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A Study on Seismic Analysis of High Rise Irregular Floor Plan Building with Different Position of Shear Walls

Vinay Agrawal, Rajesh Gupta, Manish Goyal

Abstract: ***The primary objective of any structural system is to support various types of loads acting either vertically or Horizontal or acting jointly with adequate safety. Any structural system should be designed in such a way that each and every element of the system should have ample rigidity, stiffness and strength against the anticipated loads. Any structural frame system with a provision of RC shear wall shows a desirable safety and stability up to 30 stories building height in lateral loads resistance. A RC framed shear wall is a combination of beams, columns interacting with reinforced concrete shear wall. Shear wall provide lateral stiffness to the building by cantilever action. In this study a G+19 story unsymmetrical [Floor plans] commercial building [L>3.6 least lateral dimension of building], H> 3.3 least lateral dimension of building and is modeled with different position of shear walls and analysis conducted for joint displacement, Storey drift, Storey stiffness and Base shear force. These models are modeled with ETABS for static analysis as per IS 1893 -2002. The analysis results for different models are plotted to compare and to know the behavior of RCC frame structure with different position of shear walls.***

Index Terms: Shear Wall, Core Wall, Bare Structure frame, static analysis, lateral loads.

I. INTRODUCTION

Structural design of building for lateral loads is primarily concerned with structural safety during major ground shaking due to earthquake, but serviceability and the potential economic losses are the major concern of structural design. A shear wall building frame structure is the most economical common element to stabilizing building frame during lateral loads. The shear walls act as a vertical cantilever in the form of planner wall or non-planner wall all around the stair case, lift core and service wells. Shear walls are high in stiffness and strength makes them popular choice for lateral load resisting elements. Walls located at useful position can give an efficient seismic force resisting elements. They are also capable to resist vertical gravity loads. During severe earthquake the destruction of buildings and structures causes loss of lives and property.

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The vast extent of destruction and consequent losses of life occurs when a poor construction methodology is adopted. To build a seismic force resisting structures, a detailed research, and information is necessary prior to design, detailing and performance of earthquake resisting elements.

A. Functions of Shear Wall

As the shear walls are strong enough to resist lateral loads due to their high plane stiffness and strength, shear walls transfer lateral loads to the next member in the load direction below them. These others members in a load path can be other shear walls, foundation, floors, slab or footings. They also prevent floor or roof above from excessive sways. Shear walls also prevent floor and roof members to move out from the supports. A well designed shear wall system in the tall building improves seismic performance so it very important to precisely workout the position of shear wall for getting maximum benefit to resist lateral forced and to prevent side sways.

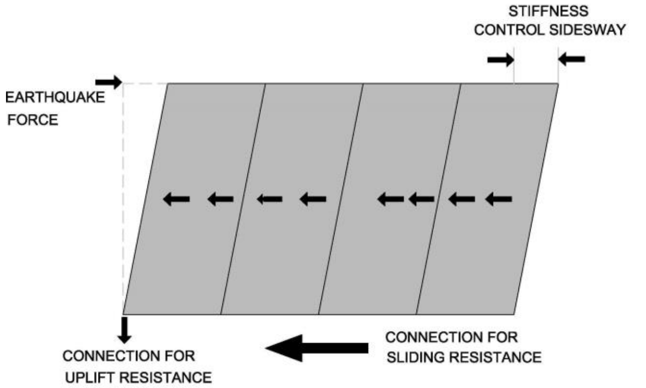

Fig. 1

B. OBJECTIVES

The main objective of the study is:

1. The effect of shear wall locations on structural response due to seismic forces.
2. Static analysis of structural system under different position of shear walls.
3. Compare the behavior of unsymmetrical building for storey drift, joint displacement, storey stiffness, storey shear forces, axial forces in columns and base shear forces under different position of shear walls.

II. METHOD OF ANALYSIS

A. Static Analysis

Criteria for earthquake resistant design of structure IS 1893-2002

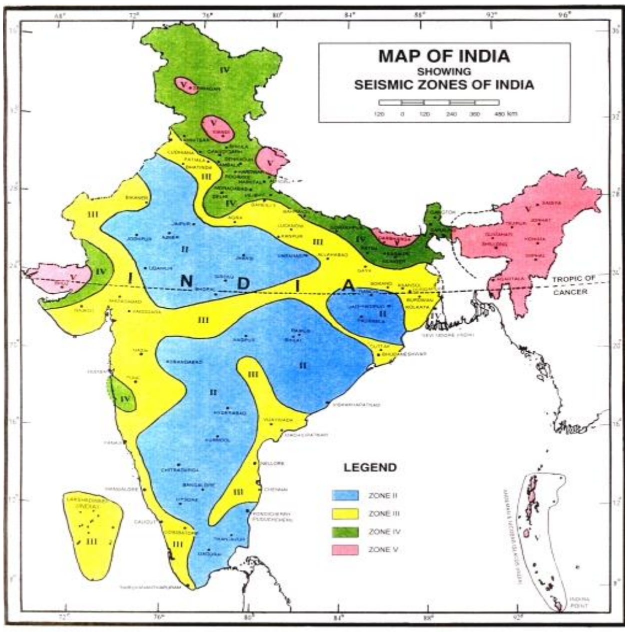

Fig. 2

The earthquake zoning map of India divides India into four zones [Zone II, III, IV & V], zone V is severe intensity while zone II is of the lowest intensity.

When a structure is subjected to earthquake, it responds by ground shaking, these ground shaking can further be divided into all three directions. As the earthquake forces are dynamic in nature and for low to medium height buildings [upto 75 m] analysis by linear static method is sufficient. In this method estimation of base shear force and is distribution is given in IS 1893-2002.

B. Design Seismic Base Shear

The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression: ***V~ = A_hW***

Where Ah = Design horizontal acceleration spectrum value using the fundamental natural period T, in the considered direction of vibration, and W = Seismic weight of the building.

