

Chart 8: Storey displacement for seismic zone V for IS 1893(part I):2016

The models analyzed as per the codal provisions in IS1893(part I):2016 have higher values of storey displacement than the models analyzed as per IS 1893(part I):2002. Maximum storey displacement for basic frame structure exceeds the permissible limits for zone V with IS 1893(part I):2002 and for zone IV, V with IS 1893(part I):2016.This is due to higher factor of safety considered in IS 1893(part I):2016.

The inclusion of all shear wall models decreases storey displacement. Most efficient is Model 5 i.e. box type shear wall at centre(with opening) for minimizing the storey displacement and brought the maximum storey displacement within the permissible limits. Decrement of maximum storey displacement of 59.28% from Model 1, 58.64% from Model 2, 55.55% from Model 3, 50.60% from Model 4 as compared to Model 5 using IS 1893(part I):2002. Decrement of maximum storey displacement of 64.66% from Model 1, 61.43% from Model2, 59.11% from model 3, 56.97% from Model 4 as compared to Model 5 using IS 1893(part I):2016.

Case 4: Maximum Storey Displacement (for Zone II, III, IV, V)

Model 1: RC frame structure without P-Delta effect

Model 2: RC frame structure with P-Delta effect

Model 3: RC frame structure with shear wall at corners of structure

Model 4: RC frame structure with shear wall at mid of the outer periphery of structure

Model 5: RC frame structure with shear wall in '+'shape at centre

Model 6: RC frame structure with shear wall in box shape at centre(with opening)

Table 3:Maximum storey displacement(for Zone II)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	91.283	113.954
Model 2	94.451	119.890
Model 3	48.383	65.132
Model 4	38.958	51.032
Model 5	72.203	86.488
Model 6	39.743	43.733

Table 4:Maximum storey displacement(for Zone III)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	117.976	143.203
Model 2	122.161	150.209
Model 3	63.572	87.116
Model 4	53.228	69.098
Model 5	87.636	108.651
Model 6	51.954	59.524

Table 5:Maximum storey displacement(for Zone IV)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	145.315	188.637
Model 2	150.036	191.701
Model 3	82.616	116.272
Model 4	70.194	95.443
Model 5	107.187	136.953
Model 6	66.613	78.328

Table 6:Maximum storey displacement(for Zone V)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	178.605	242.296
Model 2	183.849	253.53
Model 3	112.147	162.35
Model 4	98.355	135.099
Model 5	138.189	181.252
Model 6	90.727	109.213

5.2 Storey Drift Ratio

The allowable storey drift ratio is 0.004.

Case 1: Models without shear wall
M1: Frame structure analyzed as per IS 1893(part I):2002 without P-Delta effect considered
M2: Frame structure analyzed as per IS 1893(part I):2002 with P-Delta effect considered
M3: Frame structure analyzed as per IS 1893(part I):2016 without P-Delta effect considered
M4: Frame structure analyzed as per IS 1893(part I):2016 with P-Delta effect considered

Models	Zone II	Zone III	Zone IV	Zone V
Model 1	0.001599	0.001973	0.002370	0.002908
Model 2	0.001642	0.002035	0.002441	0.002984
Model 3	0.001913	0.002339	0.003001	0.003870
Model 4	0.002001	0.002446	0.003079	0.004080

Case 2: Models with shear wall at different places for IS 1893(part I):2002

Model 1: RC frame structure without shear wall
Model 2: RC frame structure with shear wall at corners of the structure
Model 3: RC frame structure with shear wall at mid of the outer periphery of structure
Model 4: RC frame structure with shear wall in '+'shape at centre
Model 5: RC frame structure with shear wall in box shape at centre(with opening)
(model definition for both case 2 & 3)

