Performance Evaluation of High-Rise Building with Reinforced Concrete Flag Walls under Wind Load

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Abstract : **There has been a considerable rise in the development of high rise buildings in our country mostly in the metropolitan cities such as Delhi and Mumbai. Usable land restriction for construction and rise in population in the cities are the main problems. It is very challenging for structural engineers in designing the tall structure. Tall structures are very critical to the lateral dynamic loads such as wind and earthquake load. To resist such lateral loads many lateral resisting systems are developed. One such interior lateral load resisting system is an outrigger system. But usage of conventional outrigger system involves trusses in the mechanical floors and thus reducing the usable rentable space. Hence a new alternative, flag walls (RC walls not reaching foundation) can be used as they save the space used by outrigger trusses. The main objective of this paper is to study the behavior of flag wall systems and conventional system of a 65-storey three dimensional model subjected to wind load. The analysis is done by using ETABS (Version.2016) software with Indian standards codal provisions for all the models. The results show that, flag system has a significant effect in reduction of lateral displacement and storey drift of tall buildings.**

IndexTerms **- Outriggers, Flag wall, lateral load resisting system.**

I. INTRODUCTION

Man has always been fascinated by height as it makes society proud. From ancient pyramids to this modern skyscraper, the power and wealth of a civilization on several occasions' spectacular and monumental structures have been expressed. In today's world it is the symbol of economic power and leadership of skyscrapers. In developing countries like India growing population and restriction of land for construction is a major problem.

The more the height more is the complexity associated with it. Wind and seismic are the two important lateral forces that needs to be considered. To resist these forces there are many lateral resisting systems. Lateral Resisting systems can be classified broadly into exterior lateral resisting system and interior lateral resisting system. One such internal lateral resisting system is the outrigger system. Outrigger systems are widely used in tall buildings to reduce the drift and displacement of tall buildings.

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II. OUTRIGGER SYSTEM

Outrigger system can be visualized as mast of the ship as the core in the building and its arms can be correlated as outrigger. Outrigger helps in reducing the drift and deflection in building. Also they reduce the overturning movement in the core. An outrigger system restricts the usage of rentable space in the mechanical floors due to the trusses. This disadvantage can be overcome by using an alternative as reinforced concrete flag walls instead of outrigger trusses.

III. Reinforced Concrete Flag walls

Flag walls are concrete walls (RC walls) in selected floors, not reaching the foundation. They provide additional stiffness, strength and ductility to the overall structure and they can be effective in reducing overall lateral drifts, inter-storey drifts and building periods similar to outriggers (S. A. Reddy and N. Anwar, 2018). These walls behave similar to outriggers hence the main advantage using flag wall is that they do not utilize space for the operations. As in the case of the conventional outriggers trusses are involved in tying together the core and the perimeter column space in between is wasted, this space could be saved by using isolated RC walls known as flag walls as an alternative.

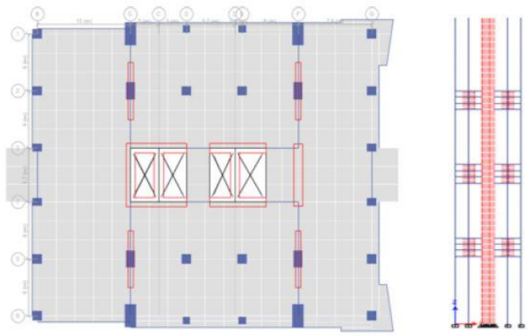

Figure.1.Typical floor plan of flag wall system. (S. A. Reddy and N. Anwar, 2018)

IV. Objective of the Study

The primary aim of the study is to investigate the application of flag walls as an alternative to outrigger system.

1. To study the performance of RC high rise building with and without flag walls.
2. To analyze & evaluate dynamic performance of RC high rise buildings in terms of storey displacement, storey drift, base shear and time period under wind load.
3. To find out the best configuration of flag wall system subjected to wind load.

V. Methodology

A 65 floor high-rise L-shaped building was considered in this study. Three models were modeled and analyzed using ETABS software. Typical floor plan and elevation is shown below.