C. Fundamental Natural Period

The approximate fundamental natural period of vibration (T), in seconds, of a moment-resisting frame building without brick infill panels may be estimated by the empirical expression:

T = $0.075\ h^{0.75}$ for RC frame building

= $0.085\ h^{0.75}$ for steel frame building

Where, ***h*** = Height of building, in m. This excludes the basement story's, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected.

D. Vertical Distribution of Base Shear To Different Floor Level

The design base shear (V~) computed above shall be distributed along the height of the building as per the following expression:

$$Qi = Vb\frac{Wihi2}{\sum_{j=1}^{n} Wjhj2}$$

W here,

Q_i = Design lateral force at floor 'i'

W_i = Seismic weight of floor i

h_i = Height of floor i measured from base,

n = Number of storey's in the building is the number of levels at which the masses are located.

III. DESCRIPTION OF BUILDING MODELS

A 20 stories unsymmetrical commercial building of 4.2 meter height at ground floor and 3.4 meter story height at all typical floor is modeled by use of ETABS Software. Building has 5 spans of 4.2 meters in Global X-direction and 9 spans of 8.4 meters in Global Y-direction. A shear wall is modeled along Global X & Y Direction as per case. The storey plan is changing in the different floors as shown in the below figures. The plans of 1st to 5th storey are same as shown below for all the models, the plans for 6th to 10th floor is same as shown in the below figures and the floor plans from 11th to 20th is same again shown as per below figures for all the model cases. The total length of shear walls in each model is same. The loading applied on the structures including dead, live and earthquake loads are according to IS 875 part 1 and 2 and IS 1893.

MODEL 1 [BARE FRAME WITH SHEAR WALL IN THE FORM OF LIFT CORE]

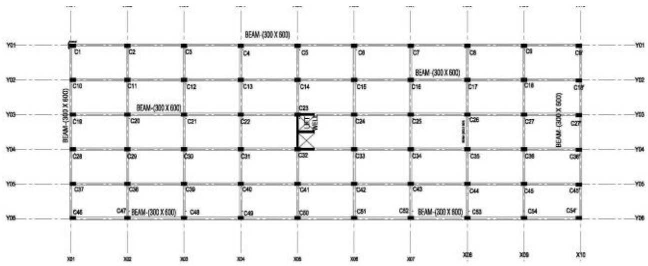

Fig. – 3, Floor Plan- 1st to 5th Floor

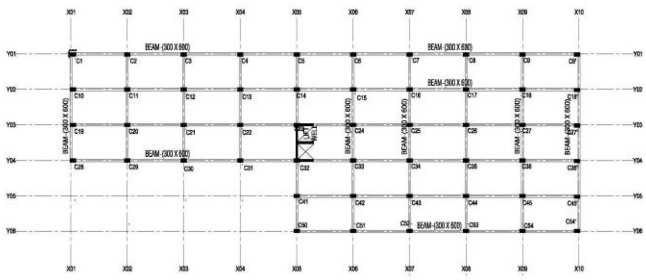

Fig.-4, Floor Plan- 6st to 10th Floor

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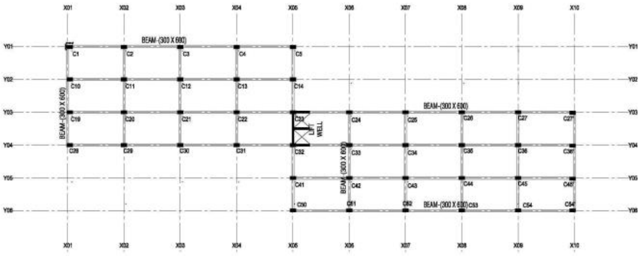

Fig.-5, Floor Plan- 11th to 20th Floor

MODEL 2 [BARE FRAME WITH CORNER SHEAR WALLS]

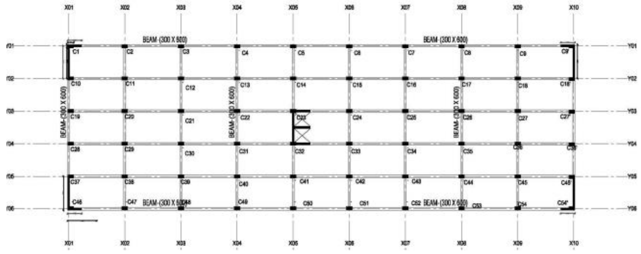

Fig-6, Floor Plan- 1st to 5th Floor

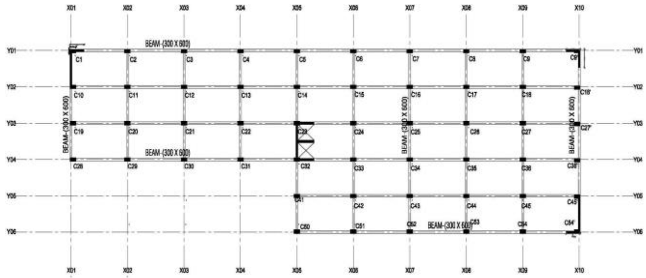

Fig-7, Floor Plan- 6st to 10th Floor

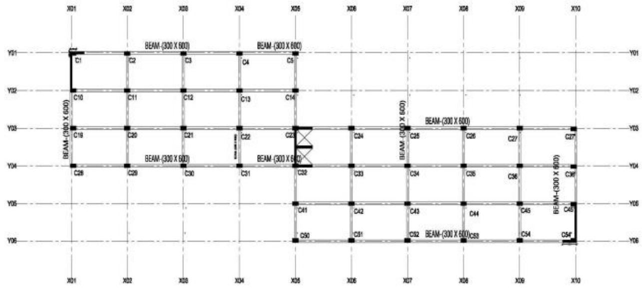

Fig-8, Floor Plan- 11th to 20th Floor

MODEL 3 [BARE FRAME WITH SIDE SHEAR WALLS]

