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Comparing the Effect of Earthquake on High-Rise Building with Shear Wall and Flange Concrete Column

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Abstract: ***Earthquake never kills people but the defective structures do. The stability and stiffness of any structure is the major issue of concern in any high rise buildings. Shear walls are structural members which resist lateral forces predominant on moment resisting frame. Shear walls are most preferred structural walls for earthquake resistance. This research is related to comparison of shear wall type structure with moment resisting type of building. The present study states three type of models, moment resisting frame i.e. model 1, Shear wall building concentrically located along X- axis on outer periphery of building i.e. model 2, and Concrete column flange concentrically located on outer periphery along the X-axis i.e. model 3. Models of the three structures with same loading were created on STAADPro and were analyzed and further they where compared for their suitability. For 10 storey building and 3 bays along X-axis of 4m each and 4 bays along Z-axis of 4m each were considered and loads were applied as per the IS specifications. The analysis was conducted as per the specifications of IS standards IS 13920, IS 1893, IS 875, IS 456. From the result it is seen that there is decrease of approximately 10% in Lateral storey shear and Base shear when the moment resisting frame was introduced with shear wall. Thus the model 2 and model 3 possessed 10% less lateral force and base shear as compared to the model 1. Also the results of Axial force, bending moment, Node displacement were found satisfactorily less than the moment resisting frame. If cost is been compared, then model 3 can be stated as economical in all sense since for the same configuration and load it greater stability and stiffness as checked from the node displacement results.***

Keywords: ***Earthquake, Shear wall, Flanged concrete column, STAADPro.***

I. INTRODUCTION

Earthquakes are the deadliest natural disasters that occur on earth. Some of the past earthquakes had severely destroyed the structures on the earth; build by human being for their livelihood. Safety and suitability is the concern behind such earthquake resistant designed structures. Moreover earthquake never kills people, the weak structures do. Earthquakes are vibrations or oscillations of ground surface caused by temporary disturbance of the elastic or gravitational equilibrium of the rocks at or beneath the surface of the earth. This disturbances and movements cause elastic impulses or waves. These waves are known as seismic waves and classified as body waves- travels within the body of earth and surface waves- over the surface of the earth. Based on the peak ground acceleration or movement there are certain zones of the earth, named as seismic zones. In India there are four zones, II, III, IV, V – last one being the most devastating.

At any particular point, the ground acceleration may be described by horizontal components along two perpendicular directions and a vertical component. In most instances only the structural response to the horizontal components of ground motion is considered since buildings are not sensitive to horizontal or lateral distortions. In virtually all earthquake design practice the structure is analysed as an elastic system; it is acknowledged that the structural response to strong earthquakes involves yielding of the structure, so that the response is inelastic. The effect of yielding in a structure is two-fold. On one hand, stiffness is reduced so that displacements tend to increase. The properties of a building are lateral stiffness, lateral strength and ductility. Earthquake-resistant design of buildings relies heavily on ductility for accommodating the imposed displacement loading on the structure.

Shearwall is a structural member positioned at different places in a building from foundation level to top parapet level, used to resist lateral forces i.e. parallel to the plane of the wall. When lateral displacement is large in a building with moment frames only, structural walls, often commonly called shear walls, can be introduced to help reduce overall displacement of buildings, because these vertical plate-like structural elements have large in-plane stiffness and strength.

Shear walls resist lateral forces through combined axial-flexure-shear action. Earthquake resistant buildings should possess, at least a minimum lateral stiffness, so that they do no swing too much during small levels of shaking. Moment frame buildings may not be able to offer this always. Also, structural walls help reduce shear and moment demands on beams and columns in the moment frames of the building, when provided along with moment frames as lateral load resisting system. Shear walls should be provided throughout the height of buildings for best earthquake performance. Also, shear walls offer best performance when rested on hard soil strata. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes.

Well-designed shear walls not only provide adequate safety but also provide great measure of protection against costly non-structural damage during moderate seismic damages. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without losing strength.

Based on materials used for construction shear walls are classified as follows,

A. RCC Shear Wall

It consists of reinforced concrete walls and reinforced concrete slabs. Wall thickness is more than 200mm, depending on the number of stories, building age, and thermal insulation requirements. In general, these walls are continuous throughout the building height. In general, the wall reinforcement consists of two layers of distributed reinforcement (horizontal and vertical) throughout the wall length.

B. RC Hollow Concrete Block Masonry Wall

RHCBM walls are constructed by reinforcing the hollow concrete block masonry, by taking advantage of hollow spaces and shapes of the hollow blocks. It requires continuous steel rods (reinforcement) both in the vertical and horizontal directions.

C. Steel Plate Shear Wall

In general, steel plate shear wall system consists of a steel plate wall, boundary columns and horizontal floor beams. Together, the steel plate wall and boundary columns act as a vertical plate girder. The columns act as flanges of the vertical plate girder and the steel plate wall acts as its web Openings in any building are required to maintain proper utility of buildings. Moreover shear walls with openings are not generally preferred because they are unable to transfer loads and generally fail. Shear wall with openings are also known as coupled shear wall. Flanged concrete column is similar to coupled shear wall, only change is the depth of beam may be restricted and attempts are made in this research work to check the strength of flanged concrete column with the regular solid shear wall. Model of a flanged concrete column is shown in figure 1. Flanges in the column can be on single side of column or on both side of the column. These flanges can be assigned on three mutual sides of the column. The main purposes of providing such flanges in column are to reduce joint displacement and to prevent plastic hinge formation near the support. This will help in improving the stiffness in the structure and provide access to the building from the opening.

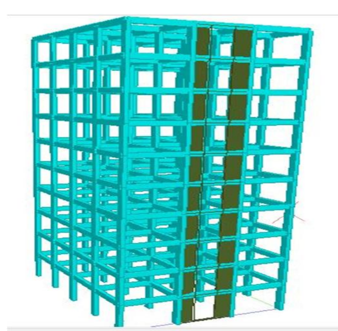


Figure 1:- Column with flange or Flanged column

II. PROBLEM STATEMENT AND METHODOLOGY

Analysis of any structure for resisting earthquake is the basic need of this study. In this project analysis of a seismic resistant structure is a need of concern, and thereby establishing a comparison between structures with normal shear wall with flanged concrete column. In high rise structures most adoptable type to resist earthquake is to provide shear wall. Basically many analysis and design software's can be adopted to analyse and design any earthquake resistant structure.

The structure selected for this project is a simple office building (Banking hall type) with the following description as stated below.

TABLE 1
PROBLEM STATEMENT FOR THE PROJECT MODELS

Sr. No.	Description of structure	Values
1	Number of bays in X direction and its width	4 bays of 4 m each
2	Number of bays in X direction and its width	4 bays of 4 m each
3	Number of bays in Z direction and its width	3 bays of 4 m each
4	Story height	3 m each
5	Number of storey (Excluding the plinth and substructure and including the Ground floor)	10
6	Depth of foundation from ground level	2.2 m
7	Plinth height	800 mm
8	Column size	400 mm x 400 mm
9	Beam size	230 mm x 400 mm
10	Thickness of Slab	150 mm
11	Density of concrete	25 kN/m^3
12	Live load on roof	1.5 kN/m^2
13	Live load on floors	3 kN/m^2
14	Floor finish	1 kN/m^2
15	Brick wall on peripheral beams	230 mm
16	Brick wall on internal beams	115 mm
17	Density of brick wall	20 kN/m^3
18	Internal Plaster	12mm
19	External Plaster	15mm
20	Density of Plaster	18 kN/m^3

For the present study following values for seismic analysis are assumed. The values are assumed on the basis of reference steps given in IS 1893-2002 and 13920-1993 and IS 456:2000. Since Nagpur or vidarbha is less vulnerable to earthquakes, for this present study assigning zone III for moderate seismic intensity as stated in table 2 of IS 1893 – 2002.

