SEISMIC AND WIND ANALYSES OF RC TALL STRUCTURES WITH SHEAR WALLS AND BRACINGS

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Abstract - In the present study, effect of different positions of bracings and shear walls on performance of 45 storeyed RC tall structure. Five different types of models with different position of shear wall and bracing are modelled using ETABS (Version 2015) software. Response Spectrum Analysis is carried out as per IS 1893–Part 1 (2002) . Seismic parameters such as storey displacement, storey drift ratio and storey shear are calculated for seismic zone IV. Lateral displacements due to Wind Load Analysis (WLA) are also found out considering IS 875–Part 3 (1987) codal guidelines. The considered RC tall structure models showed similar variation of seismic parameters. Among the inclusion of bracings and shear walls at different positions in the considered RC tall structure models, location of shear wall at middle shows lesser values of storey displacement, storey drift ratio and lateral displacements, thereby making the structure to be safe against seismic and wind forces.

Key Words : Tall structure, Shear walls , Bracings, Response Spectrum Analysis (RSA), Wind Load Analysis (WLA), Storey displacement, Storey drift ratio, Storey shear and Lateral displacement.

1. INTRODUCTION

An earthquake is a trembling movement of the ground, caused by the slippage of a fault line in the earth's crust. An explosive slippage on a fault line leads to an immediate unleash of elastic potential energy stored in rocks which are subjected to strain. This explosive unleash of energy leads to earthquake. Earthquake causes low frequency sound waves referred to as seismic waves to propagate through the earth's crust or on its surface.

Buildings are defined as structures which are utilized by the people as sanctuary for living, operating or storage. With the increase in population together with the evolution and commercial activities, speedy urbanization has taken place which has arisen continuous movement of rural individuals to urban areas. Thus it is clear that the horizontal area constraint is becoming a frightful scenario in metropolitan cities. To regulate this scenario, vertical area utilization demands the development of tall structures According to IS 16700 (2017), the structures whose height is greater than 50 m and less than 250 m are defined as Tall structures. To be safe against earthquake and wind forces, tall structures are usually provided with shear walls and bracings.

The RCC structural walls which resist the lateral forces due to earthquake and wind are referred to as shear walls. Shear walls contribute high strength and stiffness to buildings within the direction of their alignment and greatly reduce the lateral displacement of the structures. To regulate twisting in structures, these walls generally start at the foundation level and are continuous throughout the building height. The thickness of shear walls varies from 150 mm to 400 mm. Shear walls are usually provided along both length and width of the structures. Shear walls are necessary in tall structures which are subjected to wind and earthquake forces.

Bracings are the structural frames which resist lateral forces in tension or compression. Bracings are extremely economical in resisting lateral forces and wind forces in tall structures. The various varieties of bracings are X-bracing, V-bracing, Diagonal bracing, Chevron bracing, Knee bracing and Eccentric bracing. In case of tall structures, strength and stiffness is very important criteria to regulate storey drift, storey displacement and storey shear. The bracing systems resist the lateral forces and transfer the axial forces to the columns which are the good structural systems.

2. BUILDING DESCRIPTION : Table 1 shows the description of developed RC tall structure models considered in the present study.

Table 1 : Description of developed RC tall structure models

Sl. No.	Parameter	Remarks
1	Structural type	Commercial

Sl. No.	Parameter	Remarks
2	Total stories	45(3B+G+41)
3	Total height of building	157.5 m
4	Bays width in X- and Y-directions	6 m
5	Size of column	900x1200 mm
6	Size of beam	600x750 mm
7	Thickness of slab	150 mm
8	Storey height	3.5 m
9	Grade of concrete for beams	M40
10	Grade of concrete for columns	M40
11	Grade of concrete for slabs	M40
12	Grade of steel	Fe500
13	Poison's ratio of concrete	0.2
14	Density of concrete block	18 kN/m^3
15	Density of concrete	25 kN/m^3
16	Thickness of shear wall	300 mm
17	Type of bracing	X-bracing
18	Size of bracing	Single ISA 200x100x15 @ 33.6 kg/m
19	Live load on floor	4 kN/m^2
20	Dead load on floor	2 kN/m^2
21	Wall load	14.85 kN/m
22	Damping ratio	5%
23	Soil type	Medium
24	Zone factor	IV (Severe)
25	Importance factor	1.5
26	Response reduction factor	5
27	Wind speed	50 m/s
28	Terrain category	2
29	Risk coefficient (k1 factor)	1
30	Topography (k3 factor)	1
31	Windward coefficient	0.8
32	Leeward coefficient	0.5

Table 2 shows the details of RC tall structure models with different position of shear walls and bracings considered for seismic and wind analyses. Figure 2 shows the plan, elevation, and 3D view of all the developed RC tall structure models.