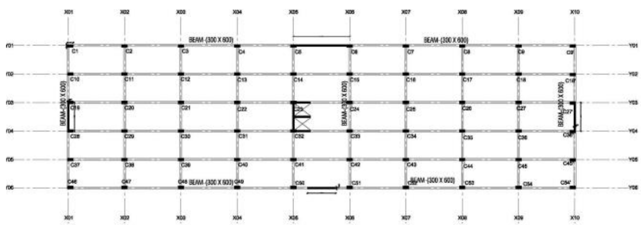

Fig-9, Floor Plan- 1st to 5th Floor

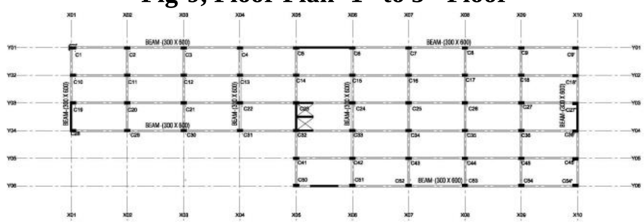

Fig-10, Floor Plan- 6st to 10th Floor

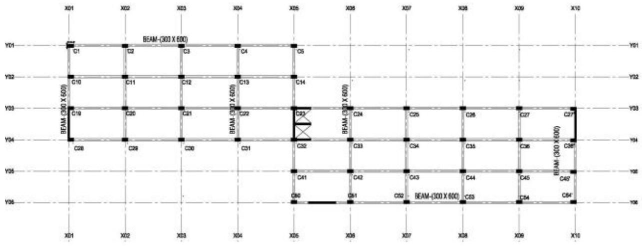

Fig-11, Floor Plan- 11th to 20th Floor

MODEL 4 [BARE FRAME WITH INTERNAL SHEAR WALLS]

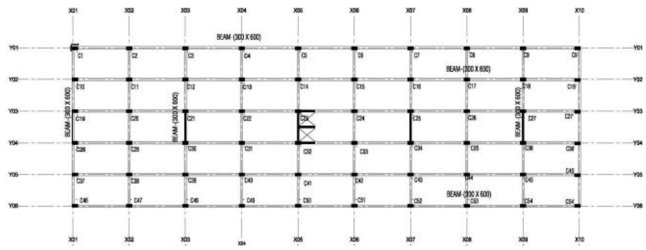

Fig-12, Floor Plan- 1st to 5th Floor

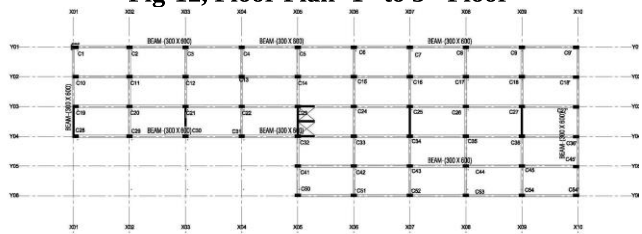

Fig-13, Floor Plan- 6st to 10th Floor

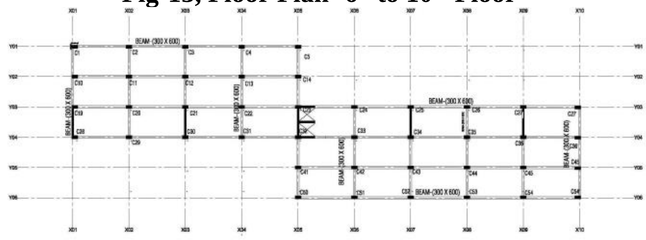

Fig-14, Floor Plan- 11th to 20th Floor

MODEL 5 [BARE FRAME WITH SHEAR WALLS AT OPPOSITE CORNERS]

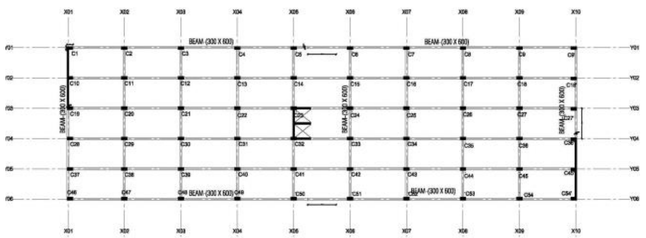

Fig-15, Floor Plan- 1st to 5th Floor

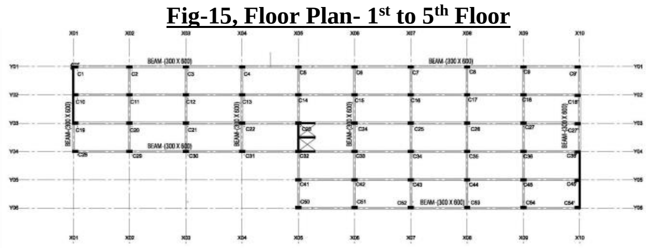

Fig-16, Floor Plan- 6st to 10th Floor

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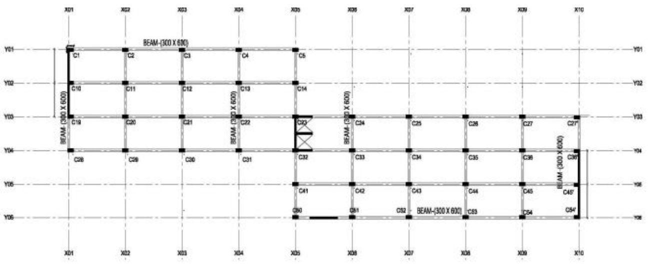

Fig-17, Floor Plan- 11th to 20th Floor

MODEL 6 [BARE FRAME WITH SHEAR WALLS IN SHORTER DIRECTIONS]

