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Parametric Study of Seismic Response Analysis of High Rise Structure

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ABSTRACT

High rise structures with complex planning and irregular vertical elevations are trending nowadays. Such high rise structures are more susceptible to seismic forces which are quite devastating and cause a huge loss to human lives and property. Hence it is very important to study the behavior of such structure to help structural engineers to create better earthquake resistant design. The usefulness of the shear walls in the structural planning of the multistory buildings to resist the lateral forces has been recognized long back. Shear walls also dissipates a great amount of energy if detailed properly, however there are many factors such as placement of shear walls, its thickness, aspect ratio, plan of the building which affects the response of the building towards lateral loads. In the present study attempt is made to study the effect of different location of shear walls on the response of the building in terms of time period and maximum displacement. The detailed investigation is carried out for zone II of Seismic zones of India as per IS 1893 (part 1):2016, considering primary loads (dead, live and seismic loads) and their combinations with appropriate load factor. Analysis is carried out in ETABS 2016. Further a case study of a U-shaped plan is carried out, to reduce the torsional irregularity structural wall system with spandrels and seismic joints were provided at certain locations.
Keywords : Seismic Analysis, Shear Walls, Spandrels, Seismic Joint

I. INTRODUCTION

Due to growing population and space constraint high rise structures are the need of the day. Dynamic actions are caused on buildings by both wind and earthquakes. Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events.

In recent years the topic of seismic loads and analysis has become of increasing importance in all over the world. This is due largely to the frequency of large magnitude seismic events that have been witnessed, often in large metropolitan areas, typically resulting in tragic loss of life. As a direct result greater efforts have been made to understand and quantify loads that might be experienced during an earthquake.

There are four aspects of buildings that architects and design engineers work with to create the earthquake-resistant design of a building, namely seismic structural configuration which includes geometry, shape and size of the building, location and size of structural elements and location and size of significant non- structural elements, lateral stiffness, lateral strength and ductility, in addition to other aspects like form, aesthetics, functionality and comfort of building.

II. LITERATURE REVIEW

Milind Mohod studied the effect of irregularity of plan and shape on the storey drift and lateral displacement in the seismic response of the structure. L-shaped, H-shaped, E-shaped, C-shaped, Plus-shaped buildings showed more displacement and storey drift than simple shaped building. It is inevitable to omit complex geometries but these can be sorted into simpler one by providing seismic joint to reduce earthquake effect.

Shaik Hussain, et. al studied the torsional effect of irregular buildings under seismic loads. Results showed an increase in shear forces in irregular structure. Buildings with irregular plan configuration cause severe damage than regular building during earthquake due to increase in drifts and displacement. Torsion is the most critical factor leading to major damage or complete collapse of buildings. Hence it is very essential that irregular buildings should be carefully analyzed for torsion and try to avoid excess irregularity especially in high rise structure.

Pradnya Nagrale et. Al studied the effect of position of shear wall along with change in building plan aspect ratio on response of a 10-storey RCC building in terms of roof displacement, maximum storey drift and maximum column axial forces. It was concluded that lateral load carrying capacity of frame increases with combined shear wall, but placement of shear wall should be made judiciously. Corner wall frame is recommended as best suitable as it shows better performance in reducing roof displacement, storey drift and column axial forces.

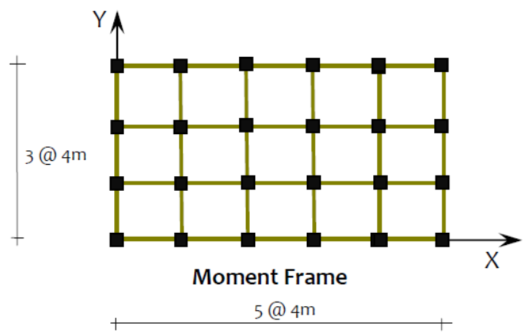
Based on current research conducted torsion, base shear, max displacement and storey drift are important parameters determining the behavior of a structure subjected to lateral loads. Values of these parameters should be within limits as per IS 1893:2016 and IS 16700:2017. Hence the objectives are

- To study the effect of different position of shear wall on the seismic response analysis of the structure.
- To study the effect of provision of seismic joint in seismic response analysis of an irregular structure