Sl. No.	Model No.	Shear wall position	Bracing position
1	TS1 (Regular)	–	–
2	TS2	Corner	–

3	TS3	Middle	–
4	TS4	–	Corner
5	TS5	–	Middle

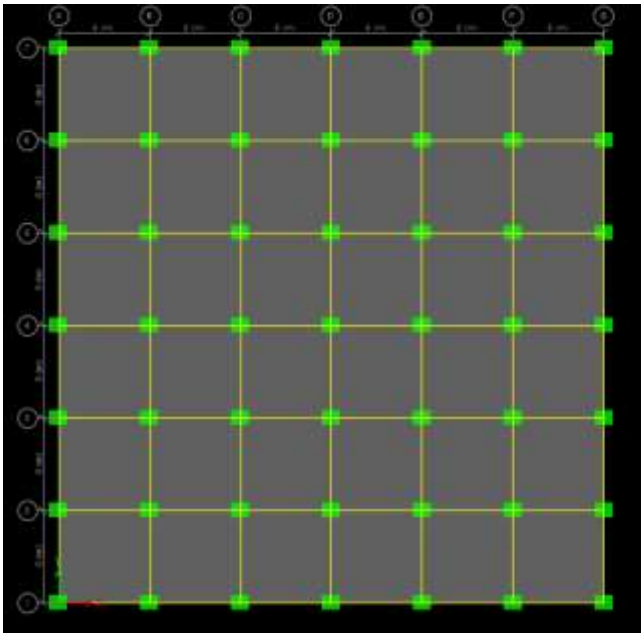


Fig. 2 (a) : Plan of Model TS1

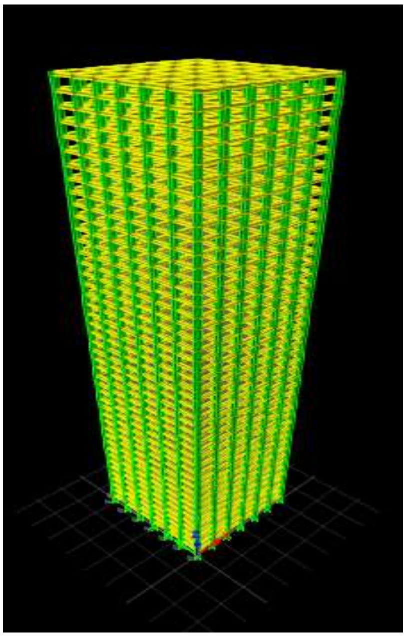


Fig. 2 (b) : 3D View of Model TS1

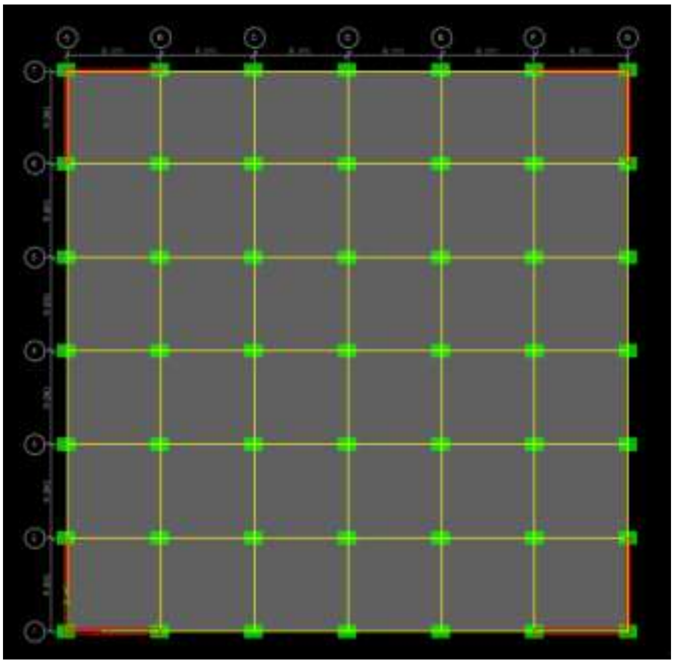


Fig. 2 (c) : Plan of Model TS2

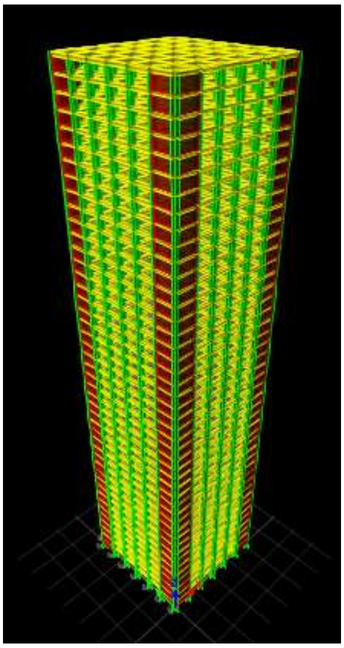


Fig. 2 (d) : 3D View of Model TS2

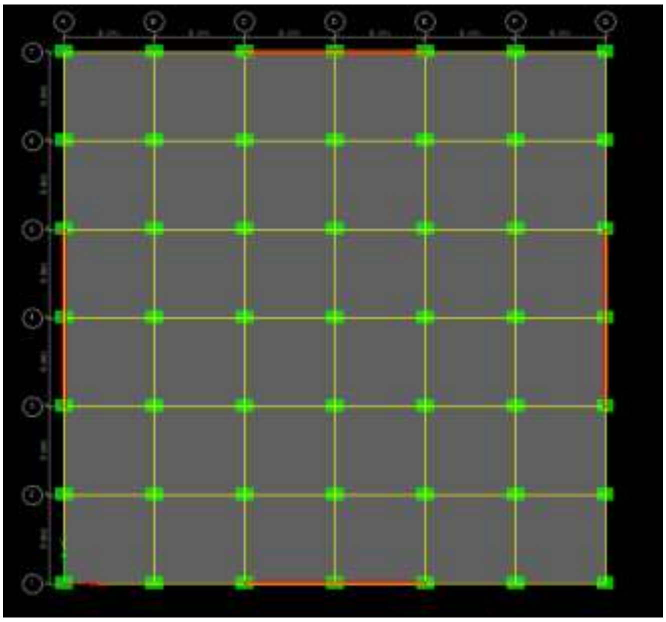


Fig. 2 (e) : Plan of Model TS3

