Analysis of High Rise Building with Dual Systems

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Abstract*: The dangerous natural hazards earthquake is the one which, cause great damage of the building and livelihood as well. The ground motion and structure behavior itself are the characters on which response of the structure depends during earthquake. In medium to high rise structures situated in earthquake prone area coupled shear walls are one of the systems commonly used to resist lateral forces. ETAB stands for extended version three dimensional analysis of building. Commonly Skyscrapers, parking garages, steel and concrete structures, high rise structures, portal frame structures with coupled shear wall are modelled using ETAB software. The study in this paper mainly emphasizes on structural behaviour of multi-storey building of regular shape with combination of coupled shear wall and bracings. Lateral load analysis for the following type of structures such as regular model, mass reduction model and soft storey models with coupled shear wall is done. Different storey height such as 30, 40 and 50 storey heights is considered. The above analysis is done using ETABS. Parameters such as axial force, shear force, bending moment and seismic response of regular model, soft storey model, mass reduction model, V bracing model and X bracing model for 30, 40 and 50 storey structures are studied. Axial force increase with increase in storey height. Soft storey and mass reduction models possess less axial force compared to regular model. Regular model is stiffer than other two models. V bracing model were effective in reducing the bending moment and axial forces in columns. Storey displacements were within permissible limits.

***Keywords*: Coupled shear wall, Base shear, Time period, Storey drift, Displacement, Static and Dynamic analysis (EQX,EQY).**

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I. INTRODUCTION

Design of earthquake resistant structure is a continuing area of research and development, ever since the earthquake engineering started. Establish susceptibility of various inadequate structures, every time they take place. The lesson imparted from the outcomes of earthquakes and the research work being carried out in the laboratories give better understanding about the performance of the structure and their component. A coupled shear wall is part of a shear wall system, made of coupling beams and wall piers and behaves as a slender cantilever beam under lateral loads. That is resisting external loads by forming a couple at the bottom of the base. The behavior of coupled shear walls is mainly governed by the coupling beams. In order to dissipate energy to provide damping during an earthquake, the coupling beams are designed for ductile inelastic behavior in order to resist earthquake force. The lateral load resisting members in buildings must be ductile and strong enough to absorb and dissipate strain energy by inelastic behavior. Reinforced concrete shear walls are an effective lateral load resisting structures. They transferred in-plane loads that are applied along its height to the wall by a diaphragm. These walls generally start at foundation level and are continuous throughout the building height. In modern structures wall openings are inevitably present due to windows, doors and service ducts. These highlights transform shear walls into coupled ones, which can be considered as at least two in-plane shear walls coupled together by an arrangement of connecting bars.

II. OBJECTIVES

The main objective of the thesis is to study the effect of earthquake forces on high rise buildings of different storey heights (30, 40 and 50 storey models) with coupled shear wall for regular, soft storey and mass reduction models. And to study the influences of bracings (X and V bracings) with coupled shear wall on structure. Axial force, shear force, bending moment, displacement, time period and base shear are the outcomes to be compared.

III. MODELLING USING ETABS

Based on the building shape whether it is regular or irregular most of the seismic analysis had prescribed the method of analysis for corresponding building. Majority of code suggest the use of linear static analysis whereas irregular building configuration dynamic analysis method is supported. In this study, lateral load analysis for the following type of structures such as regular model, mass reduction model, soft storey models with coupled shear wall is done. Different storey height such as 30, 40 and 50 storey heights is considered. The above analysis is done using ETABS. The study was carried out on multi-storey building subjected to earthquake forces. The coupled shear wall run throughout the height of the building and has constant length at the bottom of the building. Coupled shear walls are provided middle peripheral of the structure from the bottom to top of building.