TABLE 2
SEISMIC PARAMETERS

1	Zone factor for zone III	0.16 (Table 2, P.16)
2	Importance factor for office building	1 (Table 6, P.18)
3	Special Reinforced Concrete Moment resisting Frame	
4	SMRF is a moment resisting frame detailed to provide ductile behavior and comply with the requirements of 13920-1993	
5	Response reduction factor for ductile shear wall with SMRF	5
6	Type of soil	Medium (Type II)
8	Damping percent	5 % (0.05)
9	Thickness of Shear wall	230 mm
10	Brick infill panel building type.	

A. Design of Shear Walls

Shear walls are inherently less ductile and perhaps the dominant mode of failure is shear. With low design stress limits in shear walls, deflection due to shear forces is small. However, exceptions to the excellent performance of shear walls occur when the height-to-length ratio becomes great enough to make overturning a problem and when there are excessive openings in shear walls. The thickness of the shear wall should not be less than 150 mm to avoid unusually thin sections. The effective flange width for the flanged wall section from the face of web (wall) should be taken as least of, half the distance to an adjacent shear wall web, and One-tenth of total wall height. The minimum reinforcement in the longitudinal and transverse directions in the plan of the wall should be taken as 0.0025 times the gross area in each direction and distributed uniformly across the cross-section of wall. This helps in controlling the width of inclined cracks that are caused due to shear.

If the factored shear stress in the wall exceeds $0.25\sqrt{f_{ck}}$ or if the wall thickness exceeds 200 mm, the reinforcement should be provided in two curtains, each having bars running in both the longitudinal and transverse directions in the plane of the wall. The use of reinforcement in two curtains reduces fragmentation and premature deterioration of the concrete under cyclic loading. The maximum spacing of reinforcement in either direction should he lesser than l_w /5, 3tw, and 450 mm, where lw, is the horizontal length and t_w is the thickness of the wall web. The diameter of the bars should not exceed one-tenth of the thickness of that part. This puts a check on the use of very large diameter bars in thin wall sections.

B. Overview of STAADPro V8i Software

STAADPro V8i is a comprehensive and integrated finite element analysis and design offering, including a state-of-the-art user interface, visualization tools, and international design codes. It is capable of analyzing any structure exposed to static loading, a dynamic response, wind, earthquake, and moving loads. STAADPro V8i is the premier FEM analysis and design tool for any type of project including towers, culverts, plants, bridges, stadiums, and marine structures. The program hence consists of the following facilities to enable this task. Graphical model generation utilities as well as text editor based commands for creating the mathematical model. Beam and column members are represented using lines. Walls, slabs and panel type entities are represented using triangular and quadrilateral finite elements. Analysis engines for performing linear elastic and pdelta analysis, finite element analysis, frequency extraction, and dynamic response (spectrum, time history, steady state, etc.). Result viewing, result verification and report generation tools for examining displacement diagrams, bending moment and shear force diagrams, beam, plate and solid stress contours, etc.

C. Plan and Model Generated for Problem Statement

From the values mentioned in the problem definition three models are generated to study the behaviour of earthquake resistant structure. Figure 4.1 shows plan of the structure generated in STAADPro. Following are the models generated.

1) *Model 1:* Simple structure without any shear wall. Figure 4.2 illustrates this model. In this model all the parameters are considered for designing the structure as earthquake proof as per IS1893:2003.
2) *Model 2:* Structure with symmetrical shear wall on opposite side of building on outer walls of structure concentrically located. Figure 4.3 illustrates the model. In this model all the parameters are same as model 1 also parameters of shear wall are added for design of shear wall as per IS 13920:1993.
3) *Model 3:* Structure with symmetrical concrete column flanges (like shear wall with opening). Since shear wall starts from foundation level, in this type of model the structure up to plinth level has solid shear wall and the structure above plinth level have column flanges. Figure-1 illustrates the type. In this model all parameters are same as model 2 but only difference is the shear walls provided are having opening seems like flanges to the column.

D. Calculation of Load and Earthquake related Parameters:-

Dead load of slab = (0.15 x 1 x 25) = 3.75 kN/m^2
Dead load of Outer Brick wall can be calculated as = (0.23) x (2.65) x 20 = 12.19 kN/m^2
Dead load of Inner Brick wall can be calculated as = (0.115) x (2.65) x 20 = 6. 1 kN/m^2
Dead load of Parapet wall can be calculated as = (0.23) x (1) x (20) = 4.6 kN/m^2
Dead load of Plaster for outer walls can be calculated as = (0.015+0.012) x (2.65) x 18 = 1.3 kN/m^2
Dead load of Plaster for inner walls and parapet wall can be calculated as = (0.012+0.012) x (2.65) x 18 = 1.15 kN/m^2
Total Dead Load for outer walls = 12.19 +1.3 = 13.49 (considering 85% of weight due to openings) i.e 11.46 kN/m^2
Total Dead Load for inner walls = 6.1+1.15 = 7.25 kN/m^2 (Least openings are there in Partitions)
Total Dead Load for Parapet walls = 4.6 +1.15 = 5.75 kN/m^2

1) *Seismic Weight Calculation:* As per the norms given in the IS 1893:2003 for live load greater than 3, 50% of the live load is added for seismic weight. And for live load up to and less than 3, 25% live load is added for seismic weight.

Total Seismic weight floors = 3.75 + (0.25 x3) = 4.5 kN/m^2

Total Seismic weight roof floors = 3.75 kN/m^2

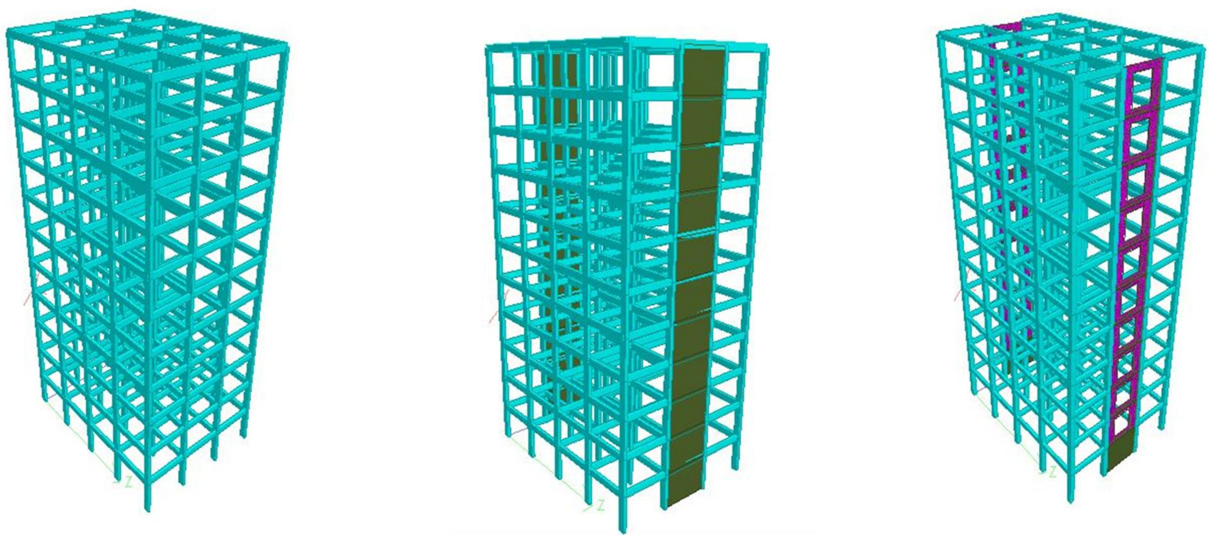
STAADPro calculates the design base shear by adding some useful parameters during analysis.

