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Comparative Study of Multi-Storied RC Building with and without Shear Wall using ETABS

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ABSTRACT

After seeing the devastation that earthquakes may cause firsthand over the last decade, it is crucial to take earthquake risk into account when developing structures of medium to high height. The need for high-rise structures was brought on by the lack of available land and the subsequent migration of people to urban regions. Considering earthquake pressures is essential for assessing a building's stability, especially in tall structures. Since column stiffness is directly related to earthquake safety, it is essential that sufficient levels of stiffness be built into the columns themselves. However, it is challenging to create columns of such a big scale in urban areas where space is at a premium. Hence an alternative was found for high rise buildings which is termed as shear wall. Shear wall behaves as a wide column. It has very high in plane stiffness and supports gravity load. It serves the purpose of carrying heavy load and provides resistance against earthquake forces. Because shear walls are so good at mitigating lateral loads caused with things like wind and earthquakes, it's crucial that they be placed in the best possible locations in multi-story structures. The primary goal, then, is to pinpoint those locations. For this reason, determining the correct and most effective placement for shear walls is crucial. A search has been undertaken for the optimal placement of shear walls in symmetrical buildings.

A 3-D analysis of shear wall structures is done by ETABS software package. Different models are drawn by adopting different locations and configurations of shear walls. Different parameters studied are Storey Displacement and Storey Drift. Based on these parameters, best model has been suggested.

Keywords: ETABS, Shear wall, Storey displacement, Storey drift, Base shear.

1. Introduction

1.1 General

A shear wall is kind of vertical structure part which can withstand the shear, moment, & axial loads imparted on it with lateral loading & gravity loading transferred to it from other supports. Reinforced concrete walls, including raise wells and shear walls, are often required for multi-story structures. The ideal building design would have the structure's mass center coincide with its geometric center. A number of structural engineering applications benefit greatly from shear walls due to their higher in-plane stiffness & strength which is utilized into resisting both larger horizontal masses & support gravity masses. A building's structural structure may be made more rigid by including a shear wall, which has the primary function of increasing the building's resistance to lateral loads.

To protect against lateral masses which could be generated with earthquakes & wind impact, shear walls are often utilized like a vertical structural element in today's high-rise structures. There will be a wide variety of shear wall forms employed, from standard square and rectangular sections to more complex designs including channels, Ls, boxes, and barbells. In a building, walls serve to partition and enclose space, while cores house and transport utilities like elevators. Openings in walls are required for windows into outside doors, walls and corridors in interior walls, and stairwells in elevated central cores. From an architectural and functional point of view, the size and location of apertures might be different.

Shear wall construction has become more popular for usage in the framework of tall buildings, especially when erecting a service flat or an office/industrial skyscraper. This technique has been developed and tested to create a cost-effective structural structure for multi-construction buildings with a height of 30-35 stories. No tall structure with a shear wall component has collapsed during severe winds & earthquakes in the 30 years of recorded service history.

2. Literature Review

Mohammed yousuf, P.M. shimpale (2016) [1] One of the primary goals of seismic design is to design and construct buildings in such a manner that they sustain as little damage to their structural components as possible during earthquakes. The purpose of this work is to conduct dynamic study of a concrete structure having non-uniform foundation. Both a symmetrical and an asymmetrical G+5 building model are selected for the study. The metalbased computer programme ETABS nine is used to analyze R.C.C. construction. 5. Response estimates are doled out, including those for things like lateral pressures, base shear, building drift, and construction shear. There are four possible column cross-section variations that are considered when evaluating their ability to withstand lateral forces. The research also discusses how changes in building configuration affect the structural reaction. An earthquake of a certain magnitude triggers dynamic reactions in accordance with IS 1893-2002(part1). Response Spectrum analysis is used for dynamic systems. Each model's dynamic response was estimated using the CQC (full quadratic combination) technique, & results were compared at five, ten, fifteen, and two hundredths of a damping.

H. Rahangdale, S. R. Satone (2016) [2], the shear wall study and design survey for the multi-story structure was dispensed. An initial study is presented in this document for a G+5 building in Zone IV, analyzing the effects of changing the location and form of the shear wall to validate parameters such as axial load & moments. To conduct this study, the industry standard software program STADD- pro was used. There is a description of the shear wall analysis done so far on this project. As a method of mitigating impact lateral loading upon structure, a shear wall may be a wall made up of braced panels (also called shear panels) in structural engineering. Braced wall lines are constructed to resist the forces of nature, particularly wind and earthquake hundreds. Different shear wall locations were discovered to cause different amounts of axial stress on the column. Lacking a shear wall, the column must bear the bulk of the load and moment. Comparing Case 3 to Cases 1 and 2, it is clear that safety is increased in Case 3. Because the reinforcing specialization of walls is quite evident and hence easily enforced on site, shear walls are straightforward to build. Therefore, shear walls amongst most efficient construction components into withstanding lateral stresses while an earthquake. Damage caused by earthquake and strong wind lateral pressures may be mitigated by the use of shear walls.

P. P. Chandurkar, Dr. P. S. Pajgade (2015) [3] Analyses of RCC buildings with & without shear walls for instability were conducted. In this research, the efficacy of a shear wall is examined using four distinct models. The first model is a blank frame, while the last three are all twin-type structures. A 10-story structure is subjected to an earthquake load into seismic zones II, III, IV, & V. For each scenario involving a commuting column and a shear wall, the lateral loading, the story drifting, & total value needed into basement have been computed. And we found that, compared to the other models, construction with a shear closure in short span at the corner (model 4) saves money while constructing a ten-story structure. One may get the conclusion that structures with less than 10 storeys would benefit little from a shear wall of such a massive size. The shear wall has been shown to be both cost-effective & efficient in high-rise construction.

