Performance Evaluation of High-Rise Building with Reinforced Concrete Flag walls under Seismic 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 dynamic earthquake load using response spectrum analysis. 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.

Key words: Flag walls, Outrigger system, lateral resisting system

I. INTRODUCTION

Man has always been interested by height as it makes society proud. In today's world it is the symbol of economic power and leadership of skyscrapers. In developing countries like India population growth and restriction of land for construction is a major problem and hence the only solution to accommodate the growing population is by increasing the height of the structure.

Complexity increases with increase in height of the structure. Wind and seismic are the two important lateral forces that needs to be considered while analyzing high-rise structures. To resist these lateral 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.

Usage of conventional outrigger system consumes the rentable space in the mechanical floors due to trusses. This disadvantage of conventional outrigger system can be overcome by using Flag Walls in the structure. Application of Flag wall could be proved economical as compared to the conventional system due to the freedom to use the rentable space which was a disadvantage in case of using conventional outrigger system.

II. REINFORCED CONCRETE FLAG WALLS

Flag walls are reinforced concrete walls (RC walls) in selected floors, not reaching the foundation which provides additional stiffness, strength and ductility to the overall structure. 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.

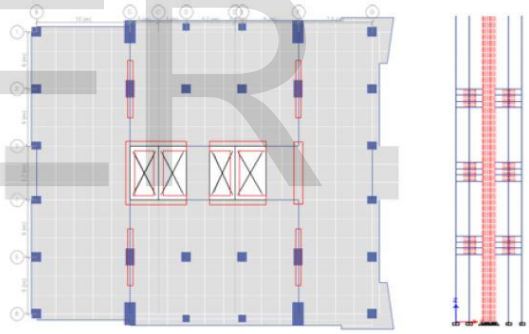

Fig 1: Typical floor plan of flag wall system. (S. A. Reddy and N. Anwar, 2018)

III. 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 performance of RC high rise buildings in terms of storey displacement, storey drift, base shear and time period dynamic earthquake load.
3. To find out the best configuration of flag wall system subjected to dynamic seismic load.

IV. 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.

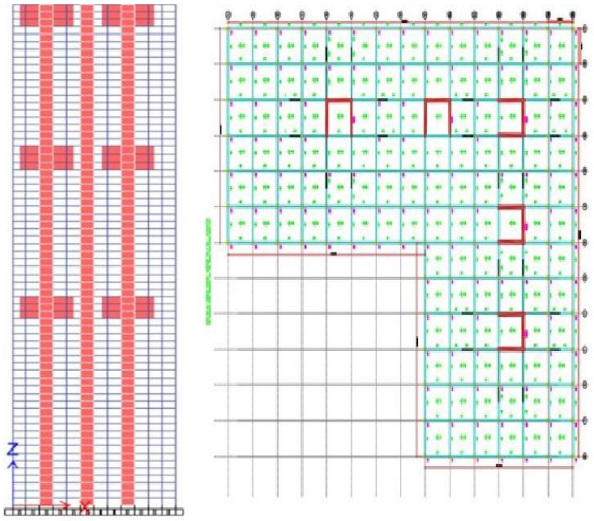

Fig 2: Plan and elevation of model

V. INPUT PARAMETERS

A G+65 high-rise structure with irregular L-shaped plan is modeled in this study. 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 earthquake 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 I: Input Parameters

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

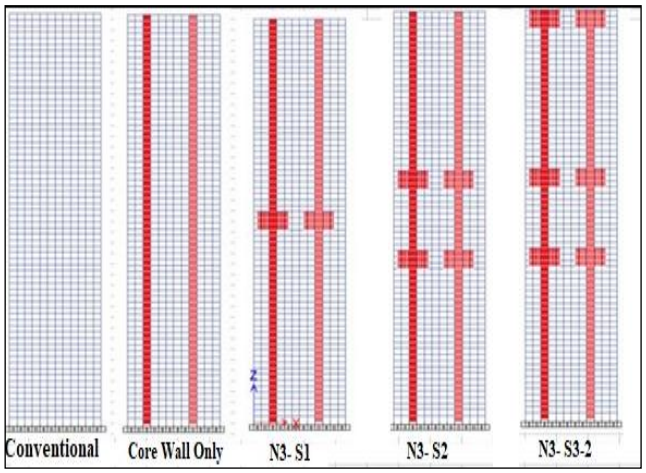

Fig 3: Elevation of models considered in this study

Table II: 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 III: Seismic Parameters

Load Type	Value
Seismic Zone	IV
Zone Factor	0.36
Response Reduction Factor, R	5
Soil Type	II, Medium
Importance factor	1.2

VI. RESULTS AND DISCUSSSION

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

A. Time Period

Application of Flag wall reduces the time period as compared to SMRF (Special Moment Resisting Frame) system. Also it can be observed from fig 3. that flag wall for three storey deep flag walls 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.

