Analysis and Comparative study of Lateral Load Resisting System in High Rise Building

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Abstract -Generally, Moment resisting frames (MRF) are known for their load resisting behavior (gravity loads). As the building height increases, the effect of lateral force on the structure also increases. MRF alone is not able to resist those lateral loads in region of higher seismic zones. In order to resist these lateral actions, lateral load resisting systems (LLRS) are very significant in tall buildings. In the analysis of tall buildings, the suitability of analysis method is very important. Stiffness is very crucial in controlling global displacement in high rise buildings. The lateral load resisting systems like shear wall, bracing systems plays a very important role in reducing the drift, displacement, story shear and also, they increase the stiffness of the building. The positioning of the structural systems plays important role in reducing the effects. In this project, G+20 building is considered and comparative study of shear wall systems with and without opening and different types of bracing systems are analyzed by response spectrum method using ETABS software. From results, we found that models with lateral load resisting system plays important role in reducing drift and storey displacement. With the presence of opening in the shear wall slightly increase story drift and displacement at stories. The model with LLRS placed at central position adds more stiffness compared to positioning at corner.

Keywords *- Moment resisting frames, drift; displacement; storey shear; storey stiffness; Lateral load resisting systems; shear wall; bracings; Etabs.*

1.INTRODUCTION

Emporis standards define a high rise building as “A multi-storey structure between 35-100 meters tall”. High rise structures provide an effective way for the commercial and residential use. Due to limited space and rapid urbanization, tall buildings are so common in cities. Along with the gravity/vertical loads, the building has to be designed for lateral loads also.

With increase in the height of the building, the lateral loads become more prominent. The lateral loads such as wind and seismic forces need to be concerned in the analysis. In order to resist these lateral forces, Lateral load resisting systems (LLRS) become more popular due to their safety and economy concern. There are various types of lateral load resisting systems, Among them majorly used systems for mid-rise and high-rise structures are:

a. Moment Resisting Frames
b. Shear Wall System
c. Braced Frames

Moment Resisting Frames: Moment Frames are the kind of structure consisting beams and columns. They carry gravity loads imposed on the floor system. The resistance to horizontal forces is primarily by the rigid frame action by development of moments and shear forces in the members and joints.

Shear wall System: The Shear wall is the structural element used to resist lateral forces parallel to the plane of the wall by cantilever action. For the building over 20 stories, the shear wall may be imperative from view of economy and to reduce the lateral deflection. These shear walls can be of various materials like Concrete, Steel and Timbers. Out of these, RC Shear wall is commonly practiced in high rise buildings. The strength and stiffness of the building depends on the shape and position of the shear wall. Majorly shear wall position is at the perimeter, centre of the building encasing shaft or stairwell. A Shear wall with opening is also known as Coupled Shear wall. In this case shear wall acts as an individual wall section and slabs above and below the openings i.e. spandrels acts as tie beam to distribute the load.

Braced Frames:
Bracing is common in steel structures. They are used along with the moment resisting frames to resist lateral forces i.e., wind and seismic forces. The diagonal bracing forms triangular configuration which helps in reducing effect of lateral forces in high rise buildings. There are mainly two types of bracing systems, frames associated with this bracing is referred as braced frames.
1. *Concentric Braced Frames*-These frames are usually triangulated and connected at the end of the other framing members (joints) to develop truss action. A few common types are X-bracing, Single diagonal bracing, Inverted V bracing etc.
2. *Eccentrically Braced Frames*-These type of systems utilize diagonal braces with one or two ends deliberately offset to the supporting member, such that bracing system is not centered. The gap between offset and bracing is called ‘fuse’ and it is designed to dissipate lot of energy during an earthquake.

Types of Seismic Analysis In Tall Building
1.Linear Static Method
2.Linear Dynamic Method
3.Non-Linear Static Method
4.Non-Linear Dynamic Method
In Dynamic analysis, we have linear dynamic analysis called as Response Spectrum Analysis. This method in which force and deformation characteristics are linear with each other and another type is non-linear dynamic method called as time history analysis, in which time history data (displacement, velocity and acceleration vs time) of previous earthquake to be known to evaluate the building.
Here Response Spectrum analysis is considered for the analysis of the models because with the help of equivalent static method, the buildings of higher seismic zones and having higher modes of vibration cannot be analysed.