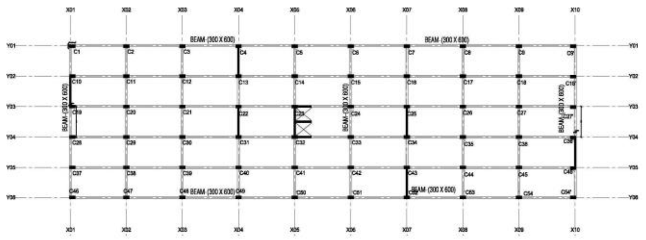

Fig-18, Floor Plan- 1st to 5th Floor

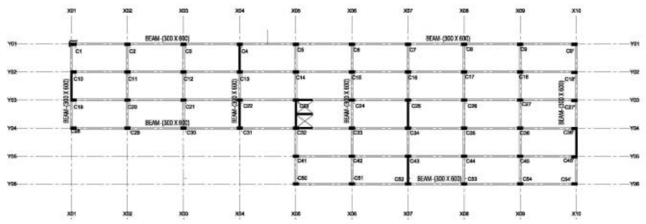

Fig-19, Floor Plan- 6st to 10th Floor

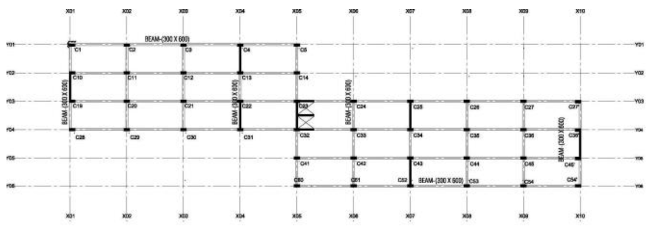

Fig-20, Floor Plan- 10st to 20th Floor

A. ETABS Model

MODEL 1 [BARE FRAME WITH SHEAR WALL IN THE FORM OF LIFT CORE]

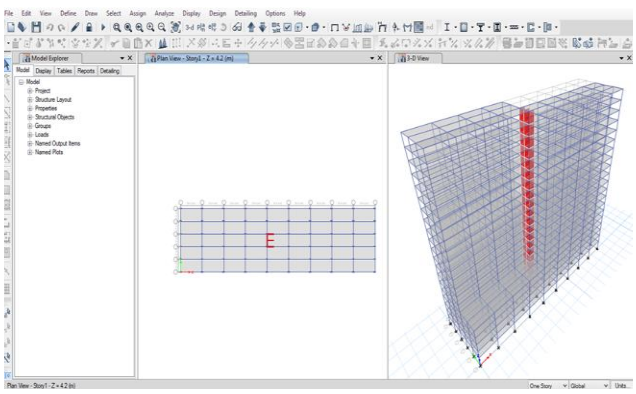

Fig. – 21, Floor Plan- 1st to 5th Floor

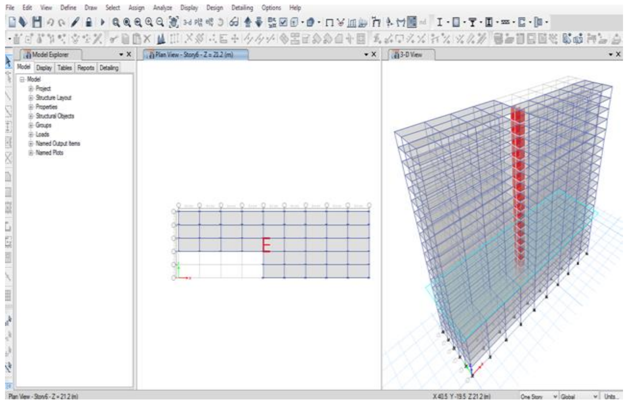

Fig. – 22, Floor Plan- 6st to 10th Floor

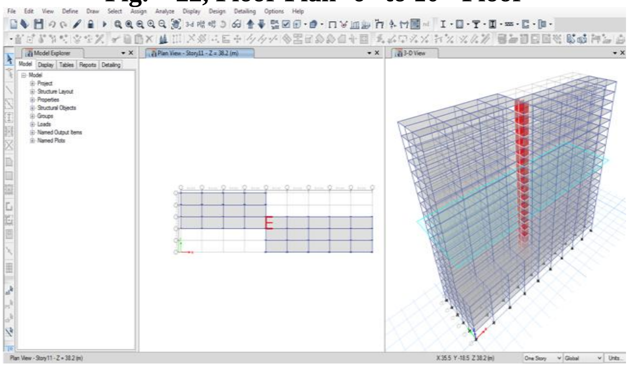

Fig. – 23, Floor Plan- 11st to 20th Floor

MODEL 2 [BARE FRAME WITH CORNER SHEAR WALLS]