TABLE I. STRUCTURAL PROPERTIES

PROPERTIES	DIMENSIONS
Plans	30, 40, 50 storey models
Column spacing	5m in both direction
Floor height	3.5m
Grade of concrete	M 40
Grade of steel	Fe 500
Slab thickness	200mm
Shear wall thickness	300mm
Coupled shear wall thickness	300mm
Bracing (X)	230mm X 230mm
Bracing (V)	230mm X 230mm
Coupled shear wall opening	3m X 1.5m
Live load	4 KN/m^2
Super dead load	1.5 KN/m2
Live load on roof	1.5KN/m2
Seismic zone	5 (very severe)
Seismic factor	0.36
Soil type	Medium type 2
Importance factor	1.5 (public building)
Reduction factor	5

TABLE II. SECTION PROPERTIES

Section	Beam	Column
30 Storey	300mm X 600mm	750mm X 750mm 600mm X 600mm 450mm X 450mm
40 Storey	300mm X 600mm	975mm X 975mm 750mm X 750mm 600mm X 600mm 450mm X 450mm
50 Storey	300mm X 300mm	1100mm X 1100mm 800mm X 800mm 650mm X 650mm 500mm X 500mm

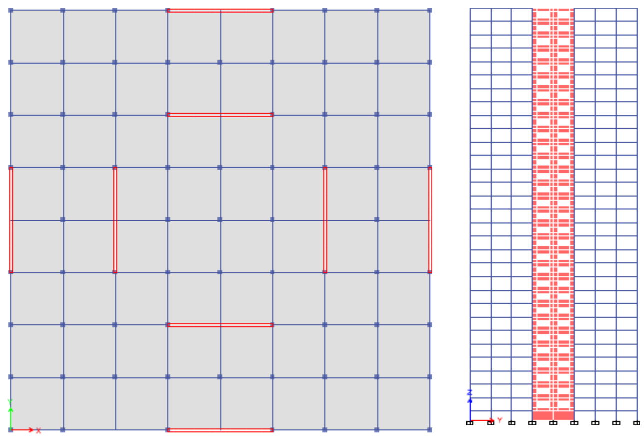

Fig 1. Plan and elevation of regular model

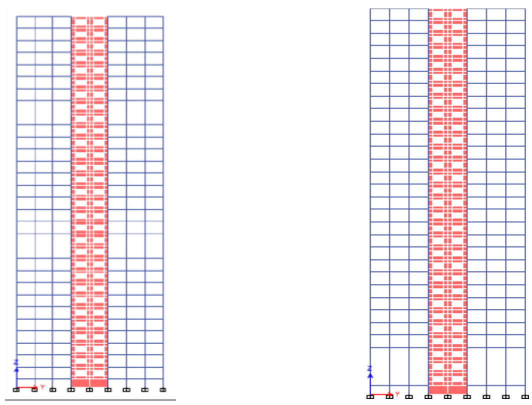

Fig 2. Elevation of mass reduction and soft storey model

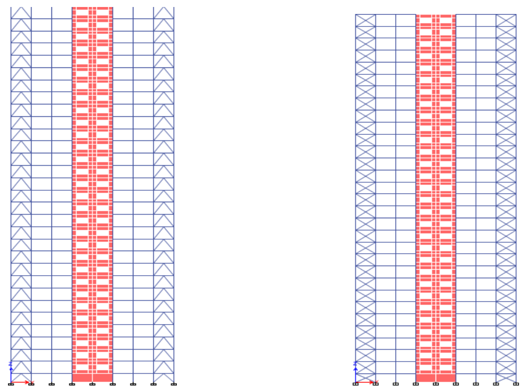

Fig 3. Elevation of V and X bracing model

IV. RESULTS AND DISCUSSIONS

Present study focuses on the behavior of high rise building with dual systems under the seismic forces. Response spectrum method analysis is carried out on 15 models of RC frame structure with shear wall and bracing combinations. Three different storey heights 30, 40 and 50 storey's are considered and modelled using ETABS Software. In this study we compare various parameter such as Shear force, bending moment, Axial forces, Base shear, Storey displacement and Time period.