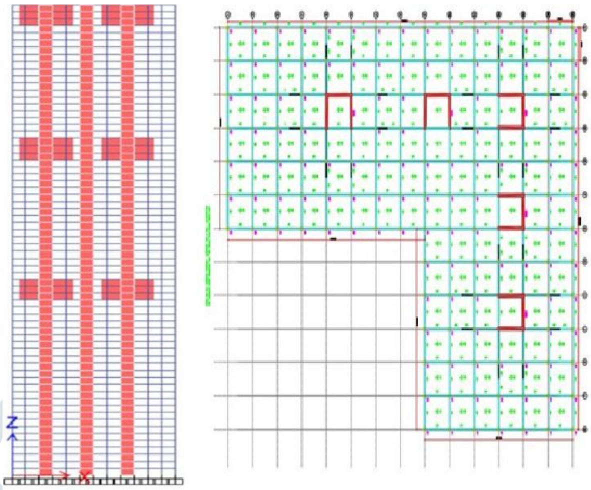

Figure.2. Plan and elevation of model

VI. Input Parameters

A G+65 high-rise structure is modeled in this study. Plan is irregular having L-shaped plan. Material Properties of each element are discussed below . Also the position of flag walls is also discussed in this section. Five models were analyzed and effect due to static and dynamic wind load was determined. A convention SMRF (Special Moment Resisting Frame) system, structure having only core wall system, flag walls at mid height, flag walls placed at two locations (0.4 h and 0.6 h) also flag walls placed at three locations (0.4 h ,0.6 h and 1 h)

Table 1. Element Sizes

Particulars	**Dimensions**	**Grade**
Beam Size	600mm x 600mm	M35
Column Size	1200mm x 1200mm	M70
Wall Thickness	900 mm	M70
Spacing Between Frame	5m	
Floor Dimension in X Direction	60 m	
Floor Dimension in Y Direction	70 m	

Table 2. Flag Wall Location

Flag Wall Location			
Model Name	***Flag wall 1***	***Flag wall 2***	***Flag wall 3***
SMRF	-	-	-
Core wall only	-	-	-
N3-S1	0.5 h	-	-
N3-S2	0.4 h	0.6 h	-
N3-S3-2	0.4 h	0.6 h	1 h
Where ‘h’ is the total height of the building from the ground			
Where ‘N ‘= Position Number & ‘S’ = Storey Depth of flag wall			

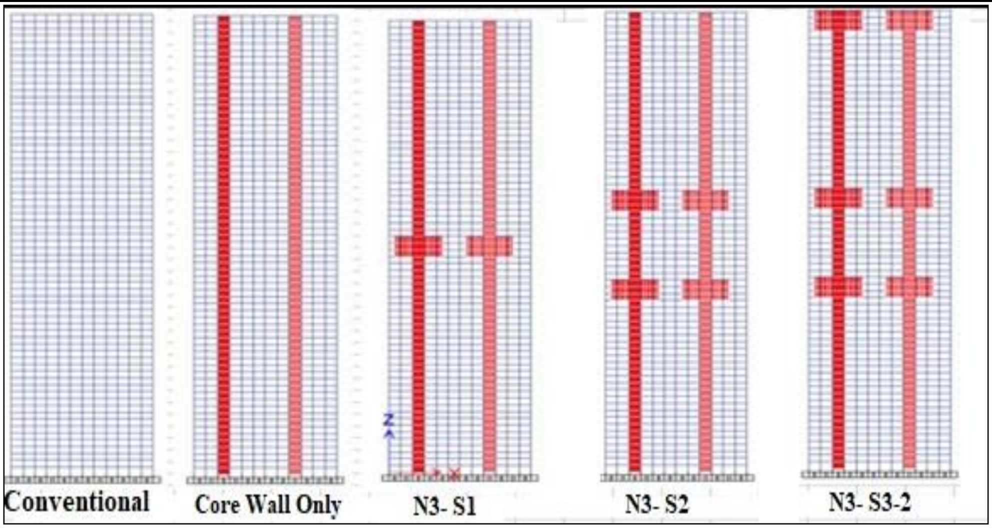

Figure.3. Elevation of models

Table 4. Loading Conditions

Load Type	Value
Live Load on Floor	4 KN/m^2
Live Load on Terrace	1.5 KN/m^2
Floor Finish	1.5 KN/m^2
Water Proofing On Terrace	3 KN/m^2
Wall Load on Beams, 230 mm Thickness Wall	19.2 KN/m

Table 5. Wind Load Inputs (IS 875-2015)

Particulars	Value
Basic wind speed	44 m/s
Terrain category	III
Probability Factor k_1	1
Topography Factor k_3	1
Importance Factor k_4	1

VII. Results And Discussions

Three parameters are compared in this study. Mainly time period, displacement and storey drift are compared for all the models.