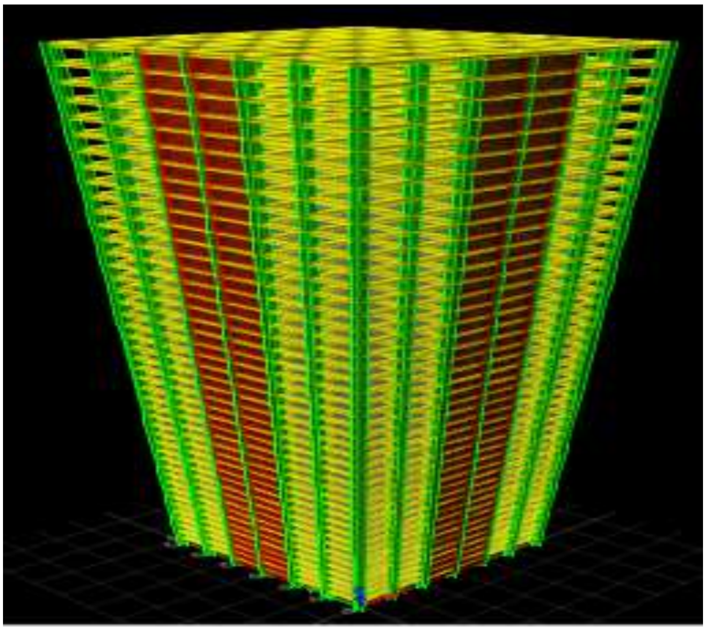


Fig. 2 (f) : 3D View of Model TS3

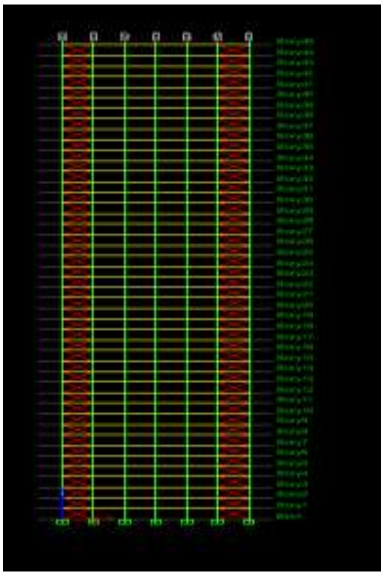


Fig. 2 (g) : Elevation of Model TS4

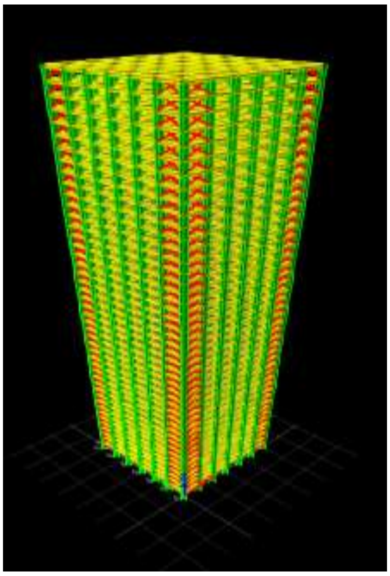


Fig. 2 (h) : 3D View of Model TS4

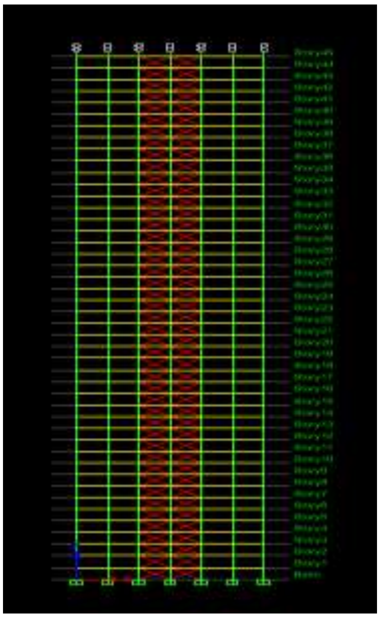


Fig. 2 (i) : Elevation of Model TS5

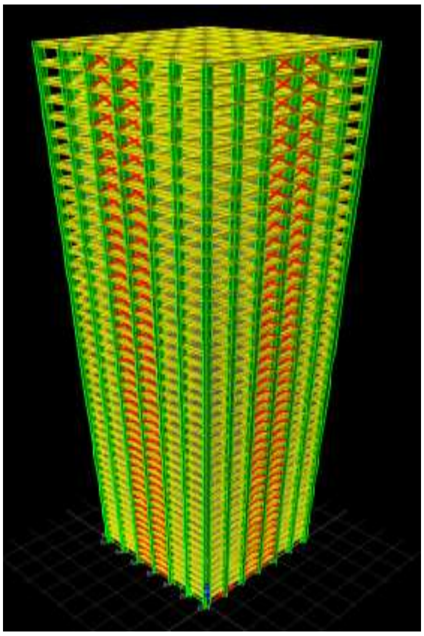


Fig. 2 (j) : 3D View of Model TS5

Fig. 2 : Plan ,elevation and 3D view of all the developed RC tall structure models with different position of shear walls and bracings