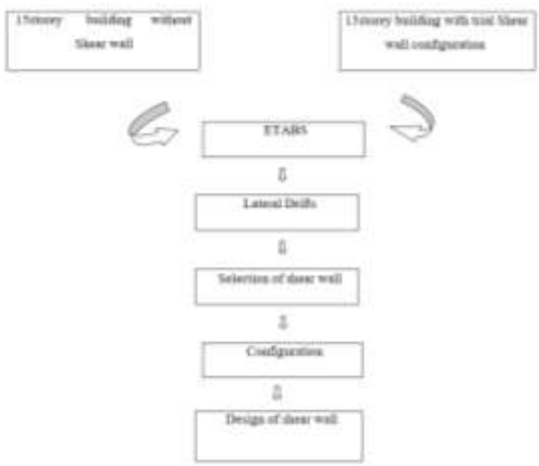
R. Chittiprolu, R.Pradeep Kumar (2014) [4], Learn about the value of shear walls into high-rising asymmetrical structures throughout research. In order to understand lateral hundreds, story drifts, & torsion effects, a research was conducted on an uneven high-rise structure with and without a shear wall. We may deduce that shear walls in an irregular building are very resistant to lateral loads. Additionally, it was concluded that lateral load analysis was done for both the structure without the shear wall & structure having shear wall using dynamic linear modeling using the response spectrum approach. The results for the frame's lateral forces and narrative drifts are contrasted. It is also shown that when shear walls are intercalary at proper positions of frames with lowest lateral forces, lateral forces are reduced. Shear walls, it is deduced, provide a high degree of protection against lateral loads in an irregular building. They may be utilized for mitigating torsion impact.

Thorat S.R. and Salimke P.J. (2014)[5], braced concrete frames' seismic reaction was compared to that of shear frames'. Measurements of shear wall width and bracing patterns (X, K, and inverted V (IV)) were taken into account. A structure with a basic symmetric layout consisting of three bays in each directions was chosen to compare the performance of shear-wall frame with that of braced concrete frame. Through strategic placement of shear walls & braced components throughout the 15-story structure, a variety of shear wall frames & braced concrete frame configurations were constructed. Brace configurations of the X, K, and FV varieties were chosen. In all, 24 still images were studied.

3. Methodology

When an earthquake shakes the ground, the building begins to vibrate. Earthquake-induced ground shaking may be resolved along either of three axes that are perpendicular to one another. The building vibrates in all three dimensions as a result of this motion. Horizontal motion is more prominent than other types of shaking.

When the soil underneath a structure shifts, the foundation shifts abruptly as well, although the roof usually remains in the same spot (inertia). Designing a building to code requires taking into account lateral force in both of building's orthogonal horizontal axes.



4. Equivalent Linear Static Analysis

Dynamic aspect of loading should be accounted for into any design to mitigate seismic damage.

Linear static techniques are frequently overkill for anything more complex than a basic regular structure. In most cases, this is permissible for standard, low- to medium-rise structures.

Code-recommended methods for analyzing multi-story buildings involve treating the structure as a discrete system with concentrated masses at floor levels. Its designing base shear is calculated with whole structure at once, & then it’s dispersed up and down the building's height. Individual lateral load resisting components are then assigned the lateral forces applied at each level.

It presupposes that the structure will only react in its base mode. This is only the case if the building is relatively short and doesn't twist much when the ground underneath it shifts. Given the building's inherent frequency, the reaction is read from a spectrum of possible responses included into the design. This is because Linear Static Procedure does not take into account the structure's nonlinearity or the dynamic impact.

5. Validation

5.1 Manual Validation

Given Conditions

DL=12KN/^{m2}

LL=4KN/m^2

Zone IV

Medium soil SMRF

No. of grid lines along X-direction-3 No. of grid lines along Y-direction-3 Spacing along X-direction-4 Spacing along Y-direction-5

Step-1: Lumped masses to various floor level

1. Dead load= 12KN/m^2

Weight of typical floor = 80X12=960N Weight of roof =80X12=960N

2. Live load= 4KN/m^2

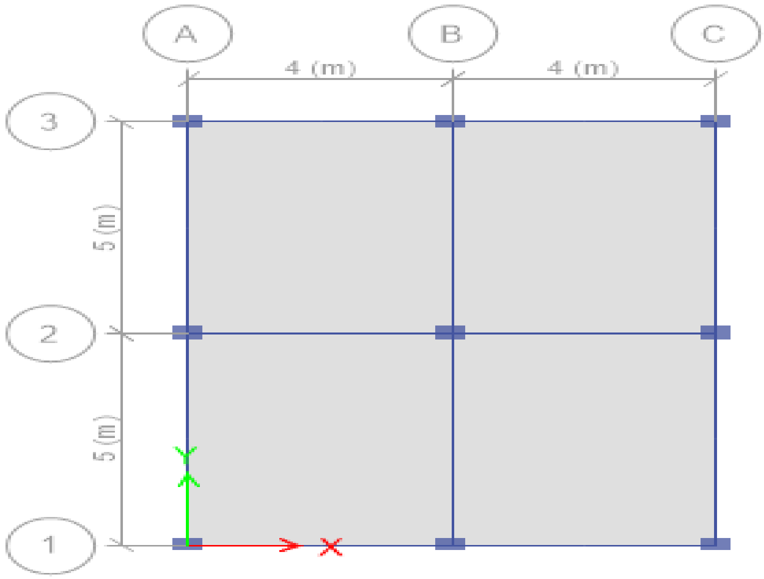


Figure. 1 Simple plan

Live load on roof =0KN Live load on each floor 4KN/m2 > 3KN/m^2 Thus, consider only 50%

Live load = 0.5X4=2KN/m^2

Total Live load on each floor =80X2=160KN

3. Lumped mass of roof DL+LL= 960 + 0 =960KN
4. Lumped mass of each floor DL+ LL =960 +160 = 1120KN

Total seismic weight of building

W= (2X1120) +960 =**3200kN. (i)**

Step-2: Fundamental Natural Period (Ta)

$$T_a = \frac{0.09h}{\sqrt{d}}$$

h= 9, d=8

Thus, **Ta=0.286 sec (ii)**

Step-3: Design seismic base shear (Vb)

$$V_B = A_h \times W$$

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

Z= 0.24 (building is in IV zone) I= 1.5 (school building)

R= 5 (SMRF)

Sa/g =2.50 (medium soil and is between 0.10 < Ta <0.55)

Ah=(0.24 X 1.5 X 2.5) / (2X5) = 0.09

Thus, **Vb= 288KN. (iii)**

Step-4: Vertical Distribution of base shear

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

FLOOR	Wi	hi	Wi*hi2	(Wi*hi2)/(Wihi2)	(Wi*hi2)*Vb/(Wi*hi2)
3	960	9	77760	0.606741573	174.741573
2	1120	6	40320	0.314606742	90.60674157
1	1120	3	10080	0.078651685	22.65168539
			128160		288KN