A. Time Period

Comparing with conventional system (SMRF) flag wall has a lower time period. Also it can be observed from fig.2. that flag wall of three storey deep at three levels has the lowest time period as compared to other models. In mode 1 there is a reduction of about 20% in the time period of flag wall system (N3-S3-2) as compared to the conventional SMRF system.

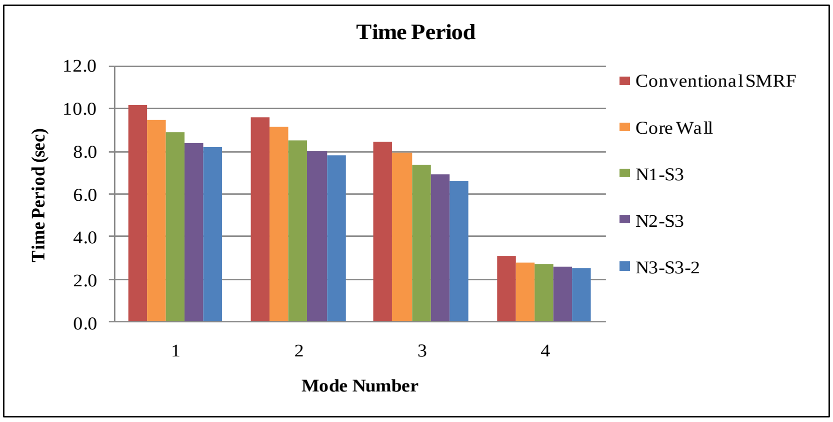

Fig. 4. Variation of time period

B. Storey Displacement

From the result studied when the G+65 storey models are subjected to static wind in X-direction it can be noted that the maximum top storey displacement of structure with conventional SMRF system is observed to be 322.16 mm while the structure with flag walls displacement reduces to 228.34 mm in N2-S3-2 case. Hence a reduction up to 29% is achieved by introducing flag walls at 0.4h ,0.6h and at top. Similarly a reduction upto 33% is observed due to application of static wind force along Y-direction in N2-S3-2 case as compared to conventional system.