The fundamental natural period of vibration (T_a) is calculated by

$T_a = \frac{0.09h}{\sqrt{d}}$, Where, "h"= height of building and "d"= width of building at plinth height in a particular direction

Hence along X- Direction, $T_a = \frac{0.09h}{\sqrt{d}} = \frac{0.09\, x\, 30}{\sqrt{12}} = 0.78$

Along Z- Direction, $T_a = \frac{0.09\, x\, 30}{\sqrt{16}} = 0.68$

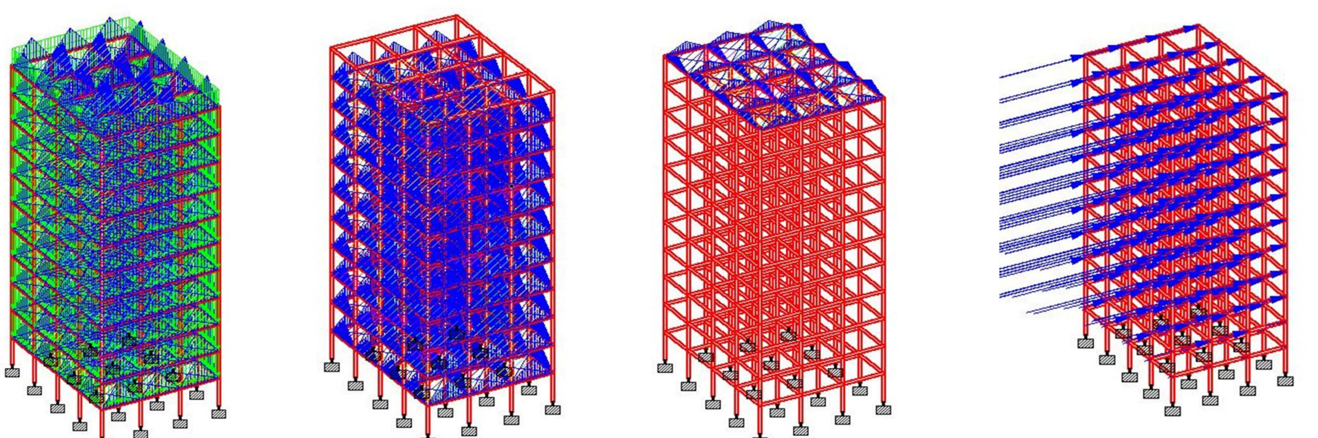


Model 1 Model 2 Model 3

Figure 2:- Models generated in STAADPro for the Problem Statement.

E. *Loadings and Analysis*

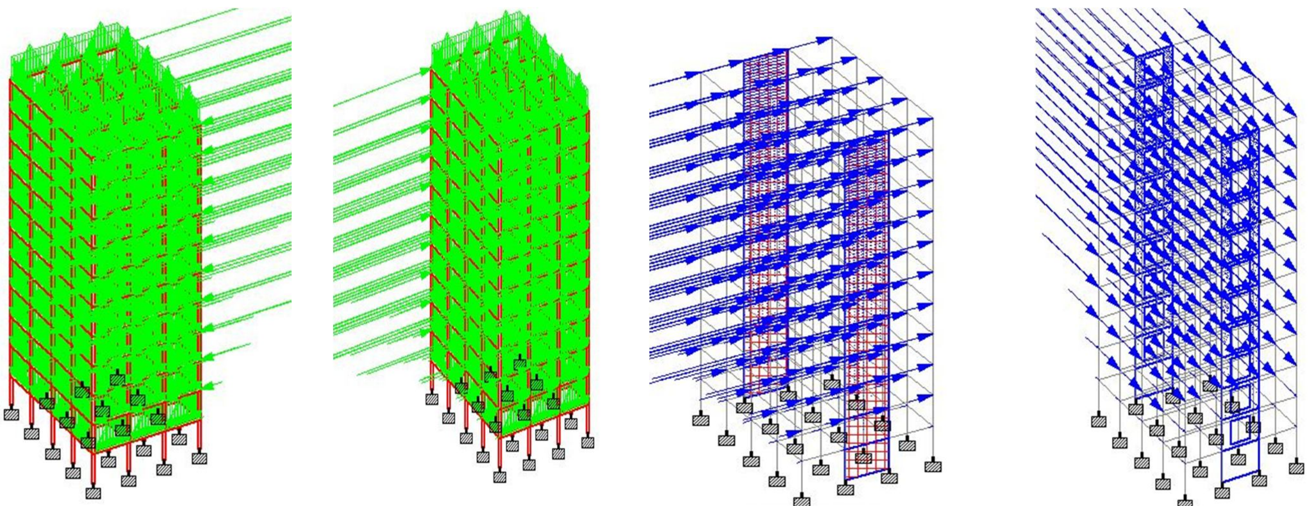
Loads as mentioned above are added and generated in STAADPro for earthquake analysis and applied to the prepared models as shown in figure 2.



Dead load Live load Roof Live Load Earthquake load in Positive X-Direction

Figure 3:- Load distribution for Model 1 (STAADPro model)

Loads as mentioned above are added and generated in STAADPro for earthquake analysis and applied to the prepared models as shown in figure 2. The Member loads (wall loads) are same for all the floors except roof floor. The intermediate members carry fewer loads as compared to exterior walls as shown in figure. Figure 2 also shows earthquake load in positive X-direction. Figure-3 shows loads definition of load combination (Earthquake and dead and live loads as stated in IS 1893) on complete structure for model 1 in positive X-Direction. Similarly the loads are distributed for the model 2 and model 3. Figure-3 also shows loads definition of load combination (Earthquake and dead and live loads as stated in IS 1893) on complete structure for model 1 in negative X-Direction. Similarly the loads are distributed for the model 2 and model 3. Figure-3 shows loads definition of load combination (Earthquake and dead and live loads as stated in IS 1893) on complete structure for model 1 in positive X-Direction. Also such loads are distributed in same manner for positive and negative Z- Directions. Similarly the loads are distributed for the model 2 and model 3. Figure-3 also shows a model 2 with earthquake load in positive X direction. These loads are distributed along the height of building. Similarly the loads are also distributed in negative X- direction. Also these loads are applied in positive and negative Z- direction in model 2and 3. Figure 3 shows earthquake load along positive z- direction on model 3. Such types of loads are also distributed in negative Z direction. Also these loads are applied in positive and negative X- direction in model 2.