A. Axial forces of models

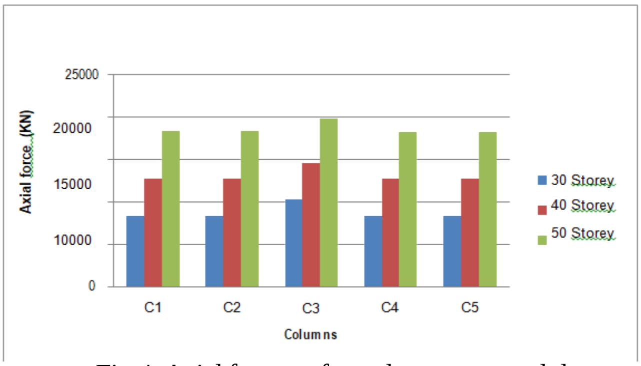

Fig 4. Axial forces of regular storey models

Axial force of regular model for 30, 40 and 50 storey structure is shown in Fig 4. C1, C2, C4 and C5 are the corner columns and C3 is the centre column. Central column C3 has maximum axial force as the forces from all sides concentrates equally on central column. Axial force of four corner columns is almost nearest value which indicates that the column forces are equally distributed to all four columns. Axial force for all 3 models indicates increase in force for all the columns. Axial force increases with increase in storey height. It has been observed that 30-35% of the axial forces are increased for every 10 storey height in each type of model. As the storey height increases the load on structure for every storey height increases, therefore axial force increases gradually.

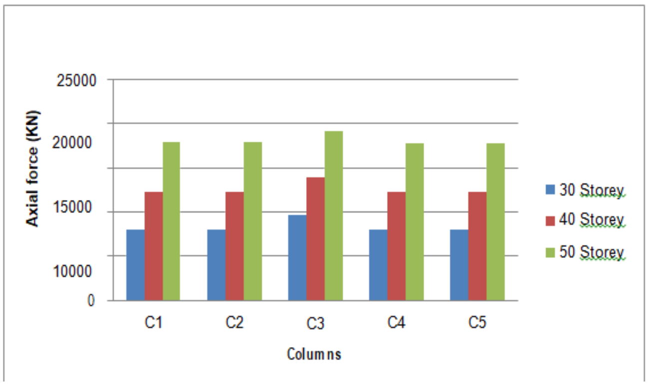

Fig 5. Axial forces of soft storey models

Axial force of soft storey model for 30, 40 and 50 storey structure is shown in Fig 5. The central column C3 has maximum force from the corner columns. Axial force of corner columns is almost nearly equal which is due to the equal distribution of the force. Comparing the models of different storey heights we can interpret that there is increase in axial force with increase in storey heights. The percentage of increase in axial force varies from 30 – 35 % for increase in each 10 storey. Forces on foundation will be less which leads to lesser size of foundation. Foundation cost gets reduced as axial force reduces. The stiffness of soft storey is less than other storey above which leads to weak zone. For soft storey the axial force is less when compared to regular building as the stiffness of regular model will be higher than that of soft storey model. There is a chance of failure which leads to collapse of the whole structure due to weak basement storey.

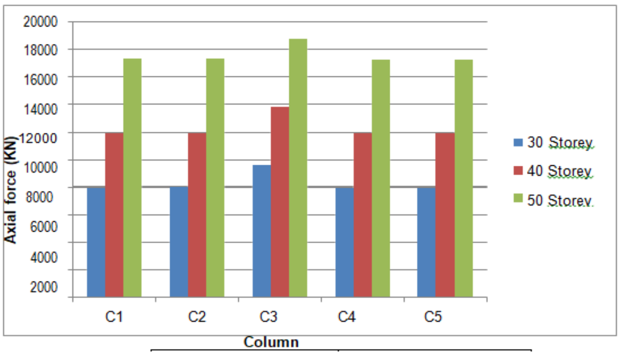

Fig 6. Axial forces of mass reduction storey models

Axial force of mass reduction storey for 30, 40 and 50 storey structure is shown in Fig 6. Mass reduction is done to reduce the dead weight of the structure which in turn reduces the forces. Mass reduction is done on every 10 storey height of the structure by removing the slab weight from the particular storey. Reduction in mass is almost same as soft storey concept which leads to reduction in stiffness of the structure. Central column C3 has maximum force when compared to all other four corner columns. Axial force for mass reduction model is less when compared to regular and soft storey models as there is considerable reduction in mass and stiffness. Reduction in mass will lead to reduction in axial force which will lead to reduction in size of foundation. But the stiffness will be less in mass reduced storey when compared to soft storey model which makes the storey weak for seismic forces and leads to collapse of the structure.