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II. OBJECTIVES

The objectives drawn from the thesis are listed below

1. To analyze the building with different lateral load resisting systems like shear wall and bracing systems at high seismic zone i.e., Zone V.
2. To study the response of structure due to lateral loads by placing shear wall in different position (center and at corners).
3. To study the response (i.e., parameters like story drift, displacement, and stiffness characteristics) of shear wall with and without openings.
4. To give conclusion about the effective type of bracing system in terms of the performance.

III. PROBLEM STATEMENT

In this work, regular building of G+20 story building in seismic zone V is considered and analyzed under the effect of lateral loads by using response spectrum method.

In this work, models with and without LLRS is analysed and compared. In this study LLRS like shear wall and bracing systems are considered.

The shear wall with and without opening are taken for the study and also different positioning of shear wall, bracing (centre and corner) are considered in this study.

Table 1 : Model Specifications

Sl.No	Parameters	Values
1	Building Plan	30 x 30 m
	a. Length in X-direction	30 (6 Bays)
	b. Length in Z-direction	30 (6 Bays)
2	Storey	G+20
3	Height of the building	72.0m
4	Floor to Floor height	3.50m
5	Base to Plinth	2.0m
6	Column size	1200 x 1200mm (bottom 5 stories) 900 x 900mm (6-12 storey) 600 x 600mm (13-20 storey)
7	Beam size	450 x 650mm
8	Thickness of RCC Slab	150mm
9	Shear wall thickness	400mm

IV. METHODOLOGY

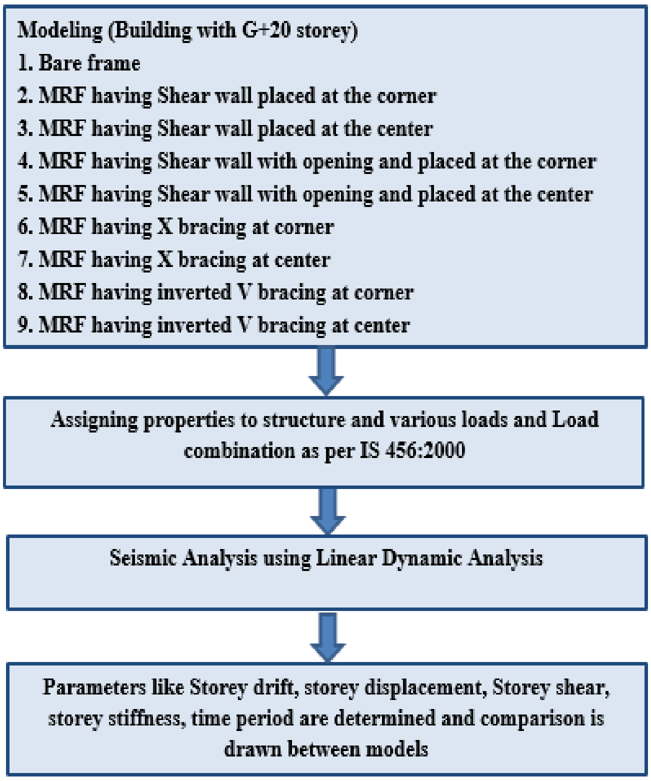

Table 2: The parameters considered for the analysis

Sl. No	Parameters	Values
1	Live Load	3.0 kN/m^2
2	Wall Load	13.90 kN/m
3	Floor Finish	1.5 kN/m^2
	Seismic Load parameters as per IS 1893:2016	
4	Seismic Zone	V
5	Seismic Zone Factor	0.36
6	Response Reduction Factor(R)	5.0
7	Importance Factor	1.20
	Wind Load as per IS 875(Part 3):2015	
8	Wind Speed	47 m/s
9	Risk Coefficient	1.00
10	Terrain Coefficient	1.20
11	Topography Coefficient	1.00
12	Windward Coefficient	0.80
13	Leeward Coefficient	0.25
14	Soil Type	II (Medium)
15	Terrain Category	4
16	Class	C
17	Damping	5%

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MODEL DESCRIPTION

The models considered for the analysis are listed below:

1. Moment Resisting Frame (MRF) or Bare Frame
2. MRF with shear wall at periphery.
3. MRF with shear wall at center.
4. MRF with shear wall with opening at periphery.
5. MRF with shear wall with opening at center.
6. MRF with X bracing at center.
7. MRF with X bracing at periphery.
8. MRF with inverted V bracing at periphery.
9. MRF with inverted V bracing at center.