Load Combination along Negative X- direction for Model 1

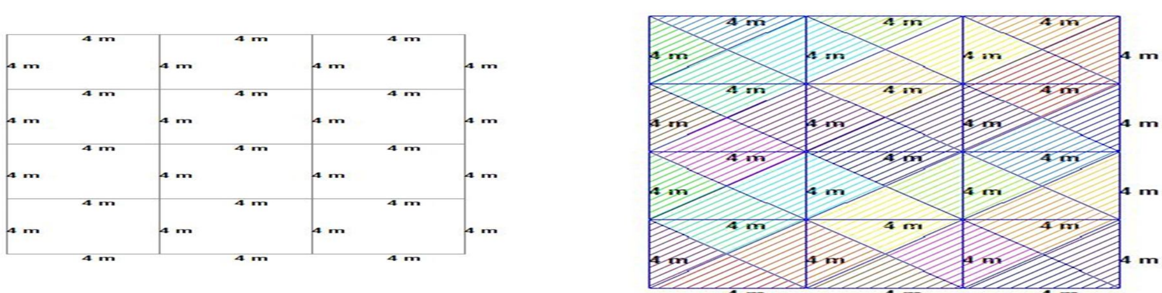
Load Combination along Positive- X direction for Model 1

Earthquake load on Model 2 along positive X- direction

Earthquake load on Model 3 along positive X- direction

Figure 3:- Dead load, live load and seismic load.

A plan generated in STAADPro and the floor loads distributed on the respective beams on each floor as per the guidelines of IS 456: 2000 shown in figure 4. All the models are same in size and height except the introduction of shear wall and column flange in model 2 and model 3 respectively.



Plan of building without loading

Plan of building with load distribution

Figure 4:- Plan of building with and without loading distribution generated in STAADPro.

III. RESULT AND DISCUSSION

The equivalent static method or seismic coefficient method had been used to find the design lateral forces along the storey in X and Z direction of the building since the building is unsymmetrical. A 10 storied RCC building in zone III is modelled using STAADPro software and the results are computed. The configurations of all the models are discussed in previous chapter. Three models were prepared based on different configuration, Model 1 for non shear wall type of multi-storeyed building, Model 2 for same building with Shear wall type and model 3 for same building with Column flange type. These models are analysed and designed as per the specifications of Indian Standard codes IS1893, IS 13920, IS 875 and IS 456: 2000.

A. Lateral Force and Base Shear

Elements or members of building should be designed and constructed to resist the effects of design lateral force. STAADPro gives the lateral force distribution at various levels and at each storey level. Lateral force of earthquake is predominant force which needs to be resisted for any structure to be earthquake resistant. The equivalent static method had been adopted to find out the lateral force in STAADPro. The Table No.3 shows Storey height and the distribution of the lateral force and the base shear at each storey level in X-direction. The average percentage decrease in lateral force for model 2 and model 3, when compared with model 1, shows that there is approximate decrease of 10% for both the models.

TABLE 3
LATERAL FORCE AT DIFFERENT FLOOR LEVEL ALONG X-DIRECTION

Floor Height	Lateral Force			Percentage force decrease from model 1	
	Model 1	Model 2	Model 3	Model 2	Model 3
33	112.372	99.061	98.917	11.85	11.97
30	162.648	147.958	147.718	9.03	9.18
27	131.745	119.846	119.625	9.03	9.20
24	104.095	94.693	94.524	9.03	9.19
21	79.698	72.499	72.376	9.03	9.19
18	58.553	53.265	53.18	9.03	9.18
15	40.662	36.989	36.927	9.03	9.19
12	26.024	23.673	23.631	9.03	9.20
9	14.638	13.316	13.293	9.03	9.19
6	6.506	5.918	5.908	9.04	9.19
3	1.626	1.48	1.479	8.98	9.04
Average Percentage (%)				9.28	9.43

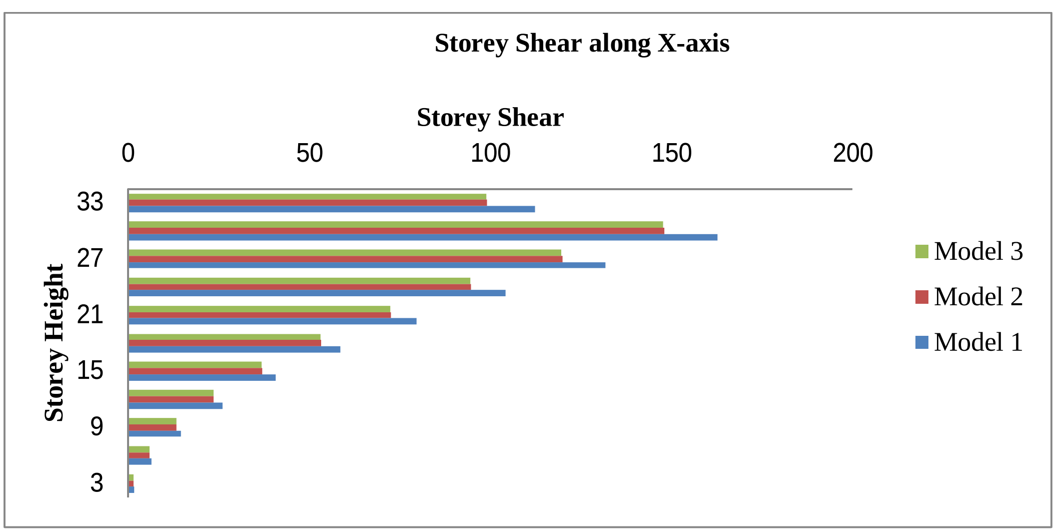


Figure 5:- Lateral force or storey shear along X-direction throughout the height.

Figure 5 shows a graph of storey height versus Lateral force in X-Direction and it is evident that the lateral force for Model 1, Model 2, and Model 3 differs from each other storey wise. It is seen that for a particular model as the storey height increases the lateral force also increases except in the parapet level since the loads on the parapet level are less. Lateral force or storey shear for model 1, model 2 and model 3 are different and approximately 10% decrease in lateral force for model 2 and model 3 is seen at each storey level when compared with model 1.

Table 4 shows base shear values at different floor level along X- Direction. Base shear is cumulative of lateral force from top storey to bottom storey. Thus the value of bottom floor shear is maximum and value of top storey shear is minimum. Introducing shear wall and column flange shows approximate 10% reduction in the base shear for model 2 and model 3 when compared with model 1. The values for each storey is cumulative of top storey thus it differs from storey to storey.

TABLE 4
BASE SHEAR AT DIFFERENT FLOOR LEVEL ALONG X DIRECTION

Floor Height	Base Shear			Percentage force decrease from model 1	
	Model 1	Model 2	Model 3	Model 2	Model 3
33	112.372	99.061	98.917	11.85	11.97
30	275.02	247.019	246.635	10.18	10.32
27	406.765	366.865	366.26	9.81	9.96
24	510.86	461.558	460.784	9.65	9.80
21	590.558	534.057	533.16	9.57	9.72
18	649.111	587.322	586.34	9.52	9.67
15	689.773	624.311	623.267	9.49	9.64
12	715.797	647.984	646.898	9.47	9.63
9	730.435	661.3	660.191	9.46	9.62
6	736.941	667.218	666.099	9.46	9.61
3	738.567	668.698	667.578	9.46	9.61
Average Percentage				9.81	9.96

Figure 6 shows base shear along X-Direction storey wise. As tabulated above the values are graphically represented in the figure 6. After introducing shear walls the base shear is reduced by 10%. It is evident that the base shear and lateral force reduces after introducing shear wall but there is reduction of base shear even for the column flange type model (Model 3).