5.2 Software Validation

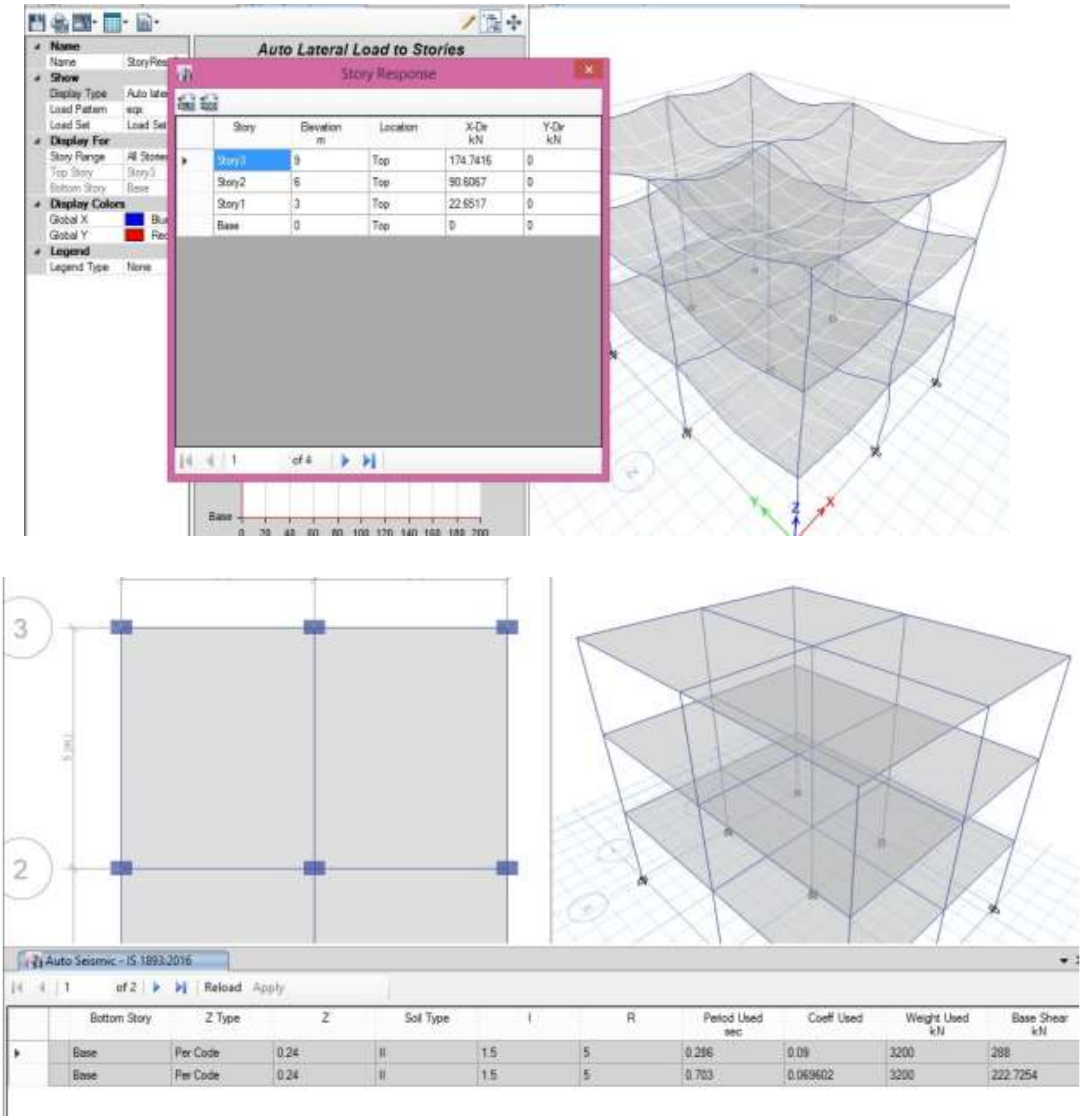


Figure. 2 Software result

Comparing Both Calculation

Table. 1 Software results

STOREY	MANUAL CALCULATION	SOFTWARE CALCULATION
3	174.53	174.75
2	90.72	90.60
1	22.75	22.65
	288KN	288KN

Both manual and software results are almost similar in which software results are giving more accurate results.

The total weight obtained in both manual and software are same i.e) 3200 KN The base shear obtained in both manual and software are to be same i.e) 288KN

Thus, the software results can be taken into consideration as it showing same results.

6. Analysis And Model In ETABS

Seismic Zones Of India

India is divided into four different earthquake zones based upon that country's seismicity (Zone 2, 3, 4 & 5). Zone 5 is predicted to have most seismic activity, while Zone 2 is connected with lowest.

Table 2: Zone factors

Zone no	Factors
5	0.36
4	0.24
3	0.16
2	0.1

6.1 Material Properties:

Strength of concrete (fck) = 30 N/mm^2

Main reinforcement

(fy) = 415N/mm^2

Shear reinforcement

(fys) = 415 N/mm^2

Young's modulus of concrete (Ec) = 3x104 N/mm^2

6.2 Loading

Table 3 Load cases

Load cases	Type	Details
Dead	Dead load	Use self-weight multiplier
Floor	Live load	Slab: 200mm
Storey	Live load	Slab: 200 mm Beams: 600x600 mm
Earthquake	Seismic load	Is:1893:2002 response reduction factor = 5

6.3. Building Details

Table 4 Building Details

S.NO	PARTICULARS	DATA
1	No. Of storey's	15
2	Plan dimension	20x20 m
3	Storey height	3.0 m
4	Grade of concrete	M25,M30
5	Grade of steel	Fe415
6	Thickness of slab	0.2 m
7	Beam size	0.6x0.6 m
8	Column size	0.6x0.6 m
9	Seismic zone	2
10	Seismic factor	0.1
11	Earthquake load for type2	As per IS 1893:2002
12	Top storey load	1.5 KN/m^2
13	Intermediate storey load	3.0 KN/m^2
14	Floor/cover load	1.0 KN/m^2

Material Properties:

Strength of concrete (fck) = 30 N/mm^2

Main reinforcement

fy) = 415N/mm^2

Shear reinforcement

(fys) = 415 N/mm^2

Young's modulus of concrete (Ec) = 3x104 N/mm^2

6.4 Loading:

Table 5 Load cases

LOAD CASES	TYPE	DETAILS
Dead	Dead load	Use self-weight multiplier
Floor	Live load	Slab: 200mm
Storey	Live load	Slab: 200 mm Beams: 600x600 mm
Earthquake	Seismic load	Is:1893:2002 response reduction factor = 5