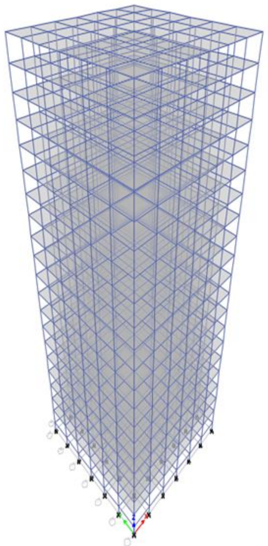

Fig.1 Bare Frame

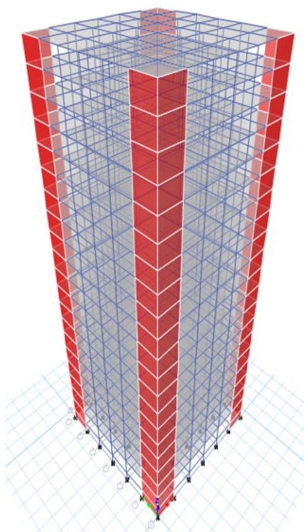

Fig.2 MRF with SW at corner

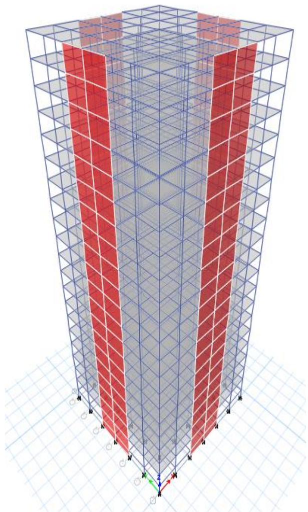

Fig.3 MRF with SW at centre corner

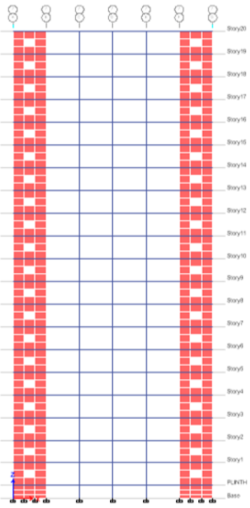

Fig.4 MRF with SW (opening) corner

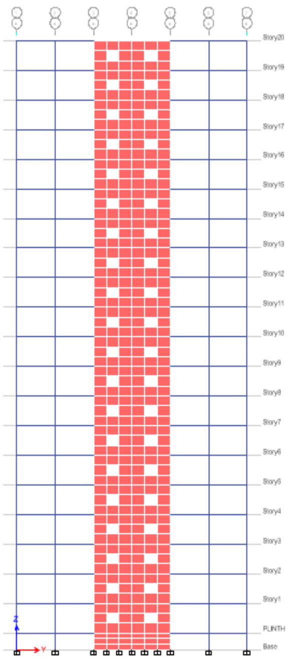

Fig.5 MRF with SW (opening) centre

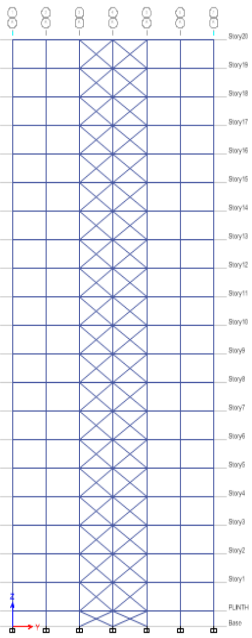

Fig.6 MRF with X bracing at centre

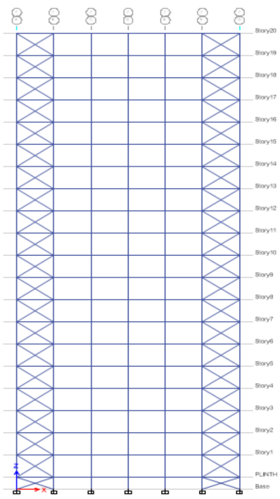

Fig.7 MRF with X bracing at corner

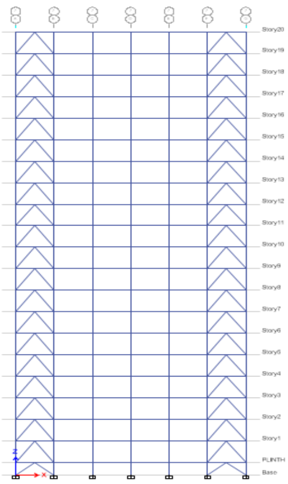

Fig.8 MRF with V bracing at corner

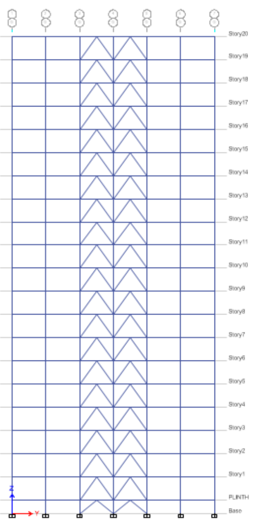

Fig.9 MRF with V bracing at centre

V. RESULTS

A. STOREY DISPLACEMENT

The lateral displacement of the top storey with respect to base of the structure is known as story displacement. The maximum displacement in X and Y directions are taken for the compilation for the load combination of 1.2DL+1.2LL±1.2 RSX and 1.2DL+1.2LL±1.2 RSY