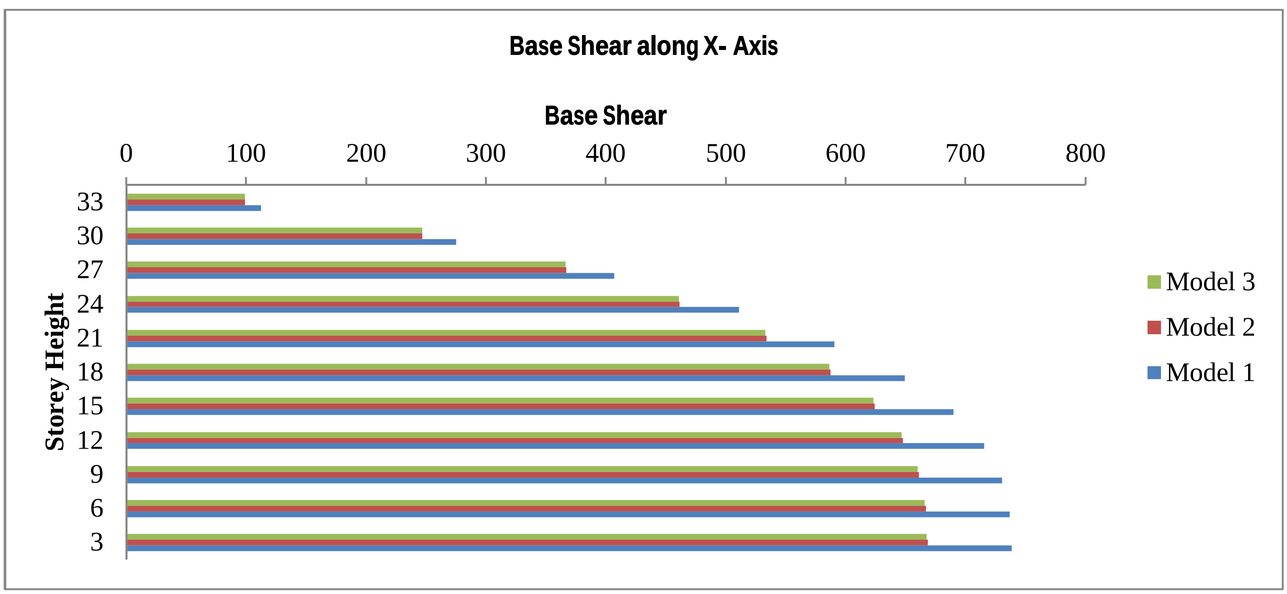


Figure 6:- Base shear along X-direction throughout the height storey wise.

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The Table No. 5 shows Storey height and the distribution of the lateral force and the base shear at each storey level in Z-direction. The percentage decrease in lateral force for model 2 and model 3, when compared with model 1, shows that there is approximate decrease of 10% for both the models, on each storey.

Figure 7 shows a graph of storey height Vs Lateral force in Z-Direction and it is evident that the lateral force for Model 1, Model 2, and Model 3 differs from each other storey wise. It is seen that for a particular model as the storey height increases the lateral force also increases except in the parapet level since the loads on the parapet level are less. Lateral force or storey shear for model 1, model 2 and model 3 are different and approximately 10% decrease in lateral force for model 2 and model 3 is seen at each storey level when compared with model 1.

TABLE 5
LATERAL FORCE AT DIFFERENT FLOOR LEVEL ALONG Z-DIRECTION

Floor Height	Lateral Force			Percentage decrease from model 1	
	Model 1	Model 2	Model 3	Model 2	Model 3
33	128.897	113.629	113.464	11.85	11.97
30	186.567	169.716	169.442	9.03	9.18
27	151.119	137.47	137.217	9.03	9.20
24	119.403	108.618	108.424	9.03	9.19
21	91.418	83.161	81.019	9.03	11.38
18	67.164	61.098	61.001	9.03	9.18
15	46.642	42.429	42.358	9.03	9.18
12	29.851	27.155	27.106	9.03	9.20
9	16.791	15.274	15.248	9.03	9.19
6	7.463	6.789	6.777	9.03	9.19
3	1.866	1.697	1.697	9.06	9.06
Average Percentage (%)				9.29	9.63

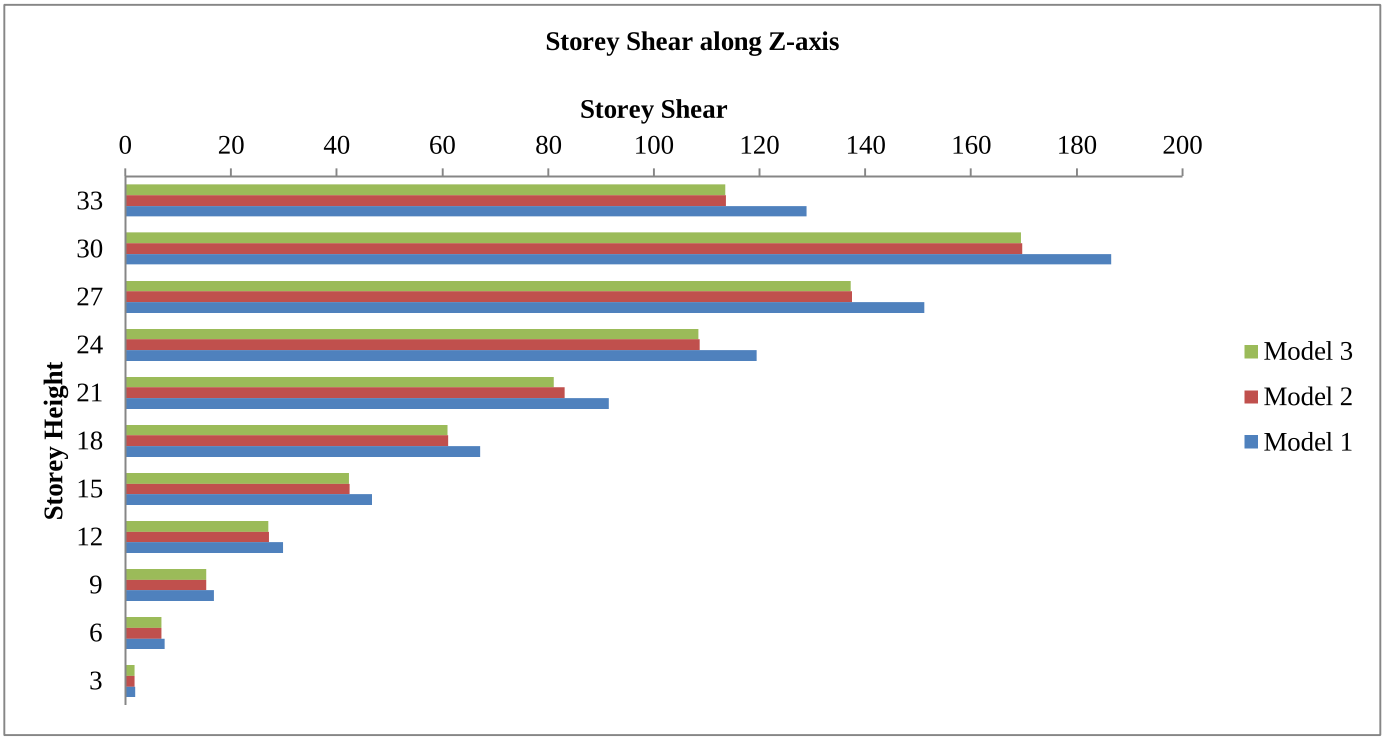

Figure 7:- Lateral force or storey shear along Z-direction throughout the height.