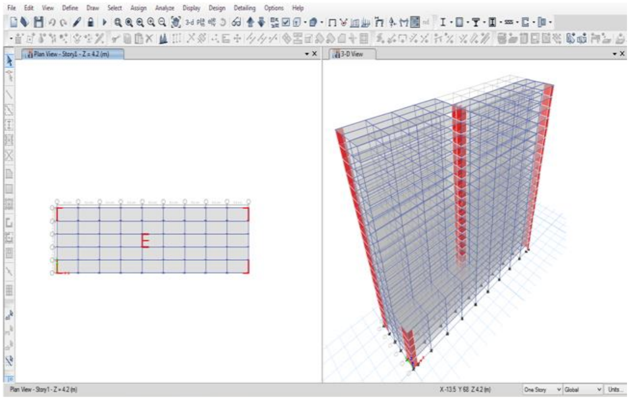

Fig. – 24, Floor Plan- 1st to 5th Floor

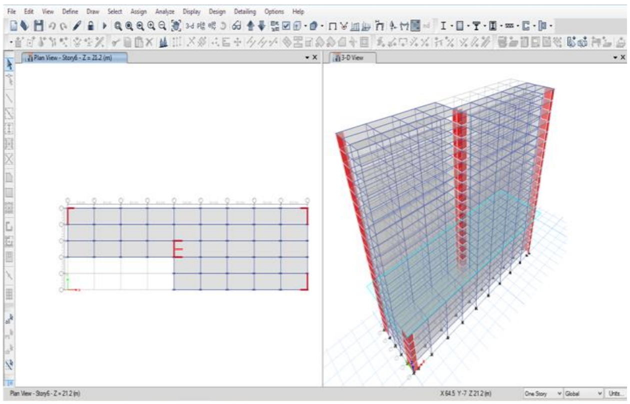

Fig. – 25, Floor Plan- 6st to 10th Floor

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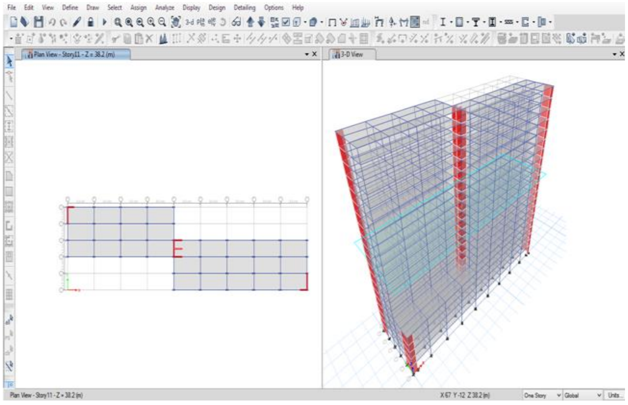

Fig. – 26, Floor Plan- 11st to 20th Floor

MODEL 3 [BARE FRAME WITH SIDE SHEAR WALLS]

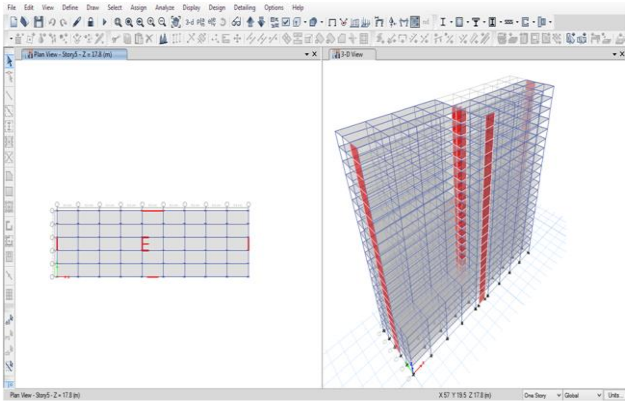

Fig. – 27, Floor Plan- 1st to 5th Floor

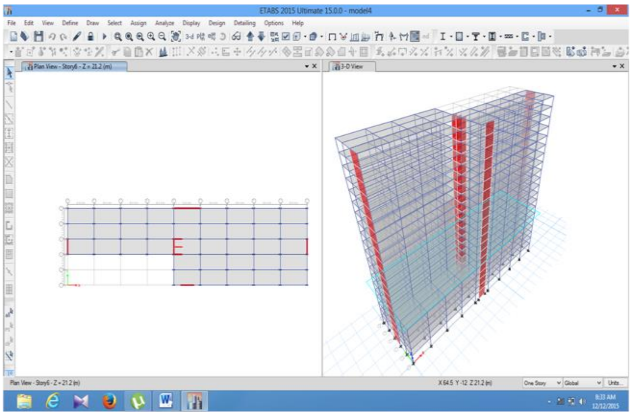

Fig. – 28, Floor Plan- 6st to 10th Floor

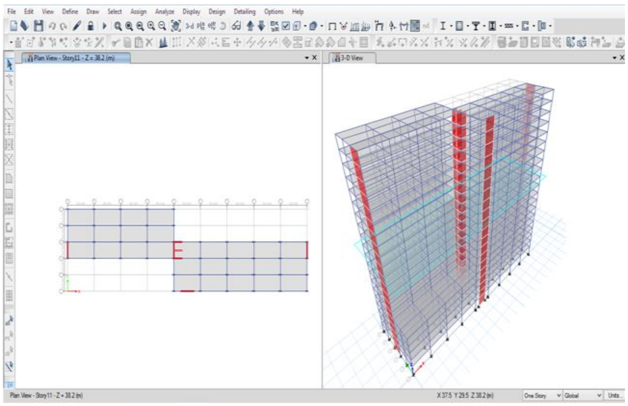

Fig. – 29, Floor Plan- 11th to 20th Floor

MODEL 4 [BARE FRAME WITH INTERNAL SHEAR WALLS]