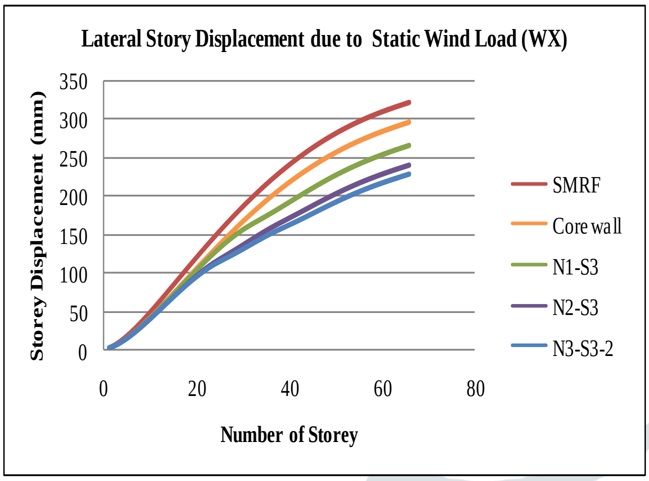

Fig. 5. Variation of displacement due to WX

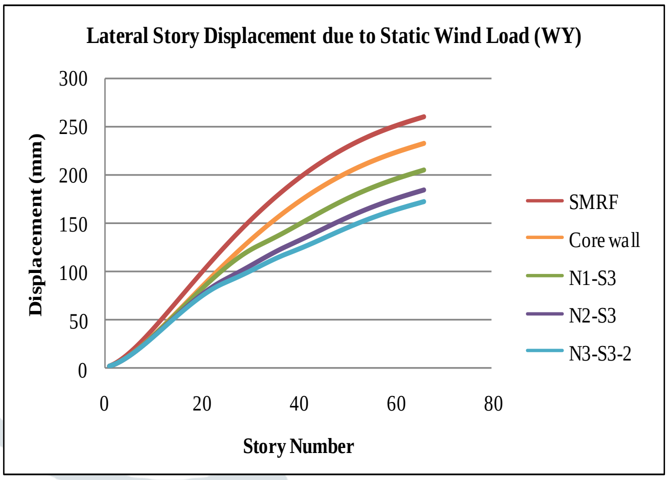

Fig. 6. Variation of displacement due to WX

For From the result studied when the G+65 storey models are subjected to dynamic wind in X-direction it can be noted that the maximum top storey displacement of structure with conventional SMRF system is observed to be 451.55 mm while the structure with flag walls displacement reduces to 332.64 mm in N3-S3-2 case. Hence a reduction up to 26% is achieved by introducing flag walls at 0.4h, 0.6h and at top.

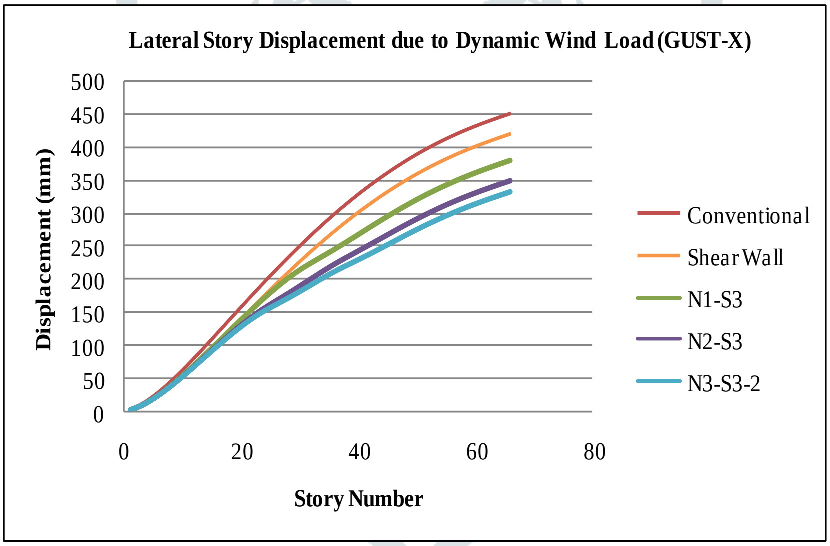

Fig. 7. Variation of time period

C. Storey Drift

From the results studied, when the G+65 storey is subjected to static wind load along X-axis, it can be noted that storey drift at 26th storey is reduced by 52% due to flag wall at 0.4h, 0.6h and at top (N3-S3-2).

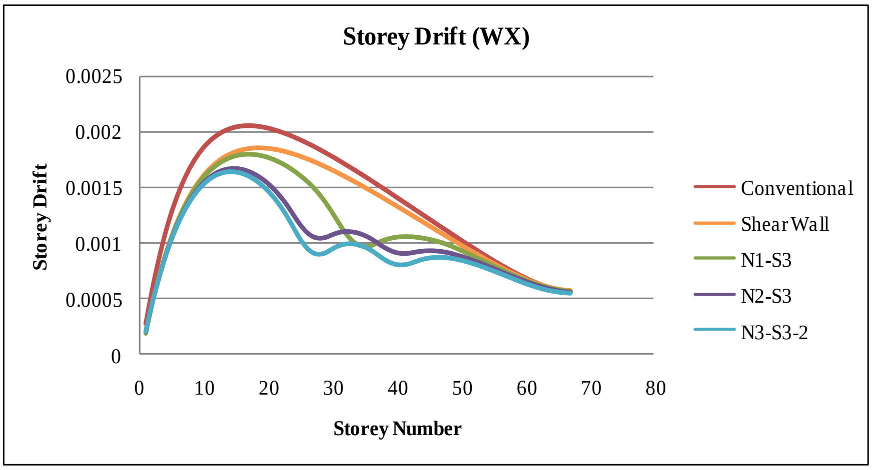

Fig. 8. Variation of time period

Similarly due to static wind load along Y-direction it can be observed that there is a reduction upto 58% due to flag walls at 0.4h, 0.6h and at top as compared to conventional system.