3. SEISMIC ANALYSIS : The developed RC tall structure models are subjected to Response Spectrum Analysis (RSA) as per IS 1893–Part 1 (2002) codal provisions. Different seismic parameters like storey displacement, storey drift ratio and storey shear, and lateral displacements due to Wind Load Analysis (WLA) are also found out considering IS 875–Part 3 (1987) codal guidelines for all the developed RC frame models from the analysis.

4. RESULTS AND DISCUSSION : Figures 3 and 4, Figs. 5 and 6, Figs. 7 and 8, and Figs. 9 and 10 show respectively the variation of storey displacement, storey drift ratio, storey shear and lateral displacement over the number of storeyes in X and Y directions, obtained for all the RC tall structure models by RSA and WLA.

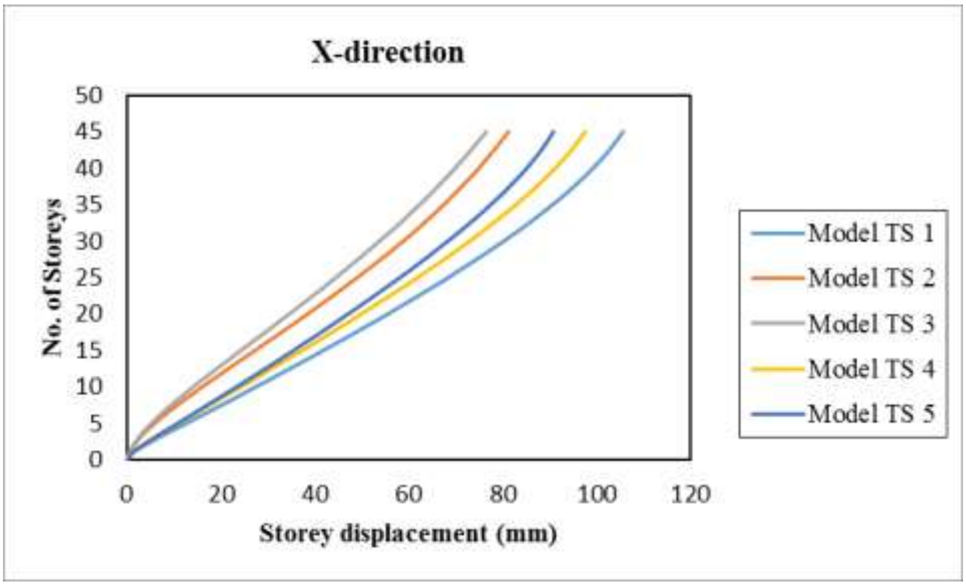


Fig. 3 : Variation of storey displacement in X–direction

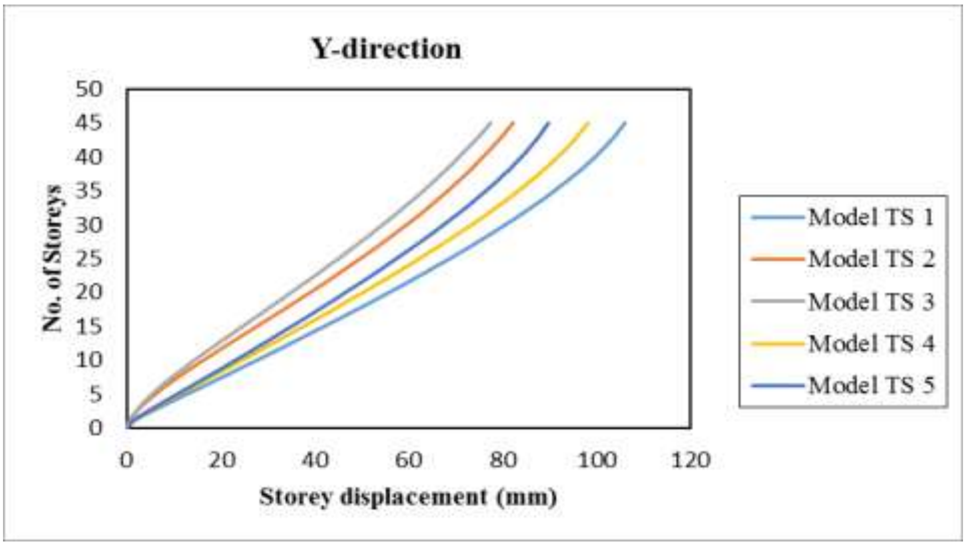


Fig. 4 : Variation of storey displacement in Y–direction

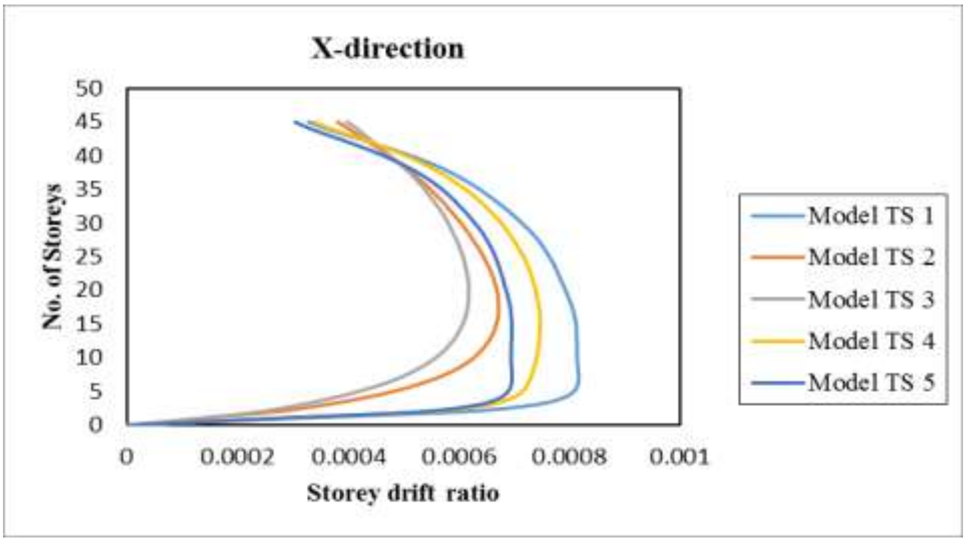


Fig. 5 : Variation of storey drift ratio in X–direction

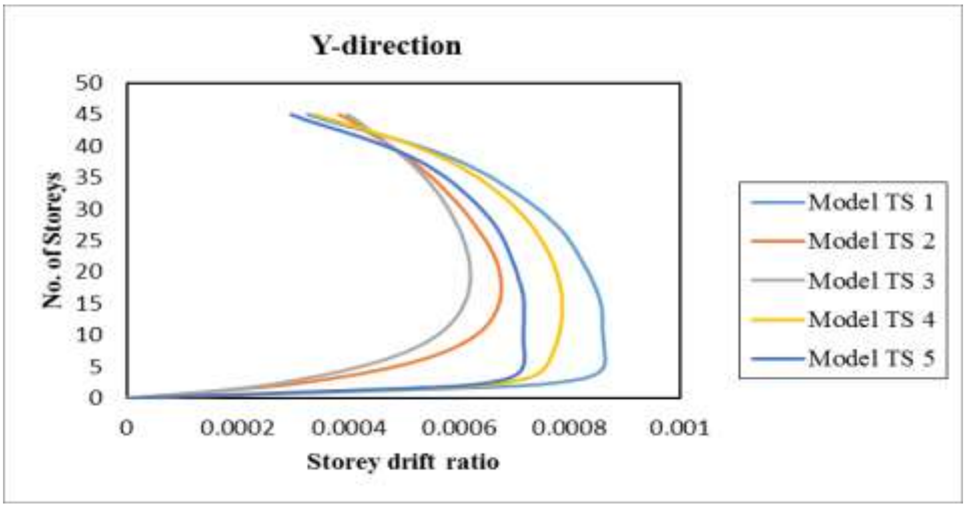


Fig. 6 : Variation of storey drift ratio in Y–direction