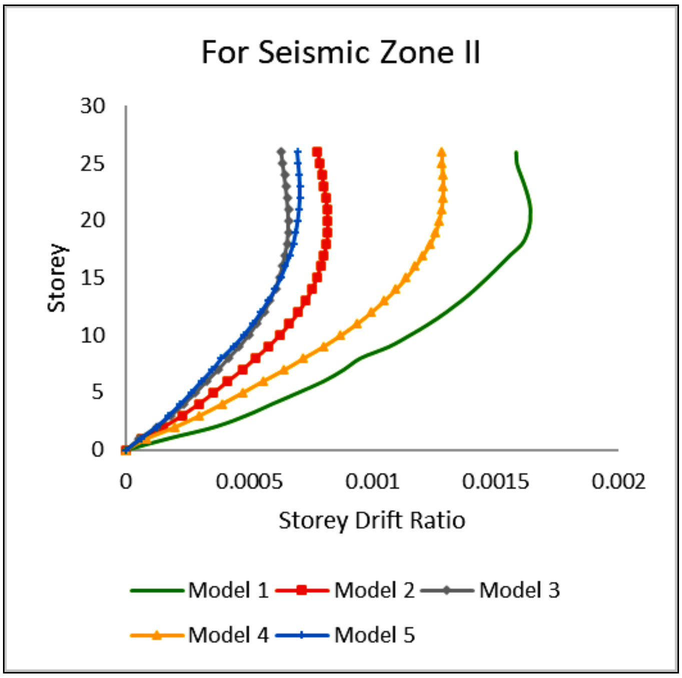

Chart 9: Storey drift ratio for seismic zone II for IS 1893(part I):2002

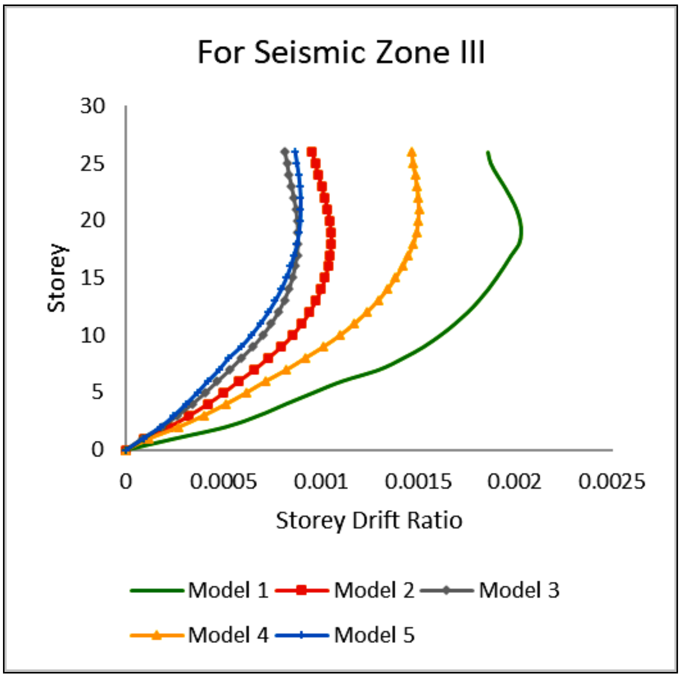

Chart 10: Storey drift ratio for seismic zone III for IS 1893(part I):2002

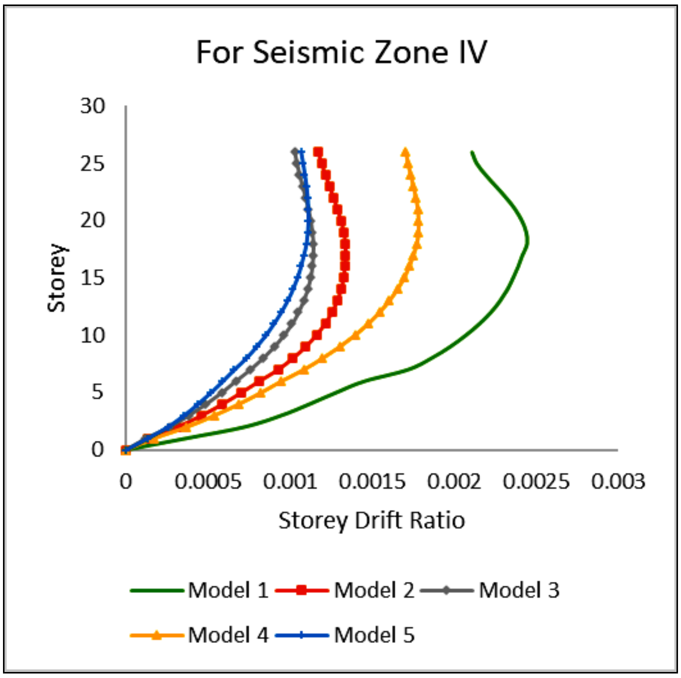

Chart 11: Storey drift ratio for seismic zone IV for IS 1893(part I):2002

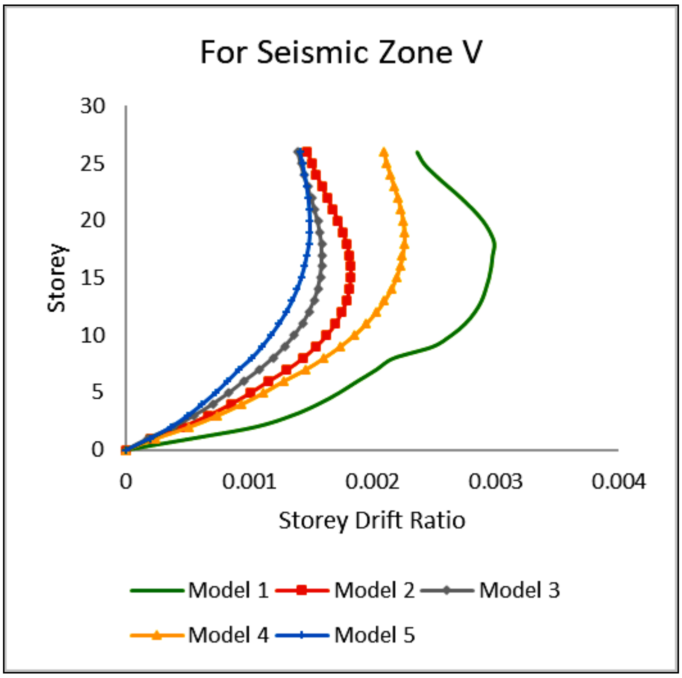

Chart 12: Storey drift ratio for seismic zone V for IS 1893(part I):2002

Case 3: Models with shear wall at different places for IS 1893(part I):2016

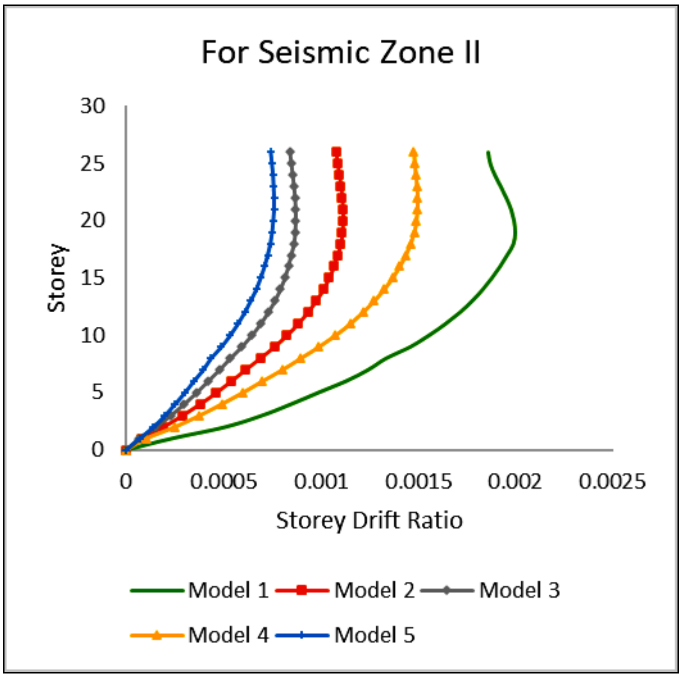

Chart 13: Storey drift ratio for seismic zone II for IS 1893(part I):2016

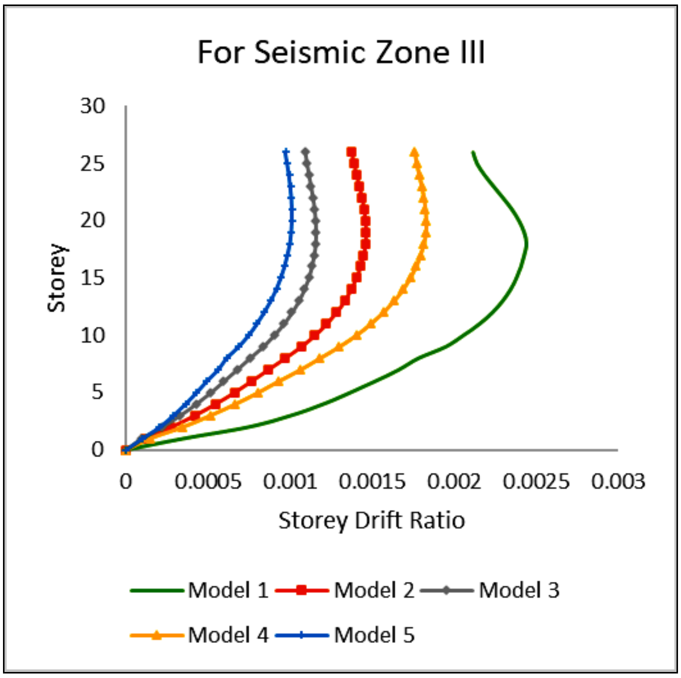

Chart 14: Storey drift ratio for seismic zone III for IS 1893(part I):2016

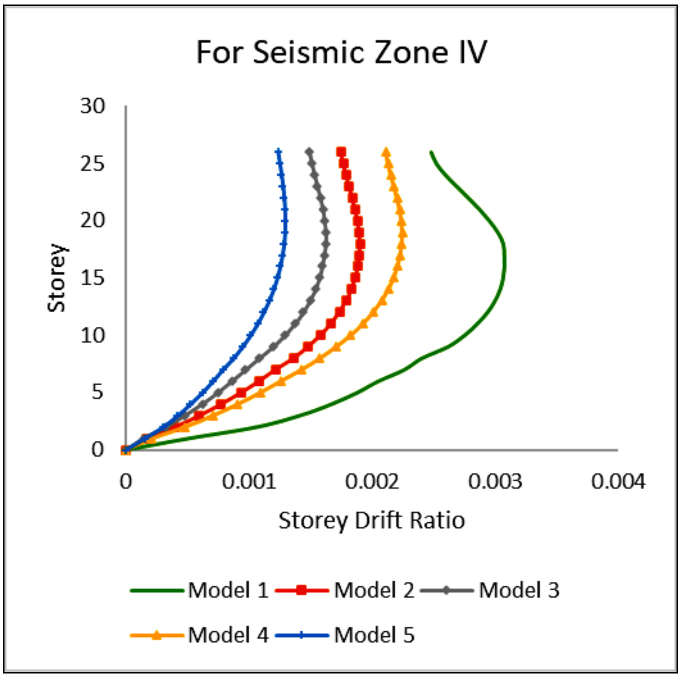

Chart 15: Storey drift ratio for seismic zone IV for IS 1893(part I):2016

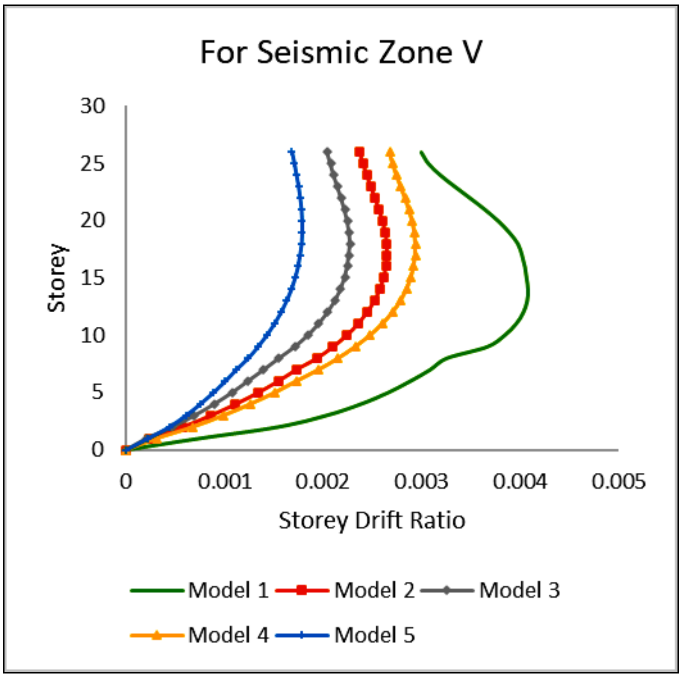

Chart 16: Storey drift ratio for seismic zone V for IS 1893(part I):2016