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TABLE 6
BASE SHEAR AT DIFFERENT FLOOR LEVEL ALONG Z- DIRECTION

Floor Height	Base Shear			Percentage decrease from model 1	
	Model 1	Model 2	Model 3	Model 2	Model 3
33	128.897	113.629	113.464	11.85	11.97
30	315.464	283.345	282.906	10.18	10.32
27	466.583	420.815	420.123	9.81	9.96
24	585.986	529.433	528.547	9.65	9.80
21	677.404	612.594	609.566	9.57	10.01
18	744.568	673.692	670.567	9.52	9.94
15	791.21	716.121	712.925	9.49	9.89
12	821.061	743.276	740.031	9.47	9.87
9	837.852	758.55	755.279	9.46	9.86
6	845.315	765.339	762.056	9.46	9.85
3	847.181	767.036	763.753	9.46	9.85
Average Percentage				9.81	10.12

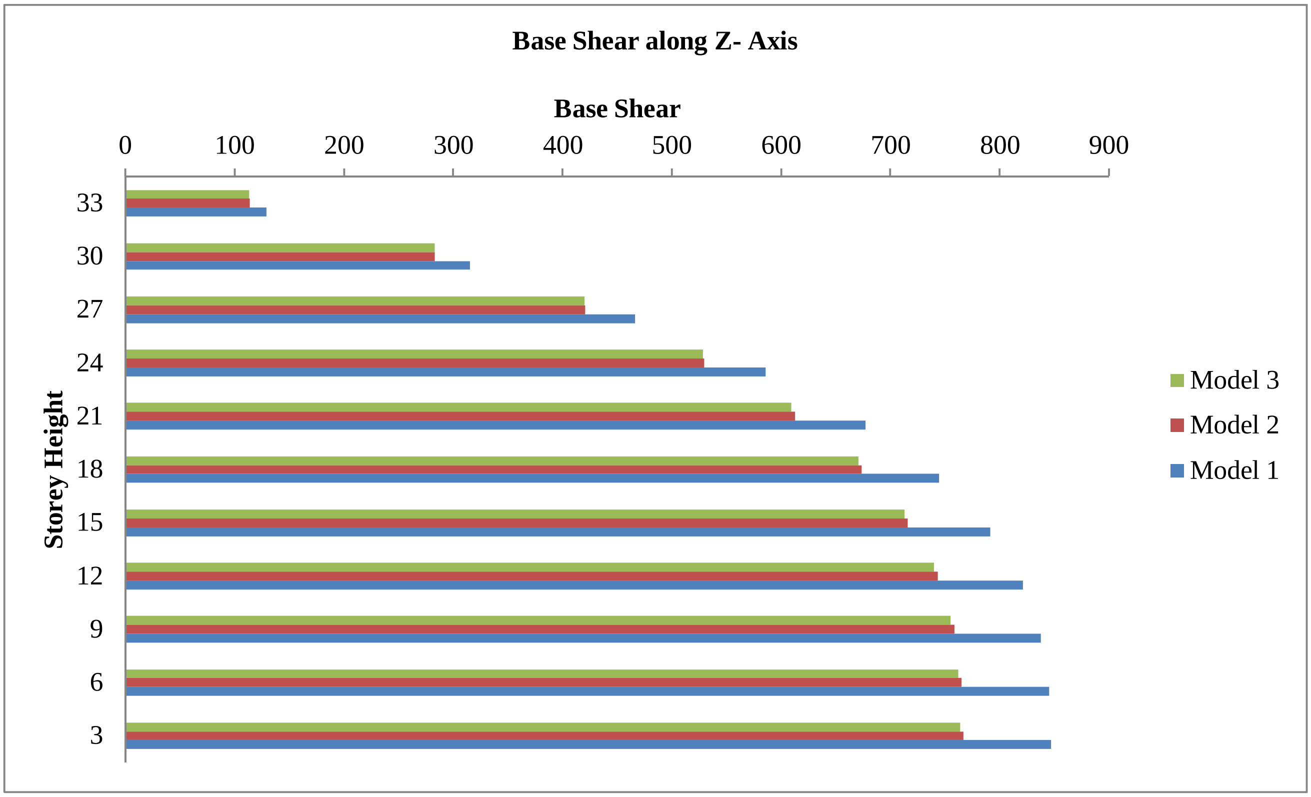


Figure 8:- Base shear along “Z”-direction throughout the height storey wise.

Table 6 shows base shear values at different floor level along “Z”- Direction. Base shear is cumulative of lateral force from top storey to bottom storey. Thus the value of bottom floor shear is maximum and value of top storey shear is minimum. Introducing shear wall and column flange shows approximate 10% reduction in the base shear for model 2 and model 3 when compared with model 1. The values for each storey is cumulative of top storey thus it differs from storey to storey.

Figure 8 shows base shear along “Z”-Direction storey wise. As tabulated above the values are graphically represented in the figure 8. After introducing shear walls the base shear is reduced by 10%. It is evident that the base shear and lateral force reduces after introducing shear wall but there is reduction of base shear even for the column flange type model (Model 3).

B. Shear Force and Bending Moment calculation

Maximum shear force and bending moment in any building is responsible for the stability of the members of any structure. The Shear force and bending moment are useful parameters for design of any member of the structure. The least the moment the lesser will be the cost of structure. Table-7 shows Maximum shear force tabulated in “Y” and “Z” direction for all the models.

TABLE 7
MAXIMUM SHEAR FORCE

Sr. No.	Model Name	Fy kN	Percentage Decrease compared to model 1	Fz kN	Percentage Decrease compared to model 1
1	Model 1	112.705	0.00	78.886	0.00
2	Model 2	109.834	2.55	83.32	-5.62
3	Model 3	108.855	3.42	81.521	-3.34

From the Table No. 7 it is clear that when the model 2 and model 3 are compared with model 1, there is percentage decrease in shear force. A graphical representation of the table is shown in figure 9.

TABLE 8
MAXIMUM BENDING MOMENT

Sr. No.	Model Name	Mz kNm	Percentage Decrease compared to model 1	My kNm	Percentage Decrease compared to model 1
1	Model 1	162.172	0.00	144.148	0.00
2	Model 2	167.05	-3.01	140.132	2.79
3	Model 3	163.015	-0.52	136.293	5.45

Table 8 shows maximum bending moment for different models in “Y” and “Z”-direction. From the table it is clear that when the model 2 and model 3 are compared with model 1, there is percentage decrease in shear force in “Y”- direction and increase in “Z”-direction. Also for model 3 there is reduction in bending moment percentage than in case of model 3. Thus it shows that model 3 is most preferable. A graphical representation of the table is shown in figure 10. Figure 11 shows bending moment diagram for all Models