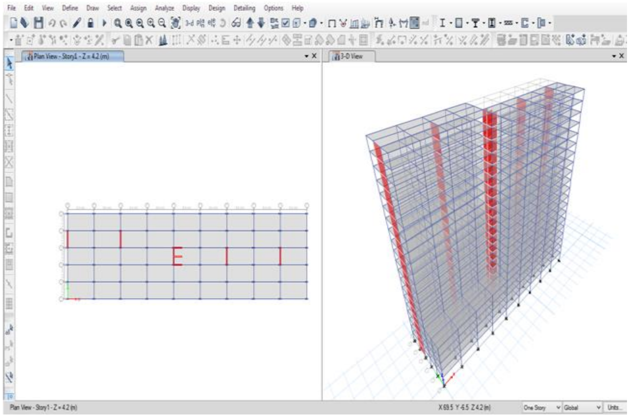

Fig. – 30, Floor Plan- 1st to 5th Floor

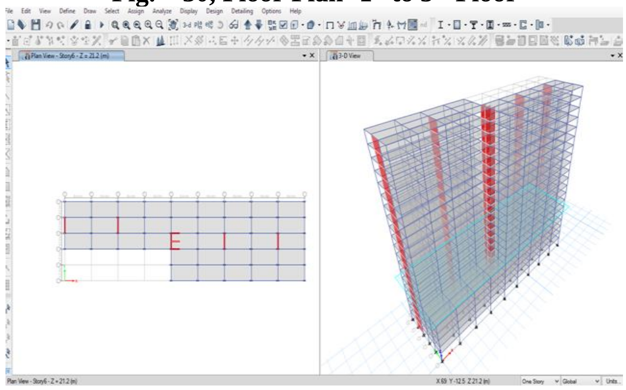

Fig. – 31, Floor Plan- 6st to 10th Floor

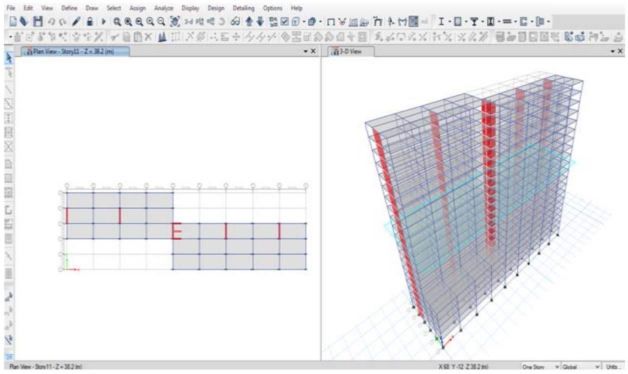

Fig. – 32, Floor Plan- 11th to 20th Floor

MODEL 5 [BARE FRAME WITH SHEAR WALLS ON OPPOSITE CORNERS]

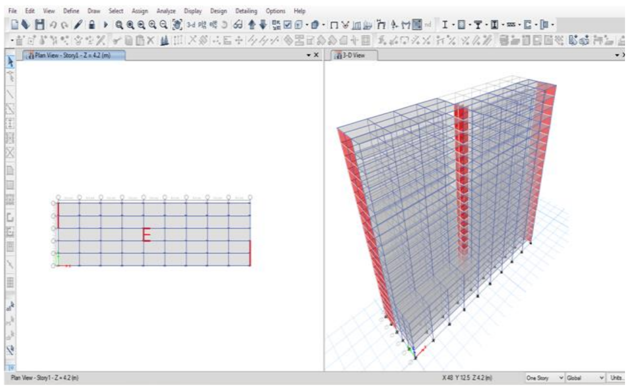

Fig. – 33, Floor Plan- 1st to 5th Floor

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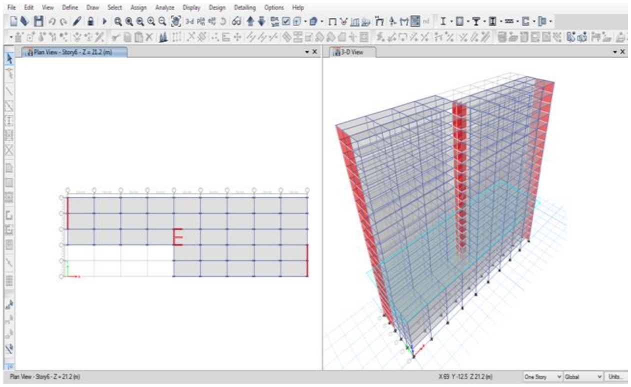

Fig. – 34, Floor Plan- 6st to 10th Floor

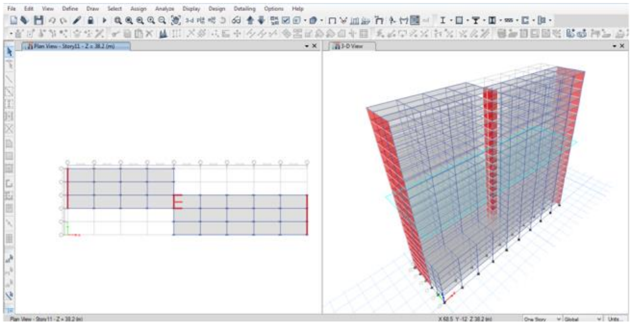

Fig. – 35, Floor Plan- 11th to 20th Floor

MODEL 6 [BARE FRAME WITH SHEAR WALLS IN SHORTER DIRECTIONS]