- Axial forces of X bracing models

Axial force of X bracing for 30, 40 and 50 storey structure is obtained. X bracings is given on all four corners of the structure and the force transfers to the column C1, C2, C4 and C5. Axial forces are computed for bracings alone on columns of the structure. Axial forces of X bracings increases linearly with increase in storey heights of 30, 40 and 50. As there is increase in the height of the storey the forces on the structure increases due to increase in dead weight of the structure. As X bracing models takes up the axial force predominantly, the structure will have high seismic withstanding capacity.

- Axial forces of V bracing models

Axial force of V bracing for 30, 40 and 50 storey structure is obtained. V bracings are given on all four corners of the structure and the force transfers to the column C1, C2, C4 and C5. Axial forces are computed for bracings alone on columns of the structure. Axial forces of V bracings increases linearly with increase in storey heights of 30, 40 and 50. V bracing model have higher withstanding capacity by transferring the lateral load safely. Axial force of V bracing is less than X bracing which leads to lesser force on foundation. Comparatively V bracing is effective than X bracing in axial force with high absorbing capacity.

B. Shear force of models

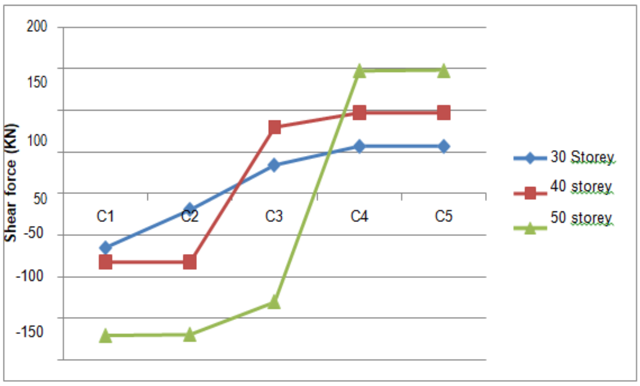

Fig 7. Shear force of regular storey models

Shear force of regular model for 30, 40 and 50 storey structure is shown in Fig 7. Maximum shear force on the column is taken into consideration. The axial force of regular model increased with increase in height of storey, hence shear force increased with varying height of storey. Graph shows the variation of shear force of columns for different storey heights. Due to higher axial force in the column the shear force gets increased. As the shear force is higher in the columns the lateral resisting capacity of the column is higher which gives a stronger structure.

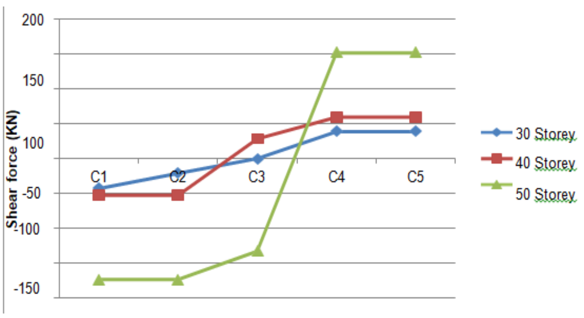

Fig 8. Shear force of soft storey models

Shear force of soft model for 30, 40 and 50 storey structure is shown in Fig 8. Maximum shear force on the column is taken into consideration. There is increase in shear force for 30, 40 and 50 storey height models. Shear force increases with increase in axial force, the axial force for soft storey model increased with increase in height of storey hence shear force increased with varying height of storey. As explained in the axial force section, the stiffness of soft storey will be less and shear force automatically gets reduced. Graph shows shear force of columns for different storey heights for soft storey model. As the stiffness gets reduced the shear force also reduces for soft storey structure. The shear resistance at soft storey will be very less which leads to weaker zone and eventually structure colapses.