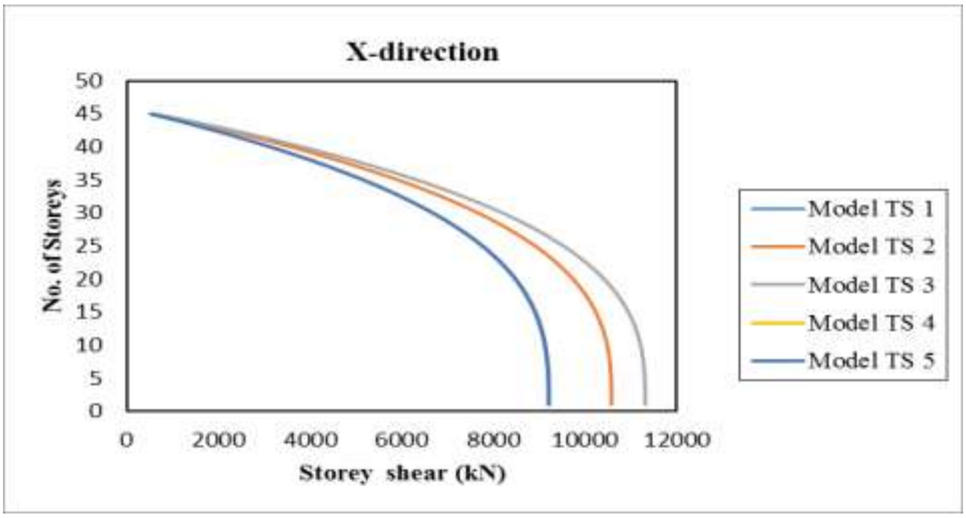


Fig. 7 : Variation of storey shear in X–direction

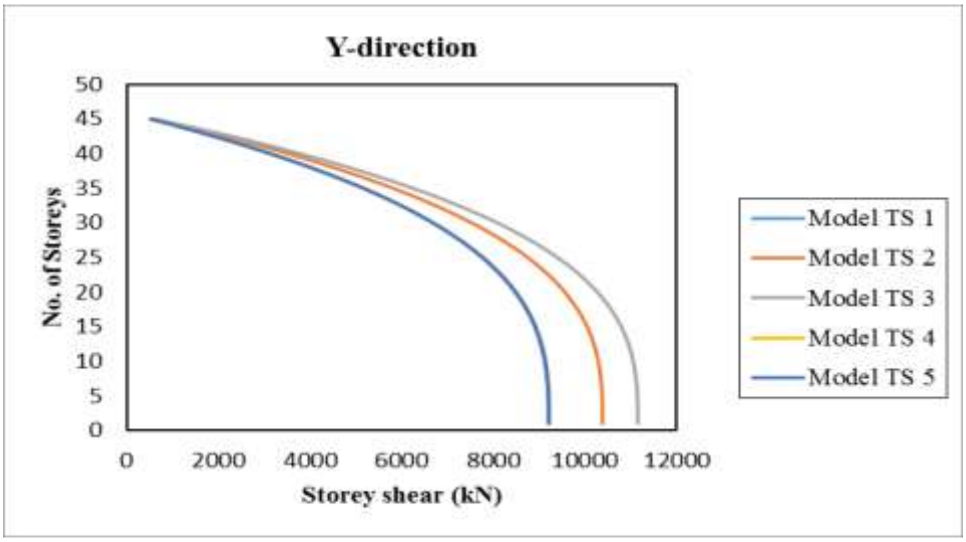


Fig. 8 : Variation of storey shear in Y–direction

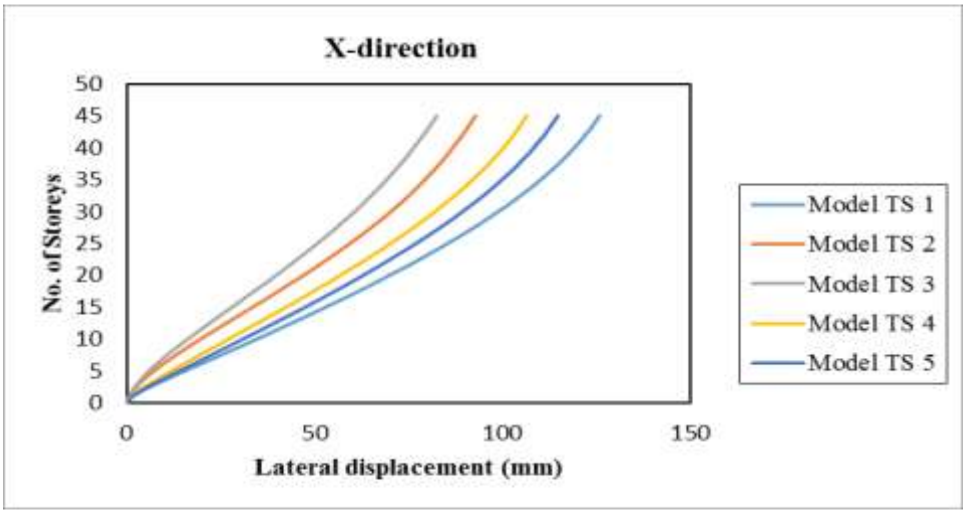


Fig. 9 : Variation of lateral displacement in X–direction

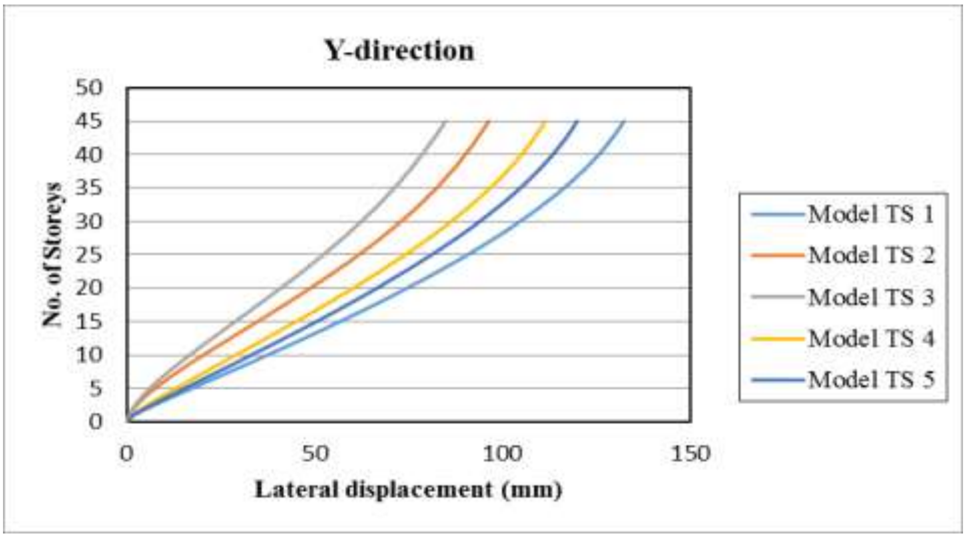


Fig. 10 : Variation of lateral displacement in Y–direction

From Figs. 3 to 10, it can be observed that all the models show relativley similar variation of sesimic paramertes in both X and Y directions.