The models analyzed as per the codal provisions in IS 1893(part I):2016 have higher values of storey drift ratio than the models analyzed as per IS 1893(part I):2002.This is due to the higher factor of safety considered in IS 1893(part I):2016.

The maximum drift ratio exceeds permissible limits only in chart 16 (seismic zone V using IS 1893(part I):2016) by model 1(frame structure without shear wall) having value of maximum drift ratio as 0.004080.

The inclusion of all shear wall models decreases storey drift ratio. Most efficient is Model 5 i.e. box type shear wall at centre(with opening) for minimizing the storey drift ratio and brought the maximum storey drift ratio within the permissible limits. Decrement of maximum storey drift ratio of 59.25% from Model 1, 57.94% from Model 2, 54.56% from Model 3, 50% from Model 4 as compared to Model 5 using IS 1893(part I):2002. Decrement of maximum storey drift ratio of 63.87% from Model 1, 60.43% from Model2, 58.04% from model 3, 56.37% from Model 4 as compared to Model 5 using IS 1893(part I):2016.

Case 4:Maximum storey drift (for Zone II, III, IV, V)

Model 1: RC frame structure without P-Delta effect

Model 2: RC frame structure with P-Delta effect

Model 3: RC frame structure with shear wall at corners of structure

Model 4: RC frame structure with shear wall at mid of the outer periphery of structure

Model 5: RC frame structure with shear wall in '+'shape at centre

Model 6: RC frame structure with shear wall in box shape at centre(with opening)

Table 5: Maximum storey drift (for Zone II)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	0.001599	0.001912
Model 2	0.001642	0.001997
Model 3	0.000822	0.001113
Model 4	0.000660	0.000871
Model 5	0.001286	0.001497
Model 6	0.000705	0.000761

Table 6: Maximum storey drift (for Zone III)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	0.001970	0.002333
Model 2	0.002033	0.002439
Model 3	0.001055	0.001461
Model 4	0.000885	0.001156
Model 5	0.001505	0.001827
Model 6	0.000896	0.001013

Table 7: Maximum storey drift (for Zone IV)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	0.002372	0.003001
Model 2	0.002443	0.003078
Model 3	0.001338	0.001903
Model 4	0.001140	0.001623
Model 5	0.001782	0.002244
Model 6	0.001109	0.001292

Table 8: Maximum storey drift (for Zone V)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	0.002908	0.003869
Model 2	0.002984	0.004076
Model 3	0.001821	0.002644
Model 4	0.001140	0.002275
Model 5	0.002258	0.002937
Model 6	0.001492	0.001786

5.3 Modal Mass Participation Ratio

The modal mass participation ratio for the models are obtained.The modes are decided in such a way that the sum of the modal mass participation ratio of all the modes should be greater than 90%.In these models it is attained at 16th mode.As per the code IS 1893(part I):2016 and IS 16700:2017 the sum of first three modes should be greater than 65% and the sum of all the modes should be greater than 90%.All the models satisfy this for 16 modes.If the conditions are not satisfied than the modes should be increased until the conditions are satisfied.The modal mass participation for all the models are tabulated in table below.