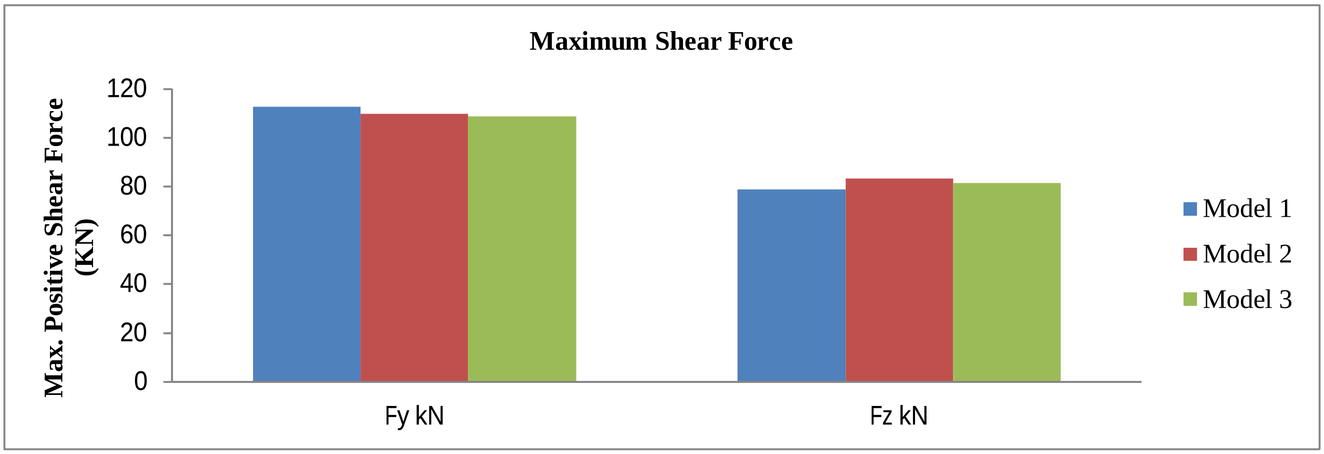


Figure 9:- Maximum Shear force

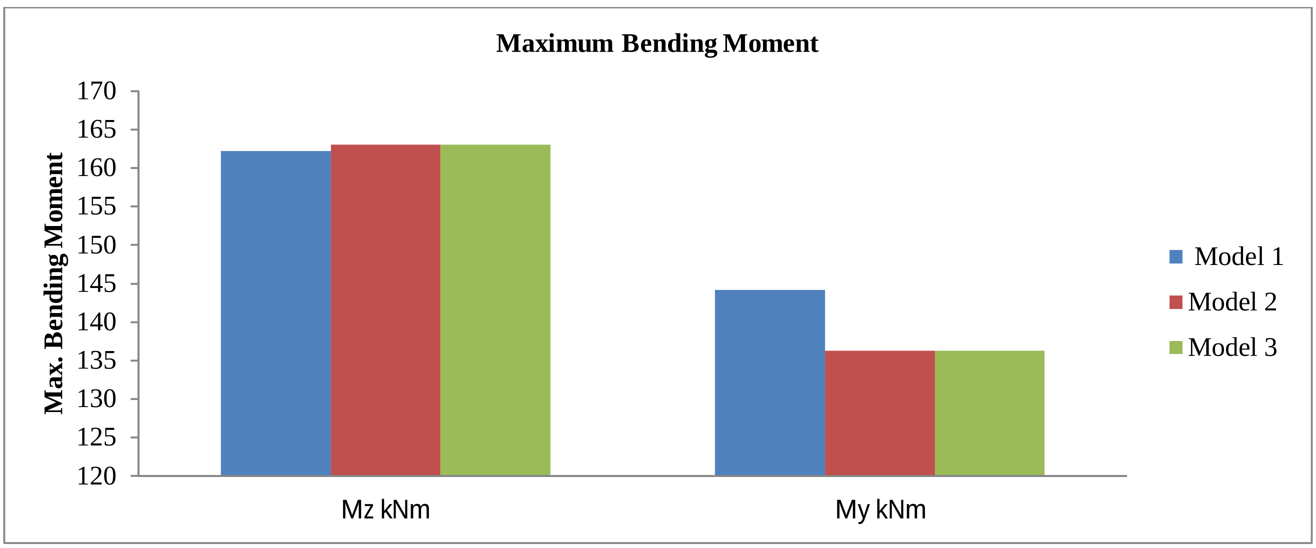
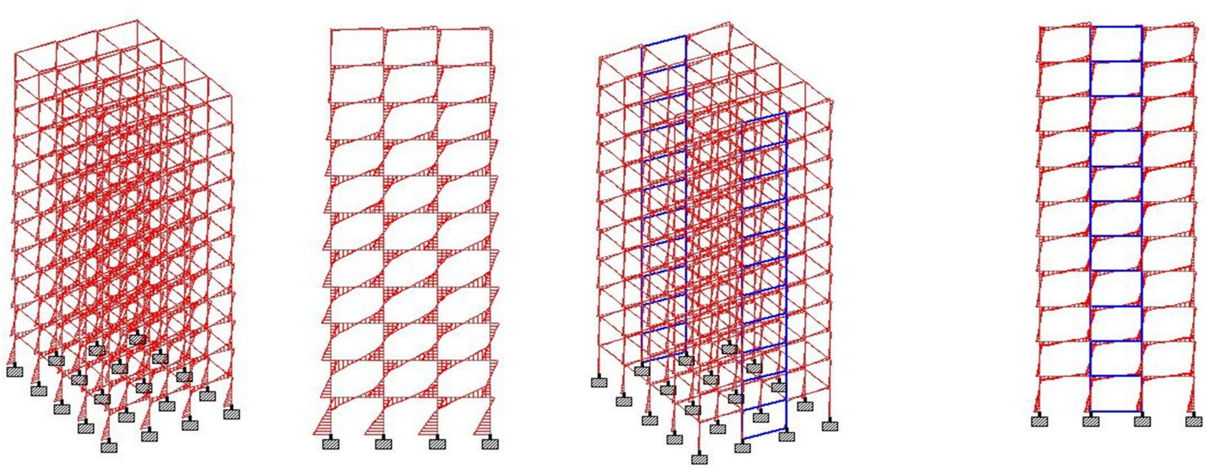
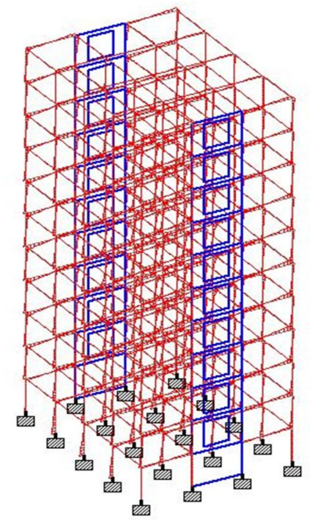


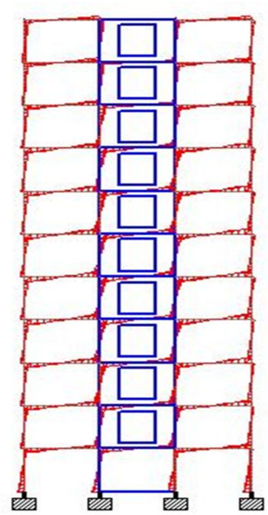
Figure 10:- Maximum Bending Moment



(a) Model 1 (b) Model 1 (Front) (c) :- Model 2 (d) :- Model 2 (Front)



(e) Model 3



(f) :- Model 3 (Front)

Figure 11:- Maximum Bending Moment for Model 1, Model 2, Model 3

C. Maximum Node Displacement

Node displacement of any structure represents the deflection of the structure whenever any load or load combination is applied on the structure. Since the building is analysed for Earthquake resistance, displacements in all the three directions are shown in Table No. 9. Maximum displacements in "X"- Direction and "Z"- Direction for load combinations are stated in the table.