6.5 Model

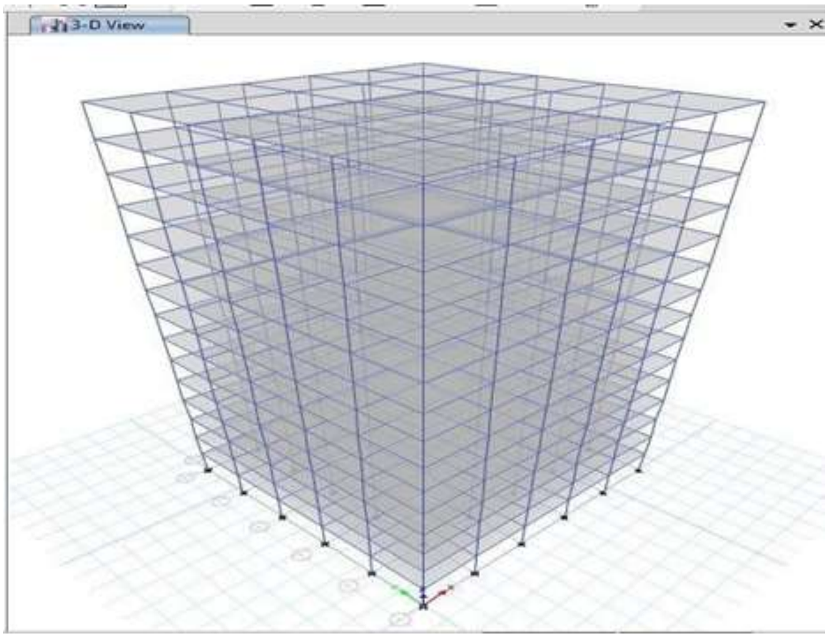


Figure 3: 3-D view of model

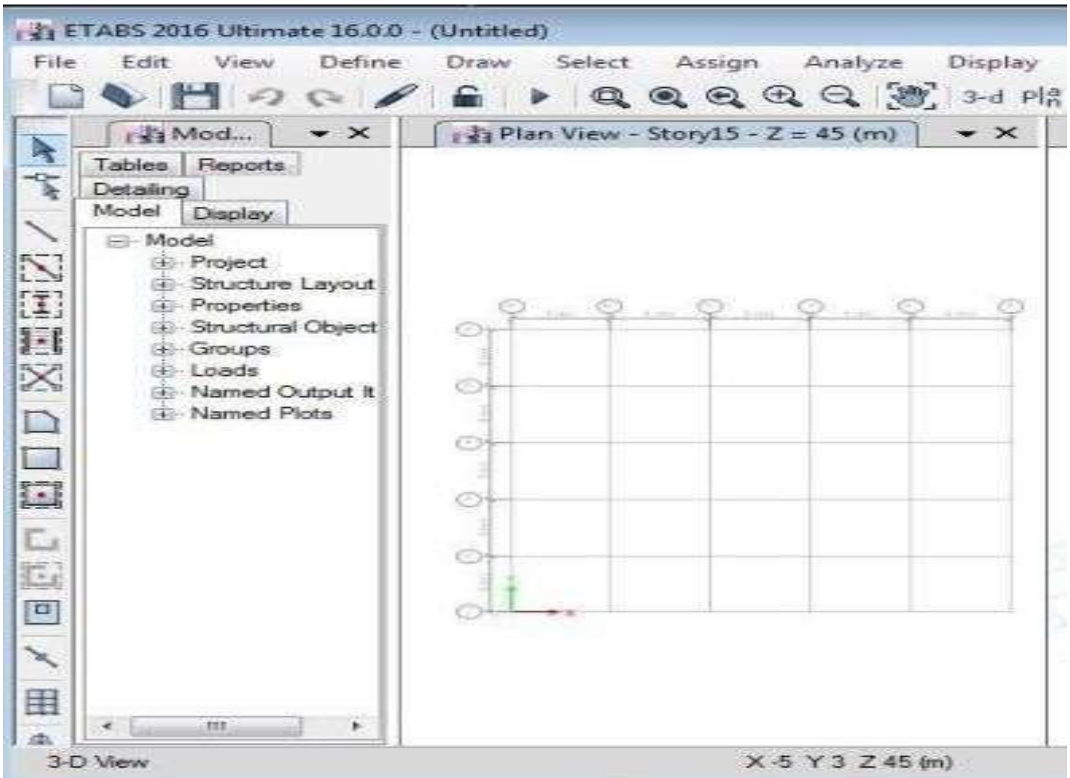


Figure 4: Floor plan

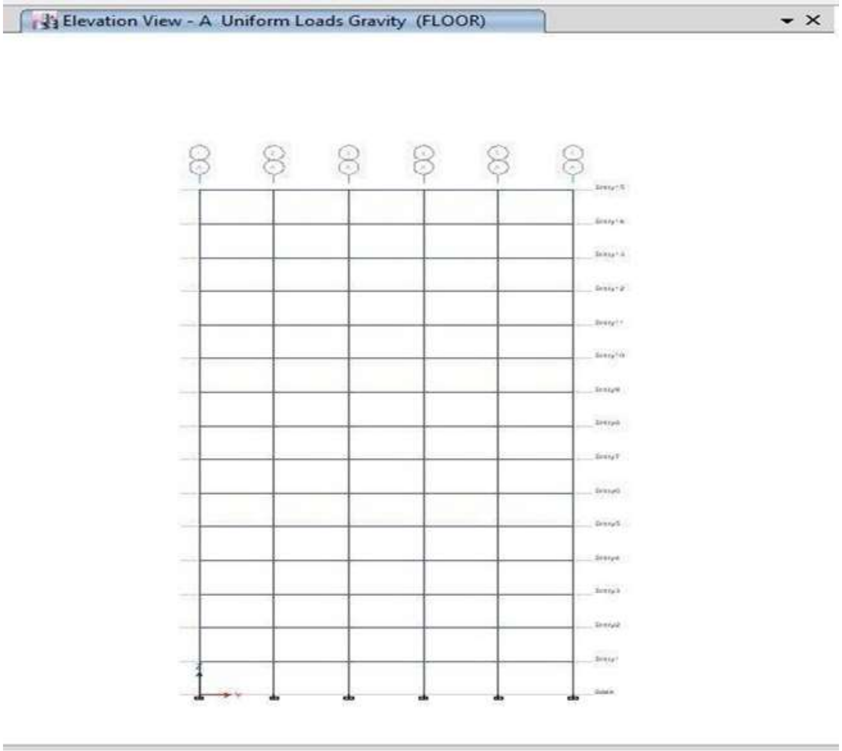


Figure 5 Elevation plan

These are models to use in your study of R.C building having shear walls in different places.