The maximum storey displacement values (i.e. at the top storey) obtained in X and Y directions by RSA for all the developed RC models with different position of shear walls and bracings is shown in Fig. 11. RSA predicts Model TS3 having shear wall at middle to show minimum value of displacement in both X and Y directions than the other considered models.

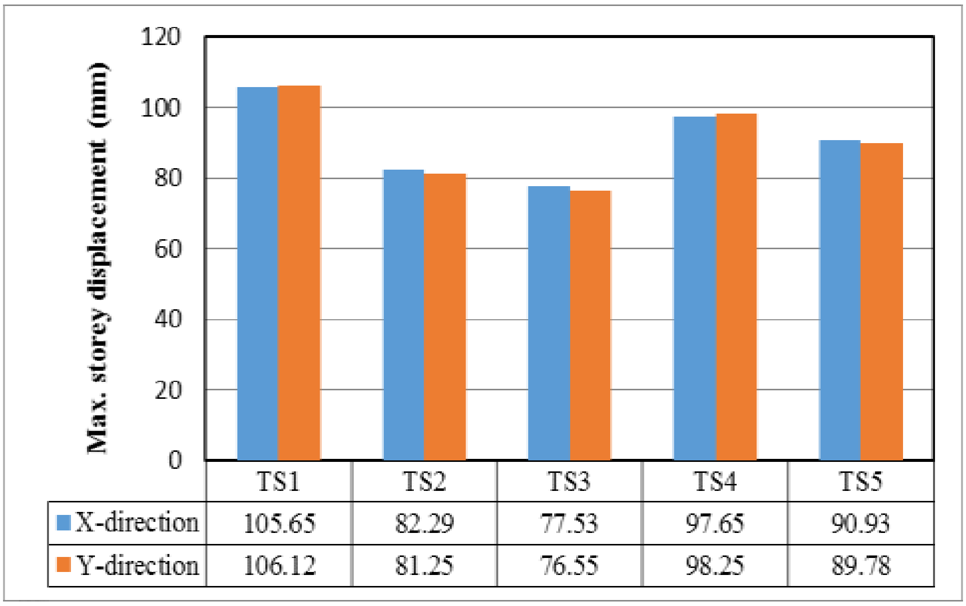
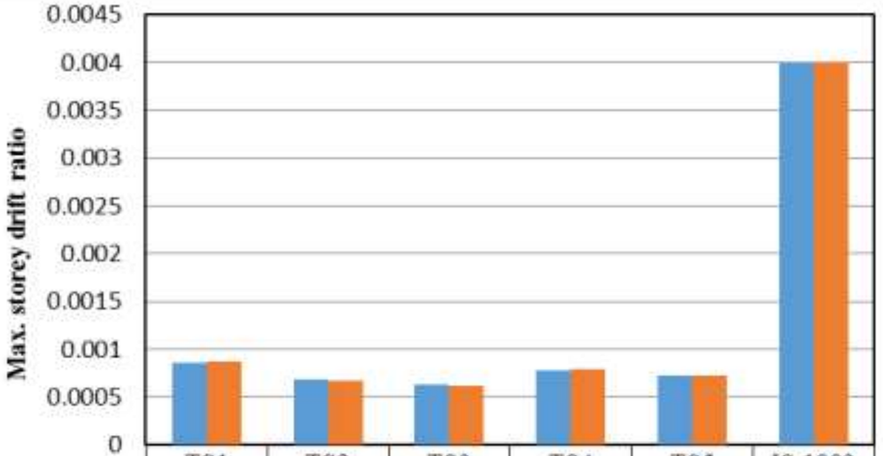


Fig. 11 : Maximum storey displacement in X and Y directions

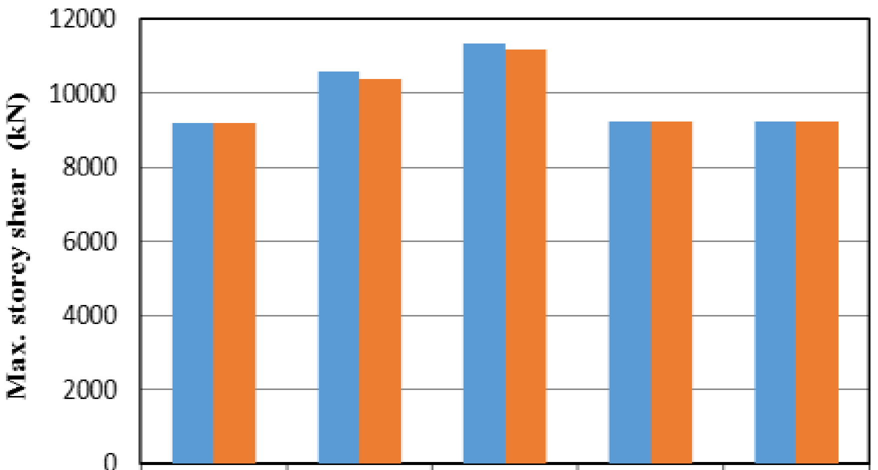
The maximum storey drift ratio obtained from all the tall structure models are within the maximum allowable limit as specified by Cl. 7.11.1 of IS 1893–Part 1 (2002). Further, Model TS3 with shear wall at middle shows minimum value of storey drift ratio in both X and Y directions than the other considered models.