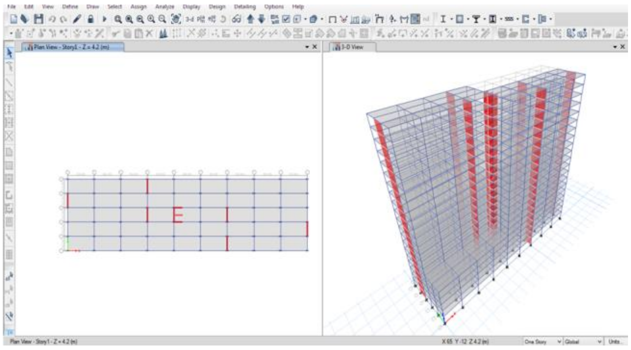

Fig. – 36, Floor Plan- 1st to 5th Floor

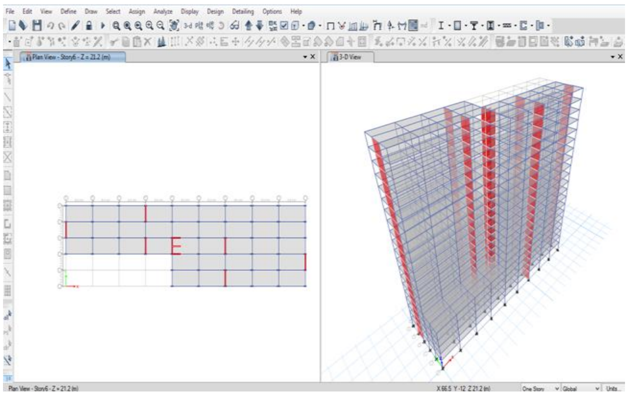

Fig. – 37, Floor Plan- 6st to 10th Floor

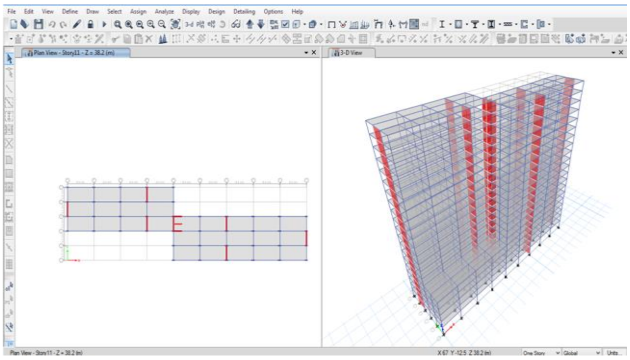

Fig. – 38, Floor Plan- 11th to 20th Floor

IV. STOREY DATA & LOAD DESCRIPTION

- Type of frame: Special RC moment resisting frame fixed at the base.
- Steel of grade Fe 500,
- Concrete of grade 35MPa
- Seismic zone: IV (i.e. Z = 0.24)
- Number of storey: 20
- Floor height :
  Ground Floor, Stilt Floor – 4.20 meters
  Upper Floors/ All typical - 3.40 meters
- Live load on floor : 4 kN/m^2
- Damping of structure : 5 %
- Loading As per IS-1893(Part-1):2002, IS:875 [part 1and part 2]
- Beams of size 300 mm width and 600 mm width – all floors.
- Columns sizes 450 mm X 900 mm – all floors
- Shear wall of thin shell type thickness of 300 mm X 4200 mm, the total length of shear walls in all model is same.
- Concrete floor of membrane type and thickness 200 mm.
- Structure is restrained for rotation and translation at the base i.e. supports are fixed

Each model of the building is subjected to the following loadings:-

Dead Load - Self Weight of RCC Frame Structure, Brick Wall & Floor Finish

Live Load on Floor – A 4.0 KN/m^2 is applied

Seismic Forces in –

(+) X and (-) X Direction

(+) Z and (-) Z Direction

After applying above load each model of the building is analyzed for static method under the following load combination generated automatically using ETABS:-

- 1.5 x [DL-Self Weight]
- 1.5 x [DL + LL]
- 1.2 x [DL + LL + EQX]
- 1.2 x [DL + LL - EQX]
- 1.2 x [DL + LL + EQX-]
- 1.2 x [DL + LL – EQX-]
- 1.2 x [DL + LL + EQZ]
- 1.2 x [DL + LL - EQZ]

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- 1.2 x [DL + LL + EQZ-]
- 1.2 x [DL + LL – EQZ-]
- 1.5 x [DL + EQX]
- 1.5 x [DL - EQX]
- 1.5 x [DL + EQX-]
- 1.5 x [DL - EQX-]
- 1.5 x [DL + EQZ]
- 1.5 x [DL - EQZ]
- 1.5 x [DL + EQZ-]
- 1.5 x [DL - EQZ-]
- 0.9 DL + 1.5 EQX
- 0.9 DL - 1.5 EQX
- 0.9 DL + 1.5 EQX-
- 0.9 DL - 1.5 EQX-
- 0.9 DL + 1.5 EQZ
- 0.9 DL - 1.5 EQZ
- 0.9 DL + 1.5 EQZ-
- 0.9 DL - 1.5 EQZ-

The results obtained from analysis are compared for followings parameters.

- Joint Displacement
- Story drift
- Story stiffness [KN/M]
- Base Shear Forces [KN]
- Storey Shear Force
- Axial Forces In Columns

V. RESULT AND DISCUSSION

The results obtained from analysis for all the models are compared and plotted in the given figures below-

A. Joint Displacement

It is observed from the curve that the joint displacement is higher in model-6, the model with shear walls are in shorter directions, and it is going to reduce when shear walls are placed on the sides of the building – model-3. The joint displacement at the joint of top storey is reduced when compared w. r. t to the model-1, around 25% when side shear walls are placed and 12% reduction in the joint displacement when corner shear walls are introduced. [Ref. Fig. No- 39]

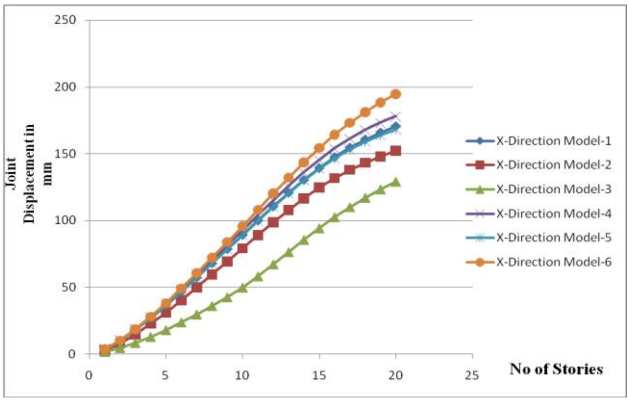

Fig. 39

Lateral Story Drift is defined as the relative movement of story relative to another adjacent story. Generally story drift increase as story height increases and again decreases for higher stories

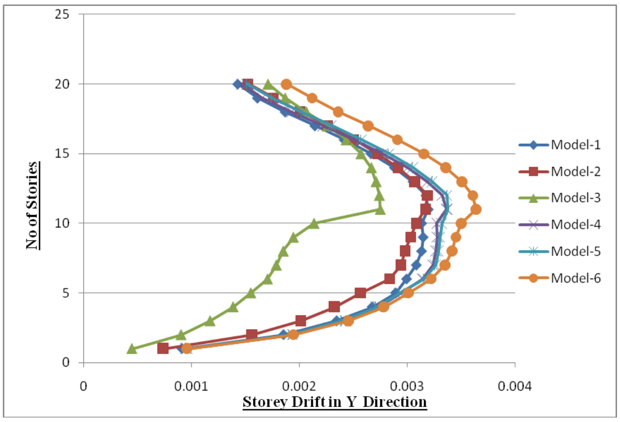

Fig. 40

The above graph represents the inter storey drift for all the six models and it is observed from the graphs that the behavior of base frame with only core wall is very erratic and the least drift is found in model 3 with side shear walls. The model 5 and model 6 is performing well in inter storey drift as their inter storey drift value is almost same amongst all the models. Drastic changes occur in the performance of model-3 for storey drift when shear walls are removed at one location from 11th storey.