I.	Bare frame (no shear walls)	M1
II.	Shear wall at central core	M2
III.	Shear walls at corners	M3
IV.	Shear walls at edge faces	M4
V.	Shear walls at core + corners	M5
VI.	Shear walls at core + edges	M6

7. Results And Discussions

Afterwards, the different properties of the storeys are evaluated with models with and without shear walls placed at key locations. In the following, we compare the findings by examining the metric of each floor.

Comparison Of A Parameter (Storey Displacement)

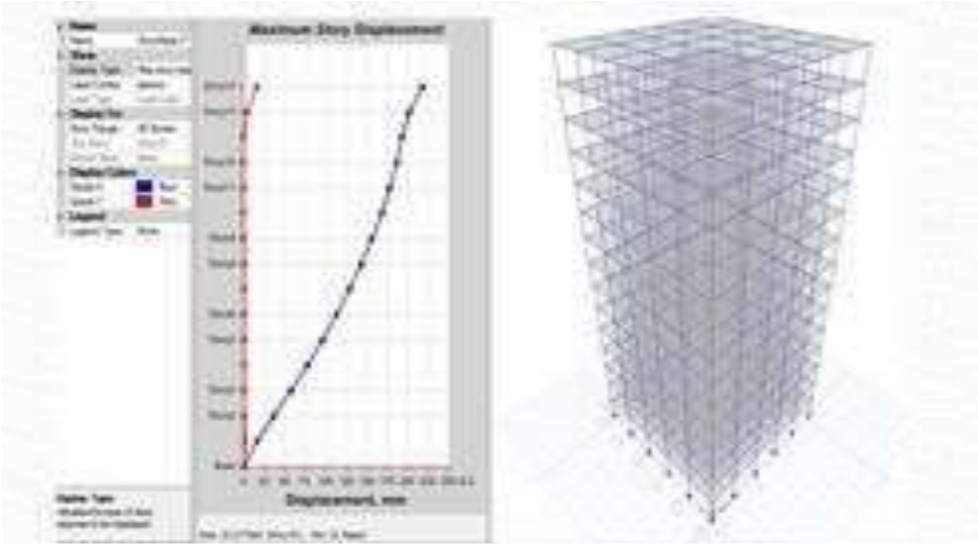


Figure 6. Model 1 storey displacement plot

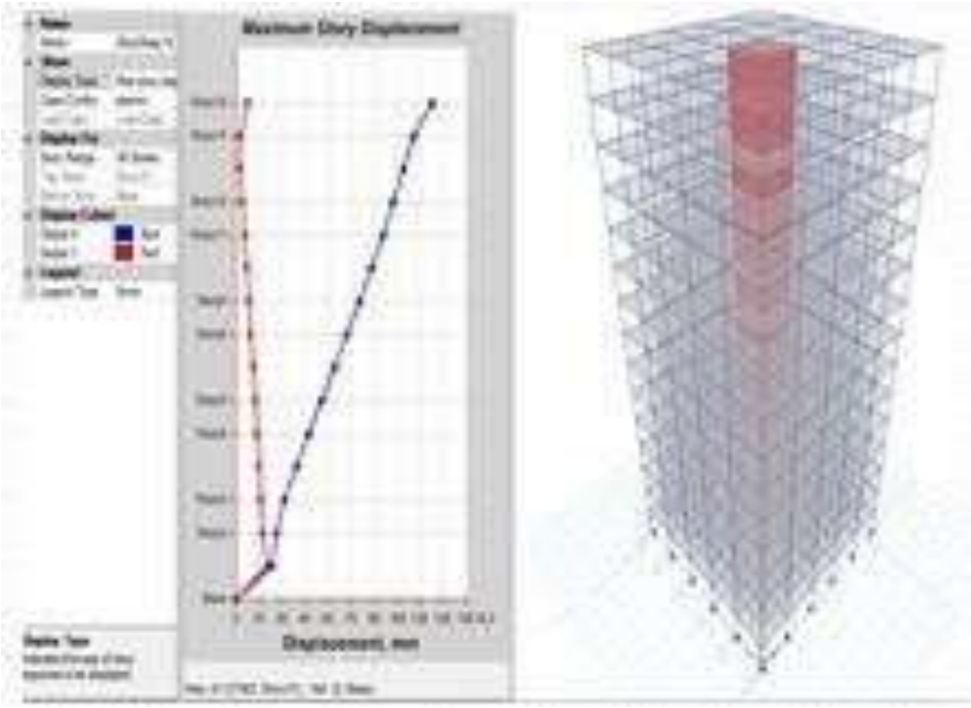


Figure 7 Model 2 storey displacement plot

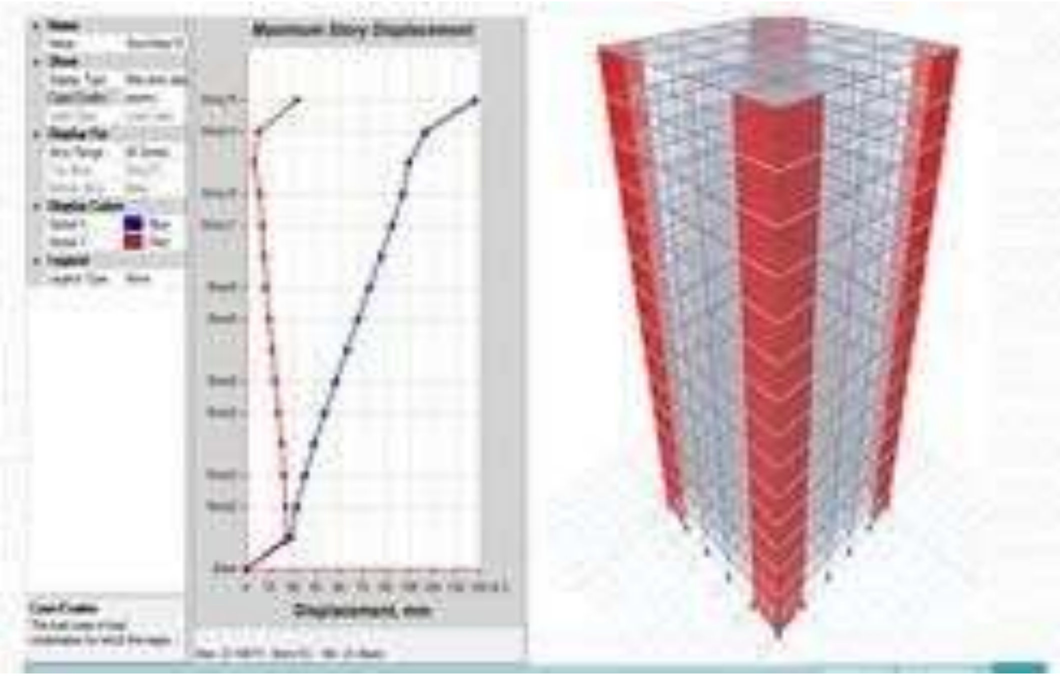


Figure 8 Model 3 storey displacement plot