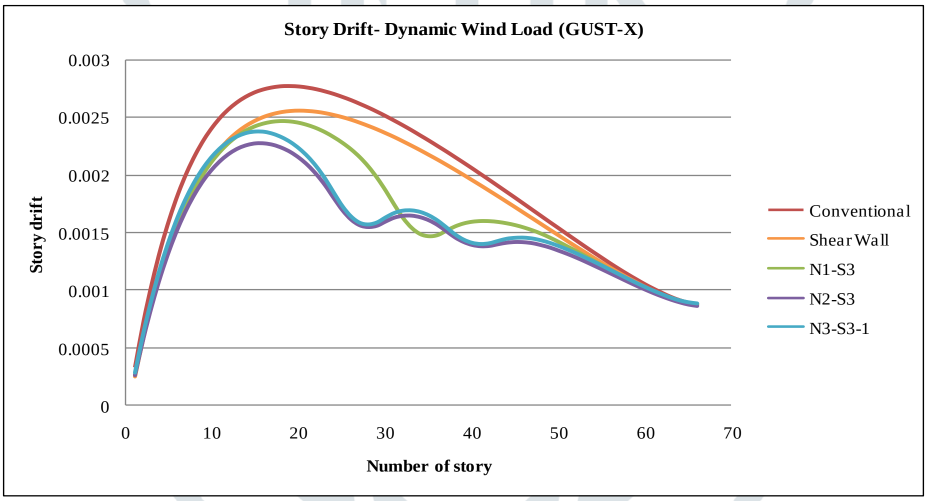

Fig. 9. Variation of time period

Table 6. Variation of storey drift

Location of flag wall	Storey Drift (GUST-X)				
	Conventional	***Core Wall***	***N1-S3***	***N2-S3***	***N3-S3-2***
0.4 h	0.00262	0.00246	0.00215	0.00156	0.00137
	0%	6%	18%	40%	48%
0.5 h	0.00235	0.00222	0.00148	0.00163	0.00149
	0%	6%	37%	30%	36%
0.6 h	0.00186	0.00177	0.00158	0.00141	0.00131
	0%	5%	15%	24%	29%

From the fig. it can be observed that a total reduction of about 48% is achieved due to flag walls compared to conventional system. From the results it can be observed that the N3-S3-2 case in which flag walls were located at 0.4h, 0.6h and at top is found to be more effective than all other cases.

VIII. CONCLUSION

The results obtained from analysis for G+ 65 storeys with and without flag walls by wind analysis both static and dynamic in terms of time period, storey displacement and storey drift. The main objective of this study is to study the performance evaluation of structure using flag walls and to use it as an alternative to conventional outrigger system.

The following conclusions are made from the present study

- Time period considerably decreased by 20% due to introduction of flag walls. Time period reduces considerably by introducing flag wall at top Storey **(N1-S3-2)**
- Drift reduction up to 48% and 50% is achieved at 26th floor when flag walls are used at two locations 0.4h and 0.6h when structure is subjected to dynamic wind load along X and Y direction respectively.
- Drift reduction up to 40% and 36% is achieved at 26th floor when flag walls are used at two locations 0.4h and 0.6h when structure is subjected to static wind load along X and Y direction respectively.
- There has been a reduction up to 29 % of storey displacement due to flag wall system along X-direction and 30 % reduction along Y-direction for model N3-S3-2 compared to conventional SMRF system when structure is subjected to earthquake load by equivalent static analysis.
- Maximum reduction in storey displacement of 26% is achieved when flag walls are placed at 0.4h, 0.6h and at top for dynamic wind load along X-axis.
- From the results it can be observed that the flag wall system perform better than the conventional RCC structural system and could be used as an alternative to conventional outrigger system as it saves space.
- Also the use of Flag wall system in high-rise buildings increases the stiffness and makes the structure efficient under lateral loads.
- Providing flag walls at top reduces the time period of the structure and also the displacement.

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