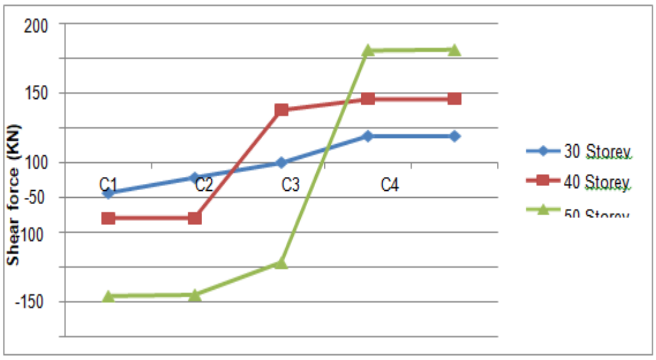

Fig 9. Shear force of mass reduction storey models

Shear force of mass reduction model for 30, 40 and 50 storey structure is shown in Fig 9. Maximum shear force on the column is taken into consideration. Shear force increases with increase in axial force, the axial force for mass reduced model increased with increase in height of storey hence shear force increased with varying height of storey. Shear force of middle column is less compared to corner columns as the outer column experiences more shear force. Shear force for mass reduction model is less when compared to regular and soft storey models as there is considerable reduction in mass and stiffness of the structure. Graph shows the variation of shear force of columns for different storey heights for mass reduction model. The shear force in mass reduction models is less compared to regular and soft storey models because the mass reduction models have double storey at every interval of 10 storey which leads to weaker zone in the structure and there is majority chance of structure collapse.

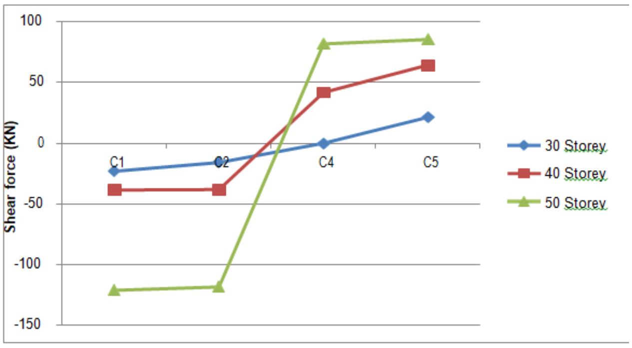

Fig 10. Shear force of X bracing models

Shear force of X bracing model for 30, 40 and 50 storey structure is shown in Fig 10. Maximum shear force on the column is taken into consideration. Shear force of the columns varies with increase or decrease with axial force. The shear force increases for X bracing model with storey height. The axial force for X bracing model increased with increase in height of storey hence shear force increased with varying height of storey. Graph shows the variation of shear force of columns for different storey heights for mass reduction model. The shear resisting capacity of bracing is less as bracing carries axial force such as tension and compression; therefore the shear value of X bracing is less than regular model.

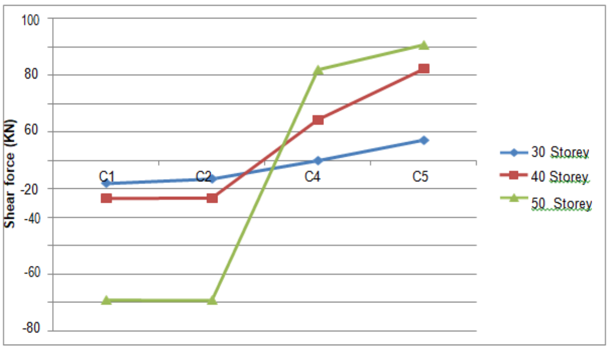

Fig 11. Shear force of V bracing models

Shear force of V bracing model for 30, 40 and 50 storey structure is shown in Fig 11. Maximum shear force on the column is taken into consideration. The axial force for V bracing model increased with increase in height of storey hence shear force increased with varying height of storey. Shear force of V bracing is less than X bracing which leads to lesser force on foundation. Comparatively V bracing is much more efficient than X bracing in resisting shear force. Graph shows the variation of Shear force of columns for different storey heights for mass reduction model. V bracing is more effective in resisting earthquake forces. Since V bracing with lesser shear value the structure possess higher lateral load resisting capacity when compared to X bracing.