B. Storey Shear Force

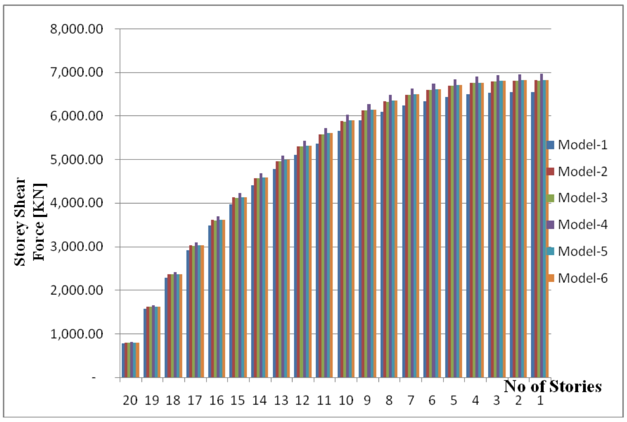

Fig. 41

It is observed from the curve that the storey shear force is least for model-1, structure with shear walls in the form of core walls and higher for model-4 structure with shear walls in shorter direction.

C. Storey Stiffness

The graph shown in Fig 42 represents the storey stiffness [KN/m] for all the six models and it is observed from the graphs that the storey stiffness of model-3 at ground level is almost two times higher than the stiffness of model-1, shear walls with core walls only, and around 25% higher in model-2 as compared to model-1.

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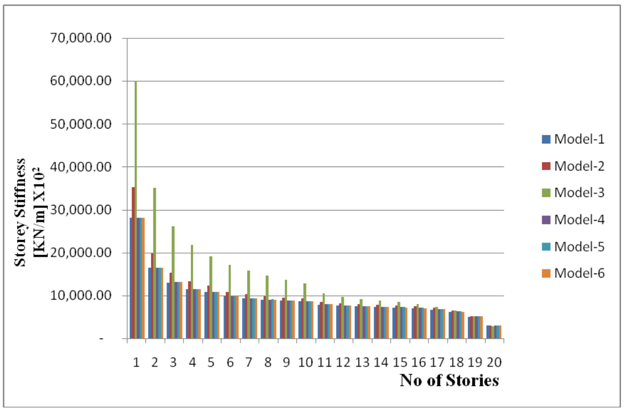

Fig. 42- KN/M X 10²

D. Seismic Base Shear

As we discussed earlier that earthquake is act as dynamics loading but to medium to high rise buildings we convert this dynamics earthquake loading to the equivalent static loading. This equivalent static loading is act as shear force on the base of the structure which is further distributed to the story level, this shear is called base shear. Base shear is shown in the table and it is observed that the base shear is higher for the building model-4 with shear walls at the interior part of the building and least for model-1 when shear walls in the form of core walls.

It is also observed from the below table that base shear is influenced by the position of shear walls.

TABLE – 1 Seismic Base Shear for Building Models

MODEL NO.	BASE SHEAR (KN)
Model - 1	6559.16
Model - 2	6828.40
Model – 3	6820.99
Model – 4	6970.51
Model – 5	6833.40
Model - 6	6788.75

E. Axial Forces in Columns

Axial force in Column C 45 is compared and observed that the axial force is higher for Model – 1 when shear walls are provided in the form of core walls and least for Model – 6. It is also observed that the axial forces in the columns are greatly influenced by the position of shear walls.

TABLE - 2 Axial Force in column

Model No.	Column No	Load combination	Axial Force (KN)
Model - 1	45	1.5 X [DL +LL]	18984
Model - 2	45	1.5 X [DL +LL]	18954
Model -3	45	1.5 X [DL +LL]	18902
Model -4	45	1.5 X [DL +LL]	17986
Model -5	45	1.5 X [DL +LL]	18953
Model - 6	45	1.5 X [DL +LL]	17550

VI. CONCLUSION

The responses of 20 story Unsymmetrical building for static analysis were investigated with different location of solid shear walls. Response according to change of the position of shear wall is studied i.e. six models were analyzed. Following are the conclusions of the study-

- The stability of building is governed by the position and % area of solid shear walls, the bare frame model-1 is comparatively less stable than other models when analyzed for lateral joint displacement, story drift, storey stiffness, storey shear forces, base shear force and the forces in axial columns.
- The displacement at the joint of top storey is reduced when compared w. r. t to the model-1, around 25% when side shear walls are placed in model-3 and 12% reduction in the joint displacement when corner shear walls are introduced in model-2.
- The behavior of base frame with only core wall is very erratic and the least drift is found in model 3 when side shear walls are placed. The model 5 and model 6 is performing well in inter storey drift as their inter storey drift value is almost same. Drastic changes occur in the performance of model-3 for storey drift when shear walls are removed at one location from 11th storey.
- The storey stiffness of model-3 at ground level is almost two times higher than the stiffness of model-1, shear walls with core walls only, and around 25% higher in model-2 as compared to model-1.
- The base shear is higher for the building model-4 with interior shear walls and least for model-1 when shear walls are in the form of core walls only.
- The axial forces in columns C-45 is higher for Model – 1 when shear walls are provided in the form of core walls and least for Model – 6

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