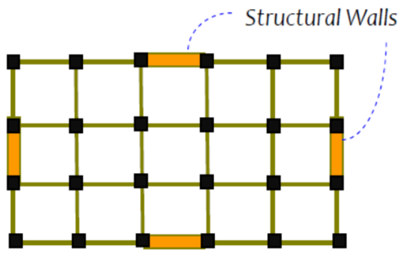
III. MODELLING

Earthquake resistant buildings should posses, at least a minimum lateral stiffness, so that they do not swing too much during small levels of shaking. When lateral displacement is large structural walls can be introduced to reduce overall displacement of the building. Structural walls are vertical plate like structural elements having large in-plane stiffness and strength which resists lateral forces through combined axial-flexure-shear action. Three buildings with same number and size of structural walls but at different location, structural walls at periphery, inner bays and structural walls forming a core at the center of the building. In the next two model wall area is same. One with separate walls and other one with combined structural wall.

IV. ANALYSIS

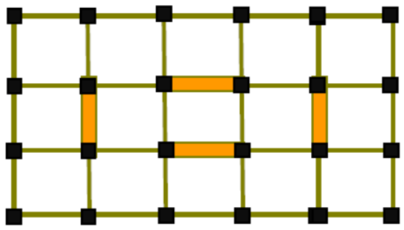


Model 1



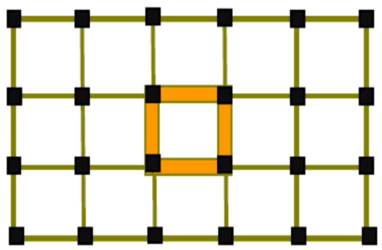
Structural Wall at Periphery

Model 2



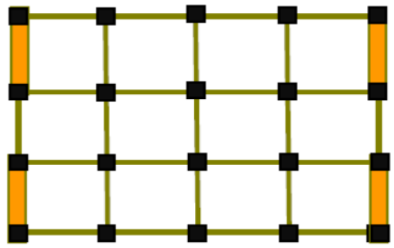
Structural Wall in Inner Bays

Model 3



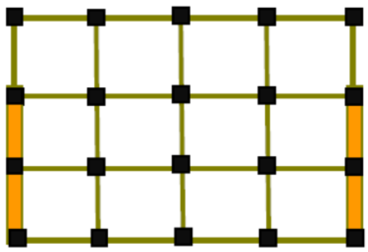
Structural Wall Core at Center

Model 4



Two Separate Structural Walls

Model 5



Combined Structural Walls

Model 6

Fig 1. Plan of Model 1- Model 6 Buildings with different position of structural wall

Table1. Modes of oscillations and displacement in buildings for Model 1- Model 6

	Model 1	Model 2	Model 3
Mode 1	Y translation (0.74s)	Y translation (0.48s)	X translation (0.48s)
Mode 2	X translation (0.72s)	X translation (0.47s)	Y translation (0.47s)
Mode 3	Torsion (0.65s)	Torsion (0.33s)	Torsion (0.47s)
Max displacement in X direction	21.6 mm	11.9 mm	11.5 mm
Max displacement in Y direction	13.4 mm	12.4 mm	10.9 mm

	Model 4	Model 5	Model 6
Mode 1	Torsion (0.37s)	X translation (0.91s)	X translation (0.48s)
Mode 2	Y translation (0.34s)	Y translation (0.38s)	Y translation (0.47s)
Mode 3	X translation (0.33s)	Torsion (0.30s)	Torsion (0.47s)
Max displacement in X direction	5.9 mm	--	--
Max displacement in Y direction	6.0 mm	8.1 mm	3.4 mm

V. CASE STUDY

Further a case study is carried out on a building with irregular configuration in plan as shown in fig.2.The properties and building configuration is summarized below:

Parameter	Type/ Value
Structure type	RCC building
Size of building	100m X 30m
Number of storey	23
Floor to floor height	3m
Slab thickness Grade of concrete	130 mm M30
Size of beams Grade of concrete	600 X 230 mm M30
Shear wall thickness Grade of concrete	160 mm, 200 mm M40
Brick wall thickness Brick density (light weight blocks)	200 mm 7.5 kN/m³
Live load	2 KN/m²
Seismic zone	II
Importance Factor	1.2
Soil condition	Type 1
Response reduction factor	4

In Model B Seismic joint is provided in building, to divide the building at junctions of the different wings that meet each other from different directions.

Further in Model C to remove the torsional irregularity from first two modes spandrels are provided equal to beam depth to provide the continuity in structural wall shown in fig 3.