C. *Bending Moment of models*

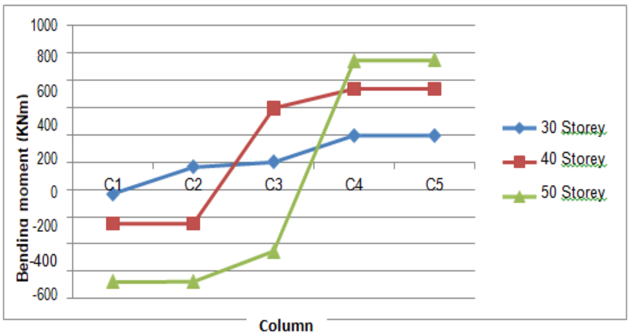

Fig 12. Bending moment of regular storey models

Bending moment of regular model for 30, 40 and 50 storey structure is given in Fig 12. Bending moment is maximum on all corner columns compared to middle column. Deflection in regular building is less than soft storey structures hence bending moment is higher in regular building. Regular model is more stiffer than other models which lead to higher bending moment. The increase in bending moment in corner columns compared to the middle column is due to the unbalanced load induced. Corner columns has two direction forces on it, hence it has maximum pull and tends to give maximum bending moment. The bending moment in regular building is higher which means that the structure is stiffer. Due to this the structure has the maximum capacity to withstand the lateral load.

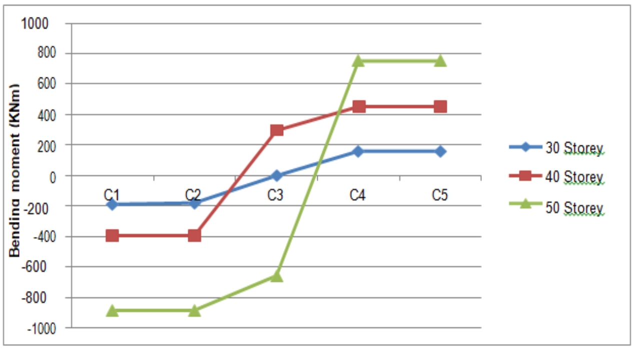

Fig 13. Bending moment of soft storey models

Bending moment of soft storey model for 30, 40 and 50 storey structure is given in Fig 13. Bending moment is maximum on all corner columns compared to middle column. Stiffness in soft storey model is less which means deflection is higher. As the deflection increases, bending moment decreases gradually. Bending moment for different storey height is shown in graph. Bending moment in soft storey model is comparatively less than regular model because the stiffness of the soft storey model is less due to weak zone. The structure tends to deflect easily in the weak zone which leads to failure of the member.

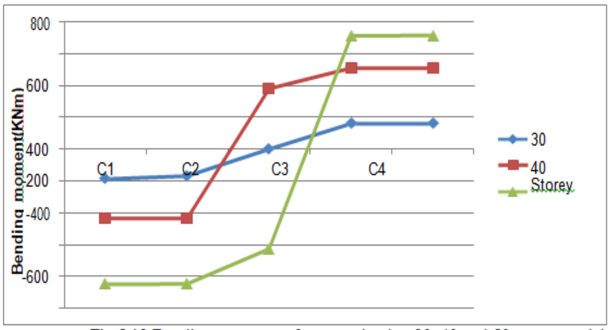

Fig 14. Bending moment of mass reduction models

Bending moment of mass reduction model for 30, 40 and 50 storey structure is given in Fig.14.Bending moment is maximum on all corner columns compared to middle column. Stiffness in mass reduction model is less when compared to other two models which means deflection is higher. As the deflection increases, bending moment decreases considerably for mass reduction model. Bending moment for different storey height is shown in graph. In mass reduction model the structure gets deflected more than other two models which leads to failure of the structure due to less stiffness of members in the structure.