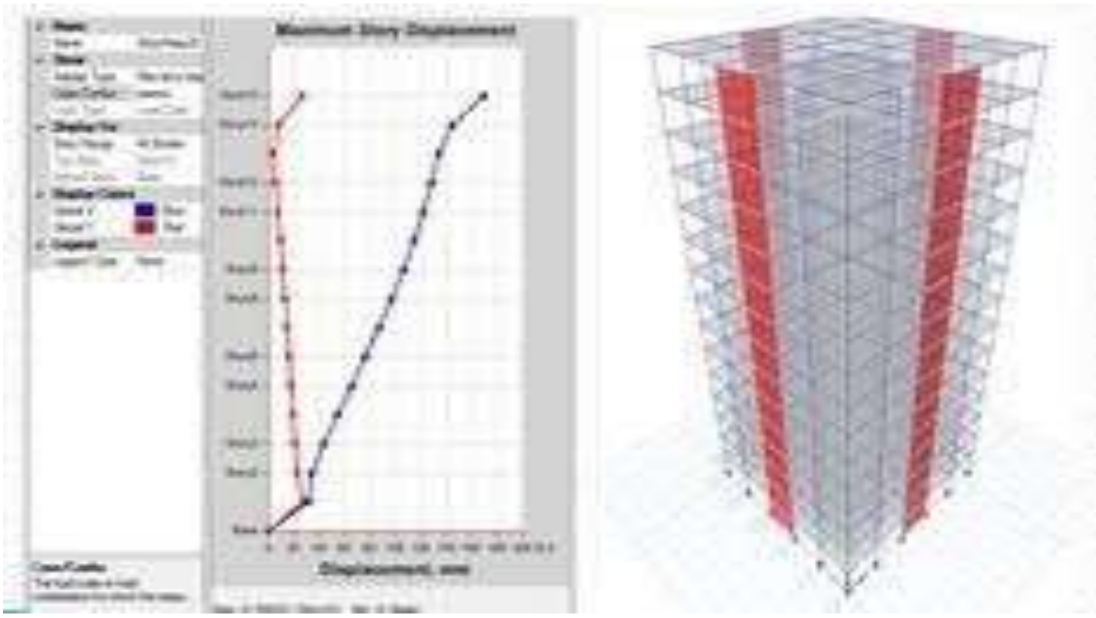


Figure 9 Model 4 storey displacement plot

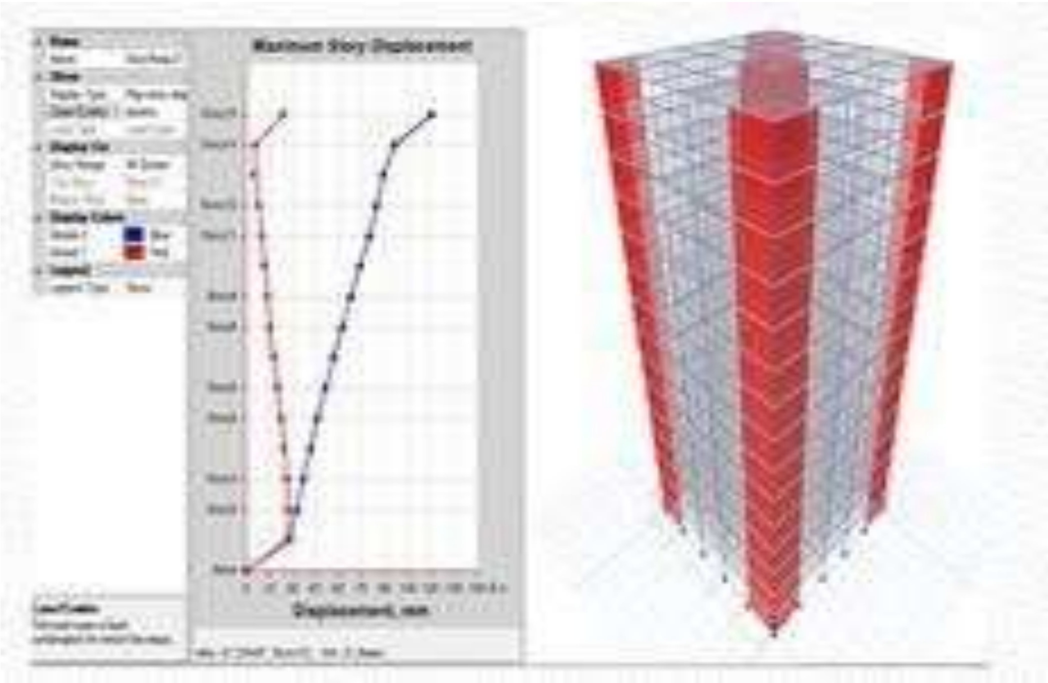


Figure 10 Model 5 storey displacement

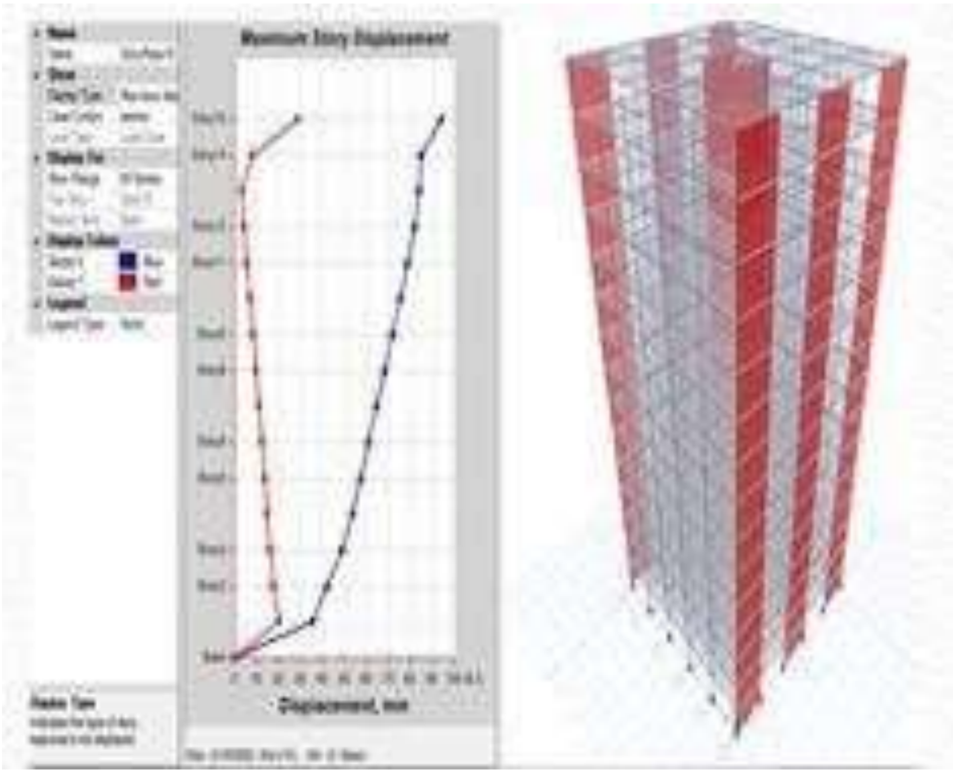
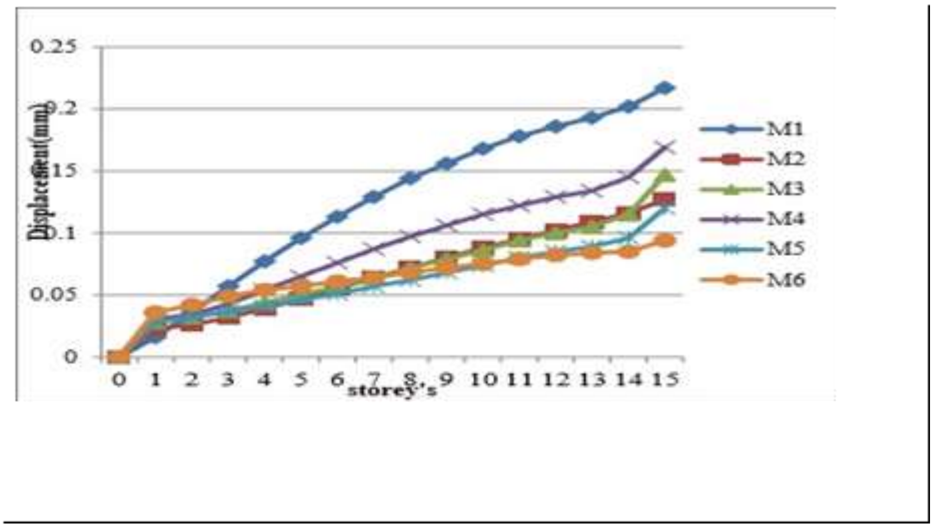
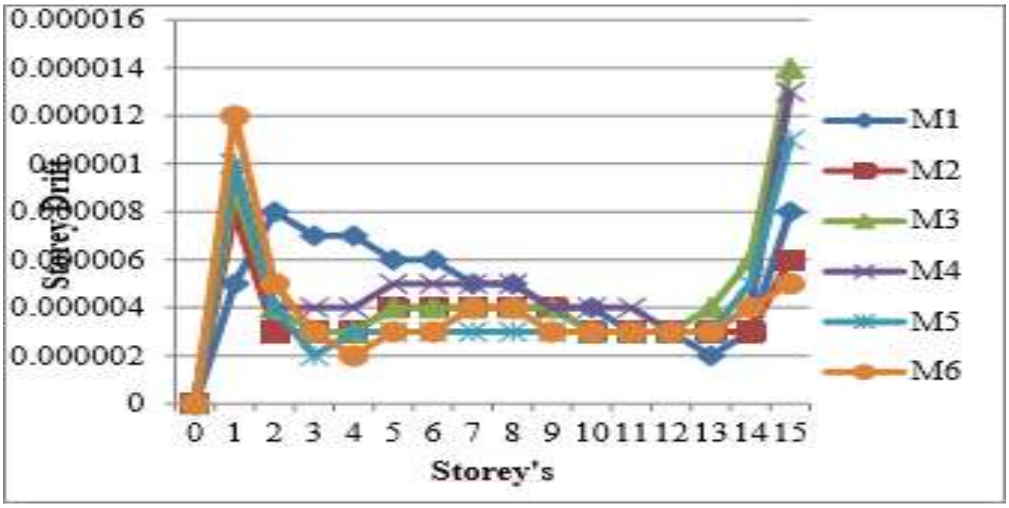


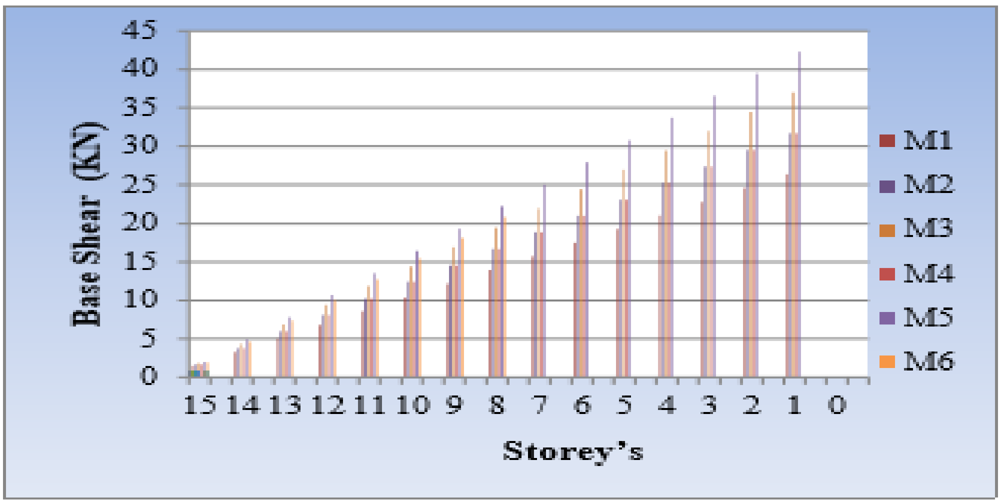
Figure 11 Model 6 storey displacement plot