Table 3: Storey Displacement as per Response Spectrum are tabulated below

Sl. No	Models	Storey displacement(mm)
1	Bare Frame	334.66
2	SW Centre	135.91
3	SW Corner	169.86
4	SW Centre (with opening)	139.78
5	SW Corner (with opening)	171.76
6	X bracing centre	147.53
7	X bracing corner	196.95
8	Inverted V bracing centre	159.45
9	Inverted V bracing corner	192.35

Fig.10 Storey displacement as per response spectrum

- From these results, its shown that model with lateral load resisting system have shown good results in terms of reducing displacement than bare frame.
- By these values, its seen that storey displacement values for the bare frame (334.66mm) exceeding codal limits (h/250) i.e., 288mm for the case considering earthquake effects.
- Among shear wall and bracing system, Shear wall system at centre has controlled effect on displacement compared to bracing system.

B. STOREY DRIFT

- By these results, the maximum drift is observed in case of bare frame i.e., 0.068. The value obtained as the drift in this case exceeds the codal provisions. The maximum storey drift ratio as per code is 0.004.
- By using structural system like shear wall, models have reduced drift values compared to bare frame. Frame with Shear wall placed at centre and corner have controlled drift i.e., 0.0024 and 0.0030 respectively. With opening the shear wall models have 0.0025 and 0.0030 drift values when placed at centre and corner respectively.
- Bracing models have reduced drift values compared to bare frame. Frame with X bracing placed at centre and corner have controlled drift i.e., 0.0028 and 0.0037 respectively. In case of inverted V bracing models have 0.0025 and 0.0030 drift values when placed at centre and corner respectively.
- X bracing system at centre had more storey drift about 16.67% than the Shear wall model.

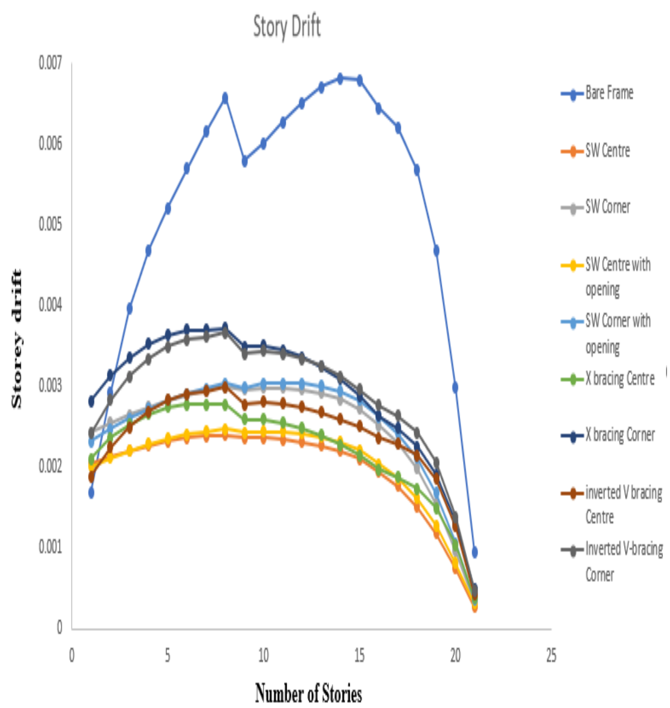

Fig.11 Storey drift as per response spectrum

C. STOREY SHEAR

Table 4: Maximum Storey Shear as per Response Spectrum are tabulated below

Sl. No	Models	Storey Shear (kN)
1	Bare Frame	23492
2	SW Centre	17832
3	SW Corner	17373
4	SW Centre (with opening)	16634
5	SW Corner (with opening)	17371
6	X bracing centre	24619
7	X bracing corner	24083
8	Inverted V bracing centre	24095
9	Inverted V bracing corner	24228