D. Seismic response for different models

TABLE III. Seismic parameters considered for 30 storey model

MODELS / PARAMETERS	REGULAR STOREIS	MASS REDUCTION STOREIS	SOFT STORIES	BRACING X	BRACING V
STOREY DISPLACEMENT (mm)	140.944	150.323	144.048	31.00	28.00
STOREY SHEAR (KN)	18636.000	17990.000	17970.000	398.3240	409.6467
TIME PERIOD (Sec)	2.866	2.899	2.909	0.042	0.039
BASE REACTION (KN)	457253.423	426829.340	426159.962	441244.955	465004.5254

Seismic response spectrum analysis is done for all the models and the response of the structure is given in the above table. Displacement of regular, soft storey and mass reduction models is compared in which mass reduction model has highest displacement. According to IS 1893 the permissible limit for 30 storey building is 210 mm. All the models are within permissible limit. In the mass reduction model the mass of the structure is reduced which reduced the stiffness of the structure hence displacement is more on the model. Due to less stiffness the storey shear is less for mass reduction model and soft storey model. As the displacement increases the time period also increases i.e., regular model has less time period compared to other two models. Mass of the regular model is more hence the base reaction of the regular model is higher than soft storey and mass reduction models. Storey displacement is less for V bracings compared to X bracing model. Storey shear is less for X bracing as stiffness of the model is less. Time period is increased for X bracing as the displacement is increased. Comparatively regular model and V bracing has less displacement and more efficient.

TABLE IV. Seismic parameters considered for 40 storey model

MODELS / PARAMETERS	REGULAR STOREIS	MASS REDUCTION STOREIS	SOFT STORIES	BRACING X	BRACING V
STOREY DISPLACEMENT (mm)	217.98	226.43	214.55	40.37	40.22
STOREY SHEAR (KN)	20411.00	19194.00	19587.00	375.56	432.14
TIME PERIOD (Sec)	3.925	3.952	3.947	0.024	0.0267
BASE REACTION (KN)	636499.30	602098.10	613057.21	621781.84	640213.52

TABLE V. Seismic parameters considered for 50 storey model

MODELS / PARAMETERS	REGULAR STOREIS	MASS REDUCTION STOREIS	SOFT STORIES	BRACING X	BRACING V
STOREY DISPLACEMENT (mm)	328.34	340.537	330.052	51.74	46.44
STOREY SHEAR (KN)	22186.00	20340.00	21204.00	225.86	254.634
TIME PERIOD (Sec)	4.984	5.253	4.985	0.0136	0.014
BASE REACTION (KN)	835679.17	757366.86	779954.45	822318.72	845422.51

Similarly as 30 storey model 40 and 50 storey models too have less displacement for regular model when compared to soft storey and mass reduction models. V bracing is efficient than X bracing for 40 and 50 storey models. According to IS 1893 the permissible limit for 40 storey building is 280 mm. All the models are within permissible limit. According to IS 1893 the permissible limit for 50 storey building is 350 mm. All the models are within permissible limit.

V. CONCLUSION

In view of the results of the investigation, the accompanying conclusions are drawn:

- Axial force of models increased with increase in storey height due to increase in load on structure and central columns are carrying maximum force.
- It has been observed that 30-35% of the axial forces are increased for every 10 storey in each type of model (regular, soft, mass reduction, X bracing and V bracing).
- Axial force of soft storey and mass reduction models is less when compared with regular model due to less stiffness. Therefore the size and cost of foundation gets reduced.
- Axial force of V bracing model is less than X bracing model, hence V bracing model is effective with high absorbing capacity.
- It has been observed that as axial force increase, shear force increases accordingly. Shear force of regular model with varying height is higher than that of soft storey and mass reduction models due to less stiffness of members.
- Shear force of V bracing model with 30, 40 and 50 storey building is lesser than X bracing model which leads to higher capacity of lateral resistance.
- Deflection in regular building is less than soft storey structures hence bending moment is higher in regular building. Regular model is stiffer than other models which lead to high resisting capacity.

- Base reactions were compared and 36.47%, 39.84% and 43.58% of total load is carried by shear walls in 30, 40 and 50 storey models respectively.
- Time period has increased 36% for every 10 storey height increment in 30, 40 and 50 respectively storey model except X and Y bracing models.
- As far as stiffness is concerned X and V braced structure showed more stiffness than other models because bracings carries maximum lateral forces without failure of structure.
- V bracing models with coupled shear wall were effective in reducing the shear force and axial forces in the columns.
- Regular model was found to be having greater lateral resisting force in comparison with other models as the stiffness is higher in regular model.
- All storey displacement was within permissible limit when checked with h/500 according to IS 1893.

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