Graph 1: storeys vs storey displacement (mm)



Graph 2: storeys vs storey drift



Graph 3 : storeys vs base shear (kn)

Table 6: Combination of storey displacement plots of above six model

Storey's	M1	M2	M3	M4	M5	M6
No's	Displacement (mm)	Displacement (mm)	Displacement (mm)	Displacement (mm)	Displacement (mm)	Displacement (mm)
15	0.217	0.127	0.147	0.169	0.12	0.094
14	0.202	0.116	0.115	0.145	0.096	0.085
13	0.193	0.109	0.105	0.134	0.089	0.084
12	0.186	0.102	0.1	0.129	0.085	0.082
11	0.178	0.095	0.094	0.122	0.08	0.079
10	0.168	0.088	0.086	0.115	0.074	0.075
9	0.156	0.08	0.079	0.106	0.068	0.072
8	0.144	0.072	0.072	0.097	0.062	0.664
7	0.129	0.064	0.064	0.087	0.057	0.064
6	0.113	0.055	0.057	0.076	0.051	0.061
5	0.096	0.047	0.05	0.065	0.046	0.057
4	0.077	0.039	0.044	0.054	0.041	0.054
3	0.057	0.032	0.037	0.043	0.037	0.049
2	0.036	0.026	0.032	0.034	0.03	0.042
1	0.016	0.023	0.028	0.031	0.029	0.036
0	0	0	0	0	0	0

Table 7 Comparison of models to model 1 by % reduction in displacement

Storey's	**M2**	**M3**	**M4**	**M5**	**M6**
No's	% Reduction in displacement	% Reduction in displacement	% Reduction in displacement	% Reduction in displacement	% Reduction in displacement
15	41.47	32.25	22.11	44.7	56.68
14	42.57	43.06	28.21	52.47	57.92
13	43.52	45.59	30.56	53.88	56.47
12	45.161	46.23	30.64	54.30	55.91
11	46.62	47.191	31.46	55.05	55.61
10	47.61	48.80	31.54	55.95	55.35
09	48.71	49.35	32.05	56.41	53.84
08	50	50	32.63	56.94	52.77
07	50.38	50.38	32.55	55.81	50.38
06	51.32	19.55	32.74	54.86	46.01
05	51.041	47.91	32.291	52.083	40.625
04	49.35	42.85	29.87	46.75	29.87
03	43.85	35.08	24.56	35.08	14.03
02	27.77	11.11	5.55	11.11	-16.66
01	-43.75	-75	-93.75	-81.25	-1.25
00	0	0	0	0	0

Table 8 Combination of storey drifts of above six models

Storey's	M1	M2	M3	M4	M5	M6
15	8.00E-06	6.00E-06	1.40E-05	1.30E-05	1.10E-05	5.00E-06
14	3.00E-06	3.00E-06	6.00E-06	4.00E-06	5.00E-06	4.00E-06
13	2.00E-06	3.00E-06	4.00E-06	3.00E-06	3.00E-06	3.00E-06
12	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06
11	3.00E-06	3.00E-06	3.00E-06	4.00E-06	3.00E-06	3.00E-06
10	4.00E-06	3.00E-06	3.00E-06	4.00E-06	3.00E-06	3.00E-06
09	4.00E-06	4.00E-06	4.00E-06	4.00E-06	3.00E-06	3.00E-06
08	5.00E-06	4.00E-06	4.00E-06	5.00E-06	3.00E-06	4.00E-06
07	5.00E-06	4.00E-06	4.00E-06	5.00E-06	3.00E-06	4.00E-06
06	6.00E-06	4.00E-06	4.00E-06	5.00E-06	3.00E-06	3.00E-06
05	6.00E-06	4.00E-06	4.00E-06	5.00E-06	3.00E-06	3.00E-06
04	7.00E-06	3.00E-06	3.00E-06	4.00E-06	3.00E-06	2.00E-06
03	7.00E-06	3.00E-06	3.00E-06	4.00E-06	2.00E-06	3.00E-06
02	8.00E-06	3.00E-06	4.00E-06	4.00E-06	4.00E-06	5.00E-06
01	5.00E-06	8.00E-06	9.00E-06	1.00E-05	1.00E-05	1.20E-05
00	0	0	0	0	0	0

8. Conclusion

1. In cases of base shear and displacement, the installation of shear walls at appropriate places is of greater importance.
2. The horizontal displacing of 15-story structure having shear wall at the core and edge faces of the structure is less than that of competing models.
3. There will be more resistance to lateral pressures if the shear wall is wider.
4. Displacement graph shows that core shear wall structures have the smallest amount of movement. Structural displacement for a 15-story building ranges from a maximum of 0.271mm for a bare frame to a minimum of 0.127mm of building having a shear wall at x-dir location. Measured deviation is consistent with parameters IS 1893:2002.
5. Fifth, the amount of base shear is directly related to how far apart the floors are. As a result, the model with the smallest amount of storey displacement also has the highest base shear value. it implies withstanding the greatest possible lateral force.
6. Six, a rough quantitative analysis allowed us to detect the best place to put a shear wall based on the results above. For the reason that it was a Model 6 with shear walls all around (the center and the periphery). But the edges are running perpendicular to the force of the earthquake.

8.1 Scope Of Future Work

1. First, although in this work I have only explored buildings up to 15 stories tall, it is certainly possible to think about structures with even more floors.
2. Only three primary parameters—floor-to-floor movement, drift, and shear at the floor and/or base—have been the focus of my research. The scope of this investigation is confined to employing linear analysis to contrast the seismic response characteristics of a structure with various shear wall positions. Torsional impacts & soft story effects are two additional building characteristics that might be accounted for to broaden the scope of the investigation. It is possible to do more research using non-linear dynamic analysis in order to more accurately assess the structural reaction to seismic pressures.
3. Three, I assumed a unidirectional seismic load and focused on regular-shaped buildings in this research. It also functions for multidirectional load acting on an uneven plan.

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