	TS1	TS2	TS3	TS4	TS5	IS 1893
X-direction	0.000861	0.000686	0.000629	0.000783	0.000728	0.004
Y-direction	0.000865	0.000677	0.000621	0.000787	0.000719	0.004

Fig. 12 : Maximum storey drift ratio in X and Y directions

The maximum storey shear (i.e. Base shear) values obtained in X and Y directions due to lateral forces, for all the developed RC tall structure models is shown in Fig. 13. Models TS1 (Regular), TS4 (with bracing at corner) and TS5 (with bracing at middle) show same values of storey shear in both X and Y directions. Whereas, in models TS2 (with shear wall at corner) and TS3 (with shear wall at middle), storey shear in X-Direction are observed to be more than the storey shear values in Y-Direction. The maximum base shear value is observed in model TS3 having shear wall at middle, than the other considered models.



	TS1	TS2	TS3	TS4	TS5
X-direction	9201	10581	11316	9221	9217
Y-direction	9201	10385	11155	9221	9217

Fig. 13 : Maximum storey shear in X and Y directions

The maximum lateral displacement due to wind load, obtained from all the tall structure models are within the maximum allowable limit as specified by Cl. 20.5 of IS 456 (2000) is shown in Fig. 14. Further, Model TS3 having shear wall at middle shows minimum value of lateral displacement in both X and Y directions than the other considered models.

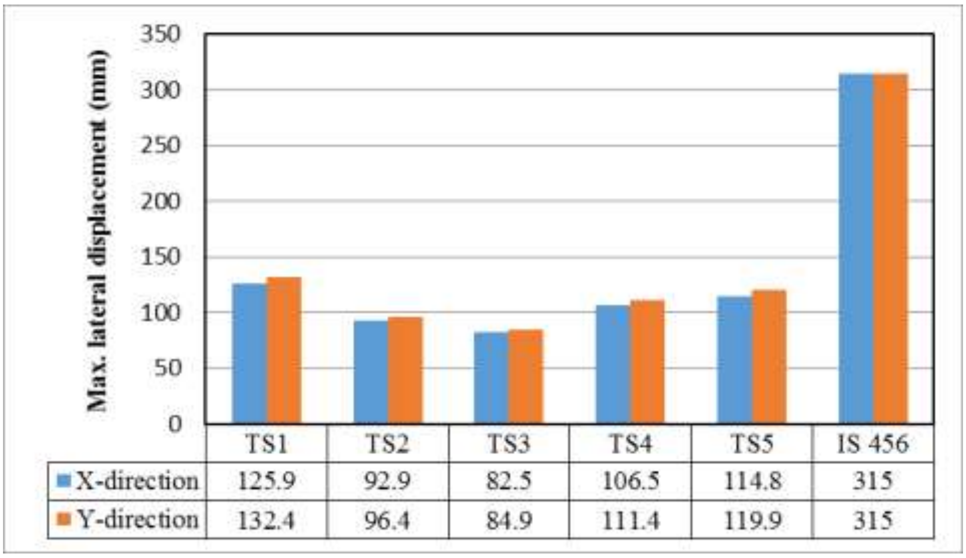


Fig. 14 : Maximum lateral displacement in X and Y directions

5. CONCLUSIONS : In the present study, effect of different positions of bracings (X–bracing) and shear walls on performance of 45 storeyed RC tall structures due to seismic and wind forces is investigated using ETABS software (Version 2015). Seismic parameters such as storey displacement, storey drift ratio and storey shear are found out using Response Spectrum Analysis (RSA) for seismic zone IV considering the stipulations laid down in IS 1893–Part 1 (2002) code. Lateral displacements due to Wind Load Analysis (WLA) are also found out considering IS 875–Part 3 (1987) codal guidelines.

The important conclusions drawn from the present study are explained below considering the results obtained from RSA and WLA.

1. All the developed RC tall structure models show similar variation of storey displacement, storey drift ratio, storey shear and lateral displacement in both X and Y directions for all the developed tall structure models.
2. RSA results indicate Model TS3 having shear wall at middle to show minimum value of maximum displacement at top storey in both X and Y directions than the other considered models
3. From seismic analysis, maximum storey drift ratio obtained for all the tall structure models are within the maximum allowable limit as specified by Cl. 7.11.1 of IS 1893–Part 1 (2002). Further, Model TS3 having shear wall at middle shows minimum value of storey drift ratio in both X and Y directions than the other considered models.
4. Models TS1 (Regular), TS4 (with bracing at corner) and TS5 (with bracing at middle) show same values of storey shear in both X and Y directions. Whereas, in Models TS2 (with shear wall at corner) and TS3 (with shear wall at middle) storey shear in X-Direction are observed to be more than the storey shear values in Y-Direction.
5. Base shear value is observed to be more in Model TS3 having shear wall at middle, than the other considered models.
6. Maximum lateral displacement due to wind load, obtained from all the tall structure models are within the maximum allowable limit as specified by Cl. 20.5 of IS 456 (2000). Further, Model TS3 having shear wall at middle shows minimum value of lateral displacement in both X and Y directions than the other considered models.

Concluding Remarks : Among the inclusion of bracings and shear walls at different positions in the considered RC tall structure models, location of shear wall at middle shows lesser values of storey displacement, storey drift ratio and lateral displacements, thereby making the structure to be safe against seismic and wind forces.

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