Model 1: RC frame structure without shear wall
Model 2: RC frame structure with shear wall at corners of the structure
Model 3: RC frame structure with shear wall at mid of the outer periphery of structure
Model 4: RC frame structure with shear wall in '+'shape at centre
Model 5: RC frame structure with shear wall in box shape at centre(with opening)

Table 9: Modal Mass Participation Ratio

MODEL	MODAL MASS PARTICIPATION RATIO			
	MODE 3		MODE16	
	Sum ux	Sum uy	Sum ux	Sum uy
1	71.41%	69.71%	94.83%	95.20%
2	67.08%	65.27%	96%	96.14%
3	66.05%	65.51%	96.41%	96.52%
4	67.74%	65.61%	95.04%	93.42%
5	66.25%	65%	96.60%	95.75%

5.4 Base Shear

The base shear of the structure is the total design lateral force acting at the base of the structure. The models analyzed as per IS 1893(part I):2016 have higher values of base shear than models analyzed as per IS 1893(part I):2002.When models with and without shear wall analyzed as per IS 1893(part I):2016 are compared ,the models with shear wall have higher values of base shear compared to models without shear wall. The base shear for vertical earthquake is computed to the models as per IS 1893(part I): 2016.According to this the 2/3rd of the lateral load acting on structure due to earthquake is considered as vertical load due to earthquake and analysed. The base shear obtained due to vertical earthquake are too less than the gravity loads and hence are ignored in design.

For Maximum Base Shear variation (for Zone II, III, IV, V)
Model 1: RC frame structure without P-Delta effect
Model 2: RC frame structure with P-Delta effect
Model 3: RC frame structure with shear wall at corners of structure
Model 4: RC frame structure with shear wall at mid of the outer periphery of structure
Model 5: RC frame structure with shear wall in '+'shape at centre

Model 6: RC frame structure with shear wall in box shape at centre(with opening)

Table 9: Maximum Base Shear (in kN) (for Zone II)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	644.717	716.925
Model 2	627.823	706.299
Model 3	931.664	1041.652
Model 4	1043.718	1179.401
Model 5	907.795	1076.816
Model 6	1235.323	1382.231

Table 10:Maximum Base Shear (in kN) (for Zone III)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	1007.261	1129.139
Model 2	979.476	1108.766
Model 3	1490.62	1655.668
Model 4	1669.898	1928.732
Model 5	1452.473	1723.352
Model 6	1976.517	2217.392

Table 11:Maximum Base Shear (in kN) (for Zone IV)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	1602.98	1782.513
Model 2	1577.808	1790.812
Model 3	2559.191	2922.596
Model 4	2576.96	2917.718
Model 5	2391.116	2738.565
Model 6	3058.75	3493.34

Table 12:Maximum Base Shear (in kN) (for Zone V)

Models	IS 1893(part I):2002	IS 1893(part I):2016
Model 1	2472.801	2831.357
Model 2	2420.616	2774.026
Model 3	3864.663	4368.767
Model 4	3885.665	4416.058
Model 5	3469.509	4080.251
Model 6	4580.16	5208.97

6.CONCLUSIONS

i. The models analyzed as per the codal provisions in IS 1893(part I):2016 have higher values of storey displacement than the models analyzed as per IS 1893(part I):2002 and exceeds the permissible limits for zone V with IS 1893(part I):2002 and for zone IV, V with IS 1893(part I):2016. This is due to higher factor of safety considered in IS 1893(part I):2016.

ii. The models without shear wall analyzed as per the codal provisions in IS 1893(part I):2016 have higher values of storey drift ratio than the models analyzed as per IS 1893(part I):2002 and The maximum drift ratio exceeds permissible limits only in chart 16 (seismic zone V using IS 1893(part I):2016) by model 1(frame structure without shear wall) having value of maximum drift ratio as 0.004076. This is due to higher factor of safety considered in IS 1893(part I):2016.

iii.The modal mass participation ratio of the models is according to the provisions in IS 1893(part I):2016 and IS 16700:2017 at mode 3 and mode 16 for the analysis.

iv. The models analyzed as per IS 1893(part I):2016 have higher values of base shear than models analyzed as per IS 1893(part I):2002.When the models with and without shear wall analyzed as per IS 1893(part I):2016 are compared,the models with shear wall have higher values of base shear compared to models without shear wall.

v. The base shear of vertical earthquake is computed to the models as per IS 1893(part I):2016.According to this the 2/3rd of the lateral load acting on the structure due to the earthquake is considered as vertical load due to earthquake and analyzed.The base shear obtained due to vertical earthquake are too less than the gravity loads and hence are ignored in design.

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