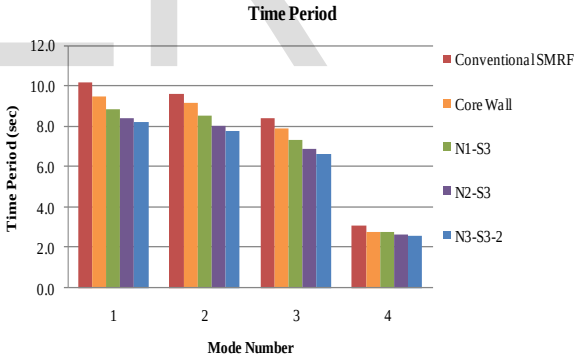

Fig 4: Variation of Time Period

B. Lateral Storey Displacement

From the result studied when the G+65 storey models are subjected to dynamic earthquake in X-direction it can be noted that the maximum top storey displacement of structure with conventional SMRF system is observed to be 402.33 mm while the structure with flag walls displacement reduces to 337.411 mm in N2-S3-2 case. Hence a reduction up to 17% is achieved by introducing flag walls at 0.4h ,0.6h and at top. Similarly a reduction upto 30% is observed due to application of seismic force along Y-direction in N2-S3-2 case as compared to conventional system.

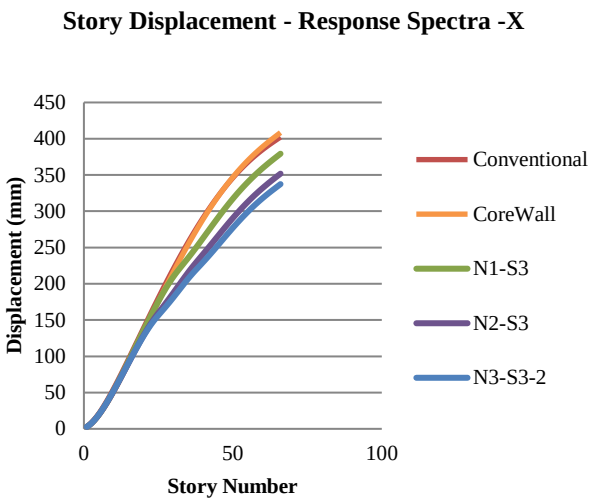

Fig 5: Variation of storey displacement along X-direction

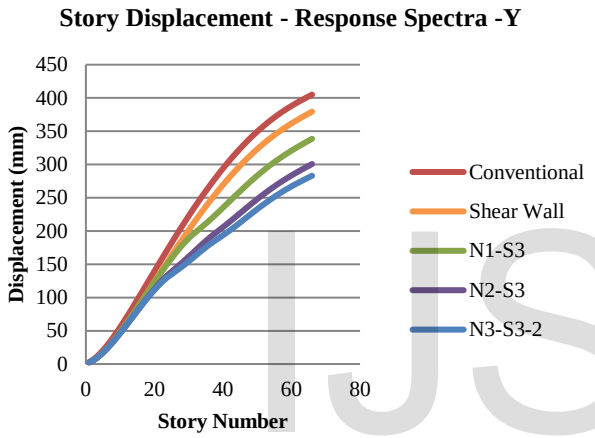

Fig 6: Variation of storey displacement along Y-direction

C. Lateral Storey Drift

From the results studied, when the G+65 storey is subjected to dynamic seismic 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).

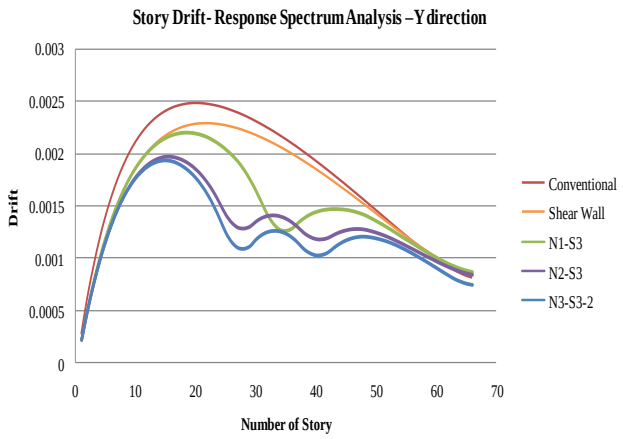

Fig 7: Variation of storey Drift along Y-direction

Similarly from the results obtained a reduction upto 40% is achieved when structure is subjected to dynamic seismic load.

D. Base Shear

A small increase in base shear is obtained along X and Y direction when structure is subjected to earthquake load. This small increase in base shear along both the direction is due to the increase in the self weight of the flag walls.

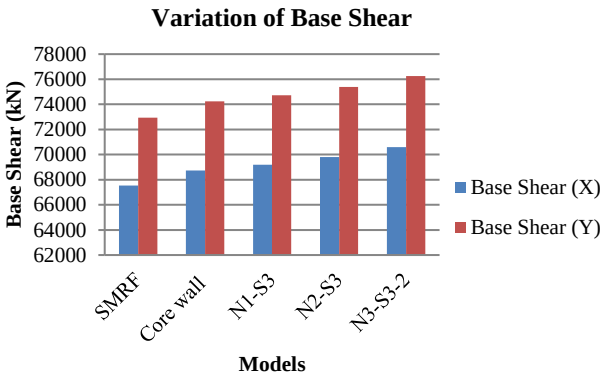

Fig 8: Variation of Base Shear

VII. CONCLUSION

The results obtained from analysis for G+ 65 storey with and without flag walls subjected to dynamic earthquake load 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 45% 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 seismic load along X and Y direction respectively.
- Maximum reduction up to 17% 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 dynamic seismic load.
- There has been a small increase in base shear. This is due to the additional of self weight of flag walls in the structure.
- 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 dynamic seismic load.

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