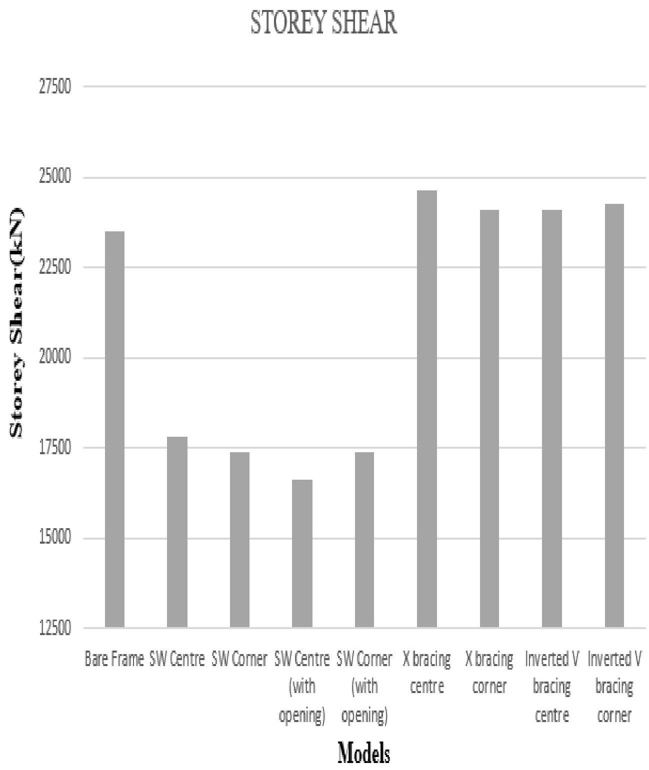

Fig.12 Storey Shear as per response spectrum

- From analysis results, It is found that storey shear values are lesser in case shear wall frame model compared to frame with bracing systems.
- Bare frame model has more storey shear about 31.74% than frame with shear wall placed at centre. It also has storey shear about 35.22% more than shear wall at corner. Bare Frame has storey shear of about 41.22% and 35.23% more than shear wall models placed at centre and corner with the openings.
- With the comparison, the bare frame model has slightly less storey shear than bracing system, For X bracing storey shear is more about 4.79% and 2.52% when placed at centre and corner respectively when compared to Bare frame. For Inverted V Bracing, storey shear is more about 2.57% and 3.13% when placed at centre and corner.
- Among Shear wall and bracing system, Bracing system have more storey shear about 38.06% than shear wall.

D. STOREY STIFFNESS

Table 5: Maximum Storey Stiffness as per Response Spectrum are tabulated below

Sl. No	Models	Storey Stiffness (kN/m)
1	Bare Frame	11704208.19
2	SW Centre	26880292.47
3	SW Corner	21445935.52
4	SW Centre (with opening)	24874653.77
5	SW Corner (with opening)	20991939.97
6	X bracing centre	29715590.29
7	X bracing corner	22015429.9
8	Inverted V bracing centre	26678274.6
9	Inverted V bracing corner	23712581

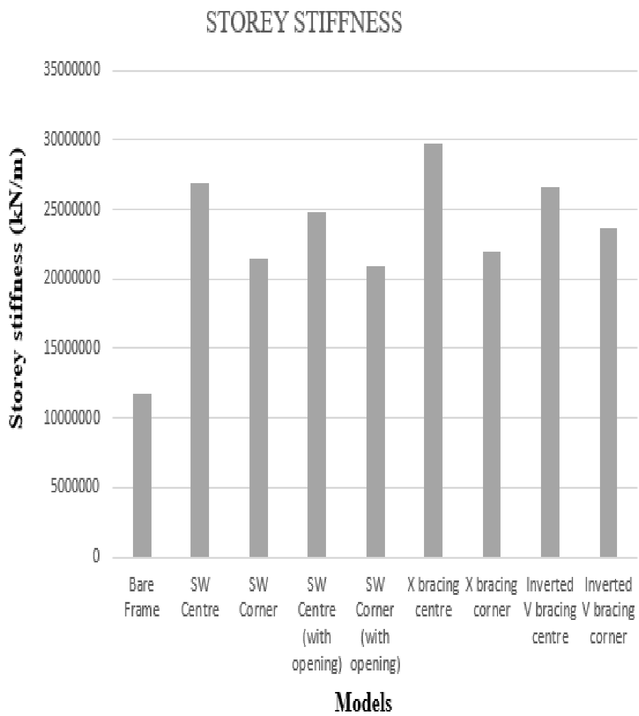

Fig.13 Storey stiffness as per response spectrum

- By these analysis results, we found that storey stiffness for the Bare frame model is minimum among different models.
- Frame with Shear wall placed at centre and corner have more stiffness about 2.29 and 1.83 times more than bare frame model. Shear wall with openings placed at centre and corner have more stiffness about 2.12 and 1.79 times more than bare frame model. With the presence of opening slight reduction in stiffness.