TABLE 9
MAXIMUM NODE DISPLACEMENT

Model Name	Direction of Displacement	Load / Load Combination	Resultant Displacement (mm)
Model 1	Max X (mm)	1.5(DL+EQX)	98.664
Model 2		1.5(DL+EQX)	45.328
Model 3		1.5(DL+EQX)	50.849
Model 1	Max Z (mm)	1.5(DL+EQZ)	105.226
Model 2		1.5(DL+EQZ)	96.911
Model 3		1.5(DL+EQZ)	95.414

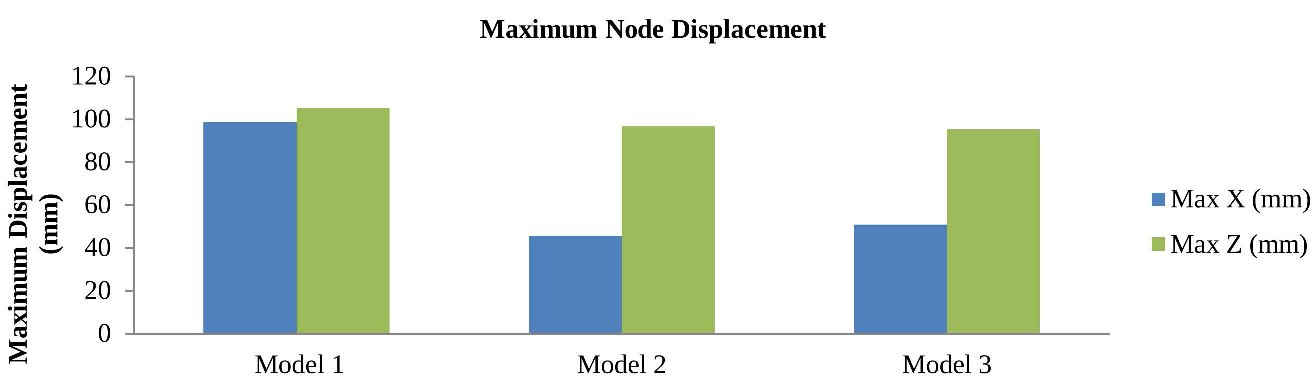


Figure 12 :- Maximum Node displacement

A graphical representation of the table displacement in X and Z direction is shown in the figure 12. The figure clearly shows that, there is a pattern of reduction in node displacement for model 2 and model 3 when compared with model 1. This briefly states that the building is stiff with shear walls and column flanges. Whereas the model 3 becomes economical as the concrete is reduced being approximate similar stiffness is acquired.

IV. CONCLUSIONS

Three different models are studied in this present research. A building with moment resisting frame named as model 1, for the same building shear walls are introduced symmetrically concentrically at outer edge and named as model 2, third type of model named model 3 is newly introduced as column flange type providing opening for shear wall. STAADPro software is used for analysis and the results obtained were satisfactory and following are the concluded remarks that can be established from the results.

A. Lateral force or storey shear at each consecutive storey level for model 1 is more as compared to model 2 and model 3. Model 3 has least lateral force on consecutive storeys as compared to model 1 and model 2.

B. Approximately on an average 10% lateral force or storey shear is decreased by introducing Shear wall for same configuration as of model 1. Model 2 and Model 3 have 10% less storey shear as compared to Model 1.

C. Base shear for model 1 is higher than model 2 and model 3. Approximately 10% decrease in base shear is calculated after introducing shear wall (Model 2) and flange column (model 3).

D. Storey shear and base shear in both the directions i.e. along X-direction and along Z-direction for model 2 and model 3 are decreased by nearly same amount i.e. approximately 10% when compared to model 1.

E. Model 2 and model 3 shows 2% **-** 3% reduction in axial force when compared with Model 1.

F. The parameter shear force shows decrease in X-direction and increase in Y-direction for model 2 and model 3 as compared to model 1.

G. The parameter of bending moment shows increase in Z-Direction and reduction in Y-direction. For model 2 and model 3 when compared with model 1.

H. There is a pattern of reduction in node displacement for model 2 and model 3 when compared with model 1. This briefly states that the building is stiff with shear walls and column flanges. Whereas the model 3 becomes economical as the concrete is reduced being approximate similar stiffness is acquired due to less consumption of concrete.

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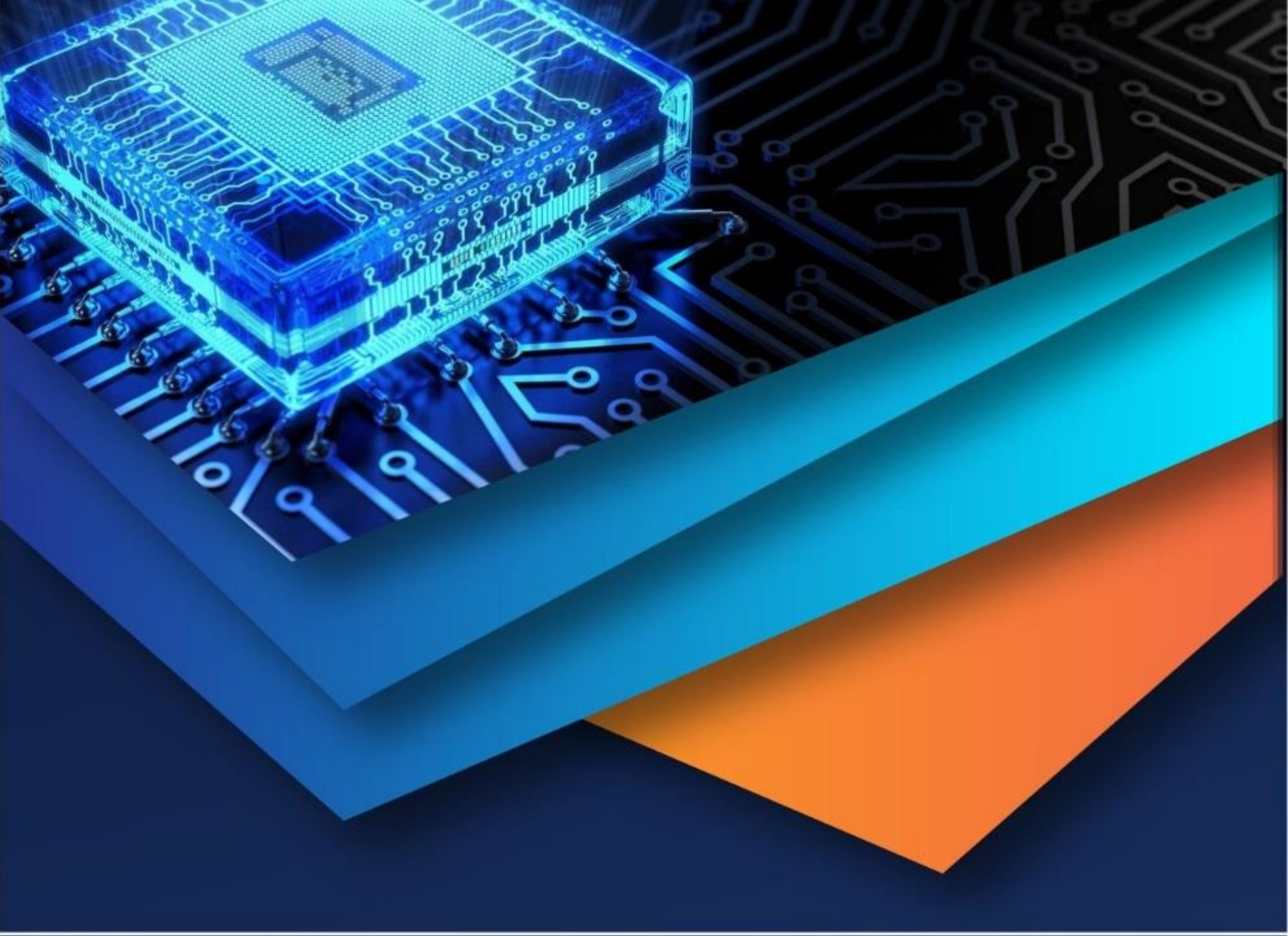

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