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- Frame with X bracing placed at centre and corner have more stiffness about 2.54 and 1.88 times more than bare frame model. Frame with Inverted V type bracing placed at centre and corner have more stiffness about 2.28 and 2.03 times more than bare frame model.
- Among Shear wall and bracing system, the bracing system (X-Bracing) has more storey stiffness about 10.54% than shear wall system.

E. TIME PERIOD

Table 6: Time period as per Response Spectrum are tabulated below

Sl. No	Models	Time period (secs)
1	Bare Frame	3.089
2	SW Centre	2.732
3	SW Corner	3.647
4	SW Centre (with opening)	2.832
5	SW Corner (with opening)	3.146
6	X bracing centre	2.362
7	X bracing corner	2.784
8	Inverted V bracing centre	2.455
9	Inverted V bracing corner	2.712

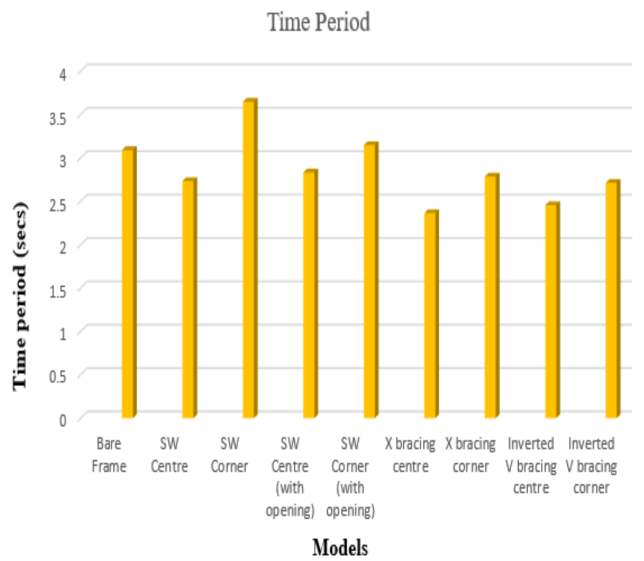

Fig.14 Time period as per response spectrum

- By these results, we can see that shear walls placed at corners have more time period 3.467sec and 3.146 sec with the openings which is observed to be more than bare frame model.
- Compared to bare frame which has time period of 3.089 sec, X bracings at centre and corner have less time period 2.36 and 2.72sec respectively. Inverted V bracings at centre and corner have less time period 2.45 and 2.71sec respectively than bare frame.
- Among the Shear wall and bracings, Bracing System (X-bracing at centre) has less time period.

VI. CONCLUSION

The significant conclusions drawn from the results which are obtained from the analysis are listed below:

- For Bare frame model (G+20 storey) in seismic zone V, the storey displacement and drift values are exceeding their limits as per code, so it is recommendable to use structural system like shear wall and bracings.
- From this limited study, In consideration of story displacement and story drift, LLRS placed at the centre effective in reducing drift and displacement in stories.
- Shear wall placed at centre has reduced displacement about 8.54% than bracing system. Among shear wall and bracing system, Shear wall placed at centre has reduced story drift about 16.67% than bracing system.
- In terms of story stiffness
    - Among shear wall model, shear wall placed at the centre has significant in reducing storey drift. For bracing models, X- Bracing at centre proved to be best in reducing drift because placing of lateral load resisting system near to CG of the structure results in increasing stiffness.
    - Among shear wall and bracing system, X type bracing placed at centre has more stiffness about 10.54% more than shear wall.
- From these results of limited study, we can say that structural systems like shear wall and bracing systems adds stiffness to frame and reduces displacement.
- In terms of Storey shear, Model with the Shear walls are efficient in reducing storey shear about 38.07% compared to bracing. Among the models, Shear wall with centre is most efficient in reducing shear.
- In terms of time period, the Bracing System (X-bracing at centre) has less time period compared to all models, indicates more stiffness.
- With the 11.05 percent of opening (size-1.67x1.16m), Shear wall performs suitably without much difference compared to shear wall without voids.
- With limitation to this study, providing lateral load resisting systems for plan regular building at centre is more effective than providing at corners.

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