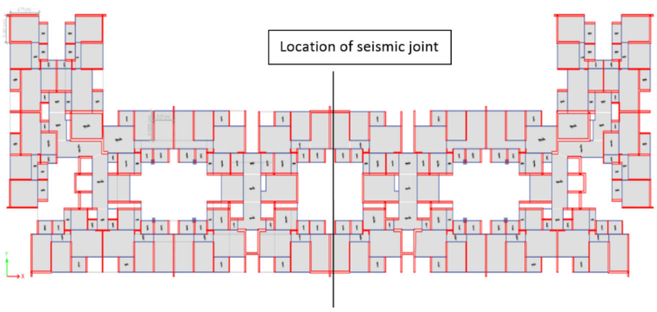


Fig 2. Model A: Plan of building with irregular configuration (U shape)

Fig 3. Model B: Part of building plan with seismic joint

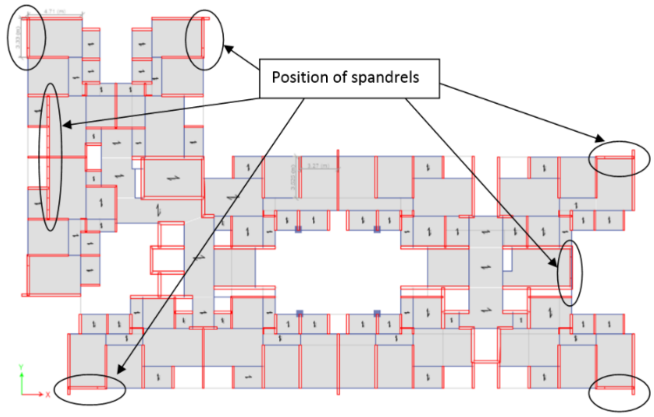


Fig 4. Model C: Part of building plan with seismic joint and spandrels

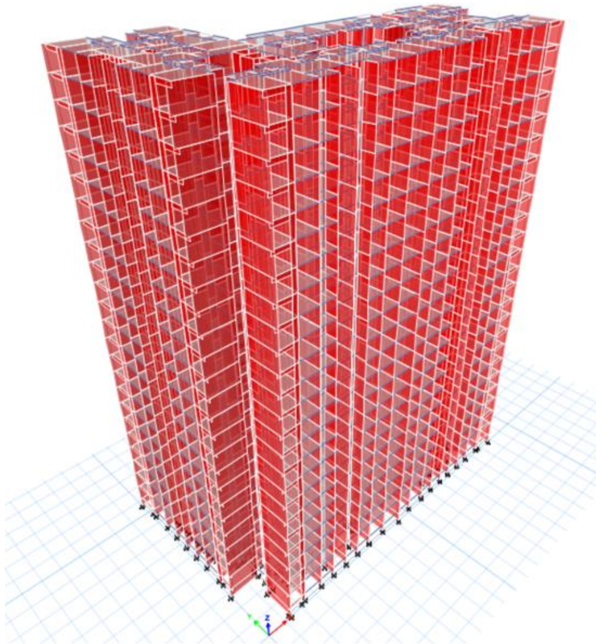


Fig 5. Model C: 3D view of Part of building with seismic joint and spandrels

VI. RESULTS AND DISCUSSION

Table 2a: Modal participating mass ratio for Model A

Case	Mode	Period sec	Sum UX	Sum UY	Sum UZ	Sum RX	Sum RY	Sum RZ
Modal	1	1.94	0.4985	0	0	0	0.2366	0.1797
Modal	2	1.802	0.4985	0.6733	0	0.3279	0.2366	0.1797
Modal	3	1.743	0.6829	0.6733	0	0.3279	0.319	0.6817

Table 2b: Modal participating mass ratio for Model B

Case	Mode	Period sec	Sum UX	Sum UY	Sum UZ	Sum RX	Sum RY	Sum RZ
Modal	1	1.94	0.5043	0.1465	0	0.0716	0.2389	0.0274
Modal	2	1.84	0.505	0.2805	0	0.1413	0.2395	0.5651
Modal	3	1.74	0.683	0.6728	0	0.3285	0.319	0.6807

Table 2c: Modal participating mass ratio for Model C:

Case	Mode	Period sec	Sum UX	Sum UY	Sum UZ	Sum RX	Sum RY	Sum RZ
Modal	1	1.794	0.6735	0.0079	0	0.0037	0.3136	0.0022
Modal	2	1.519	0.6807	0.6773	0	0.3194	0.317	0.0066
Modal	3	1.353	0.6843	0.6808	0	0.3212	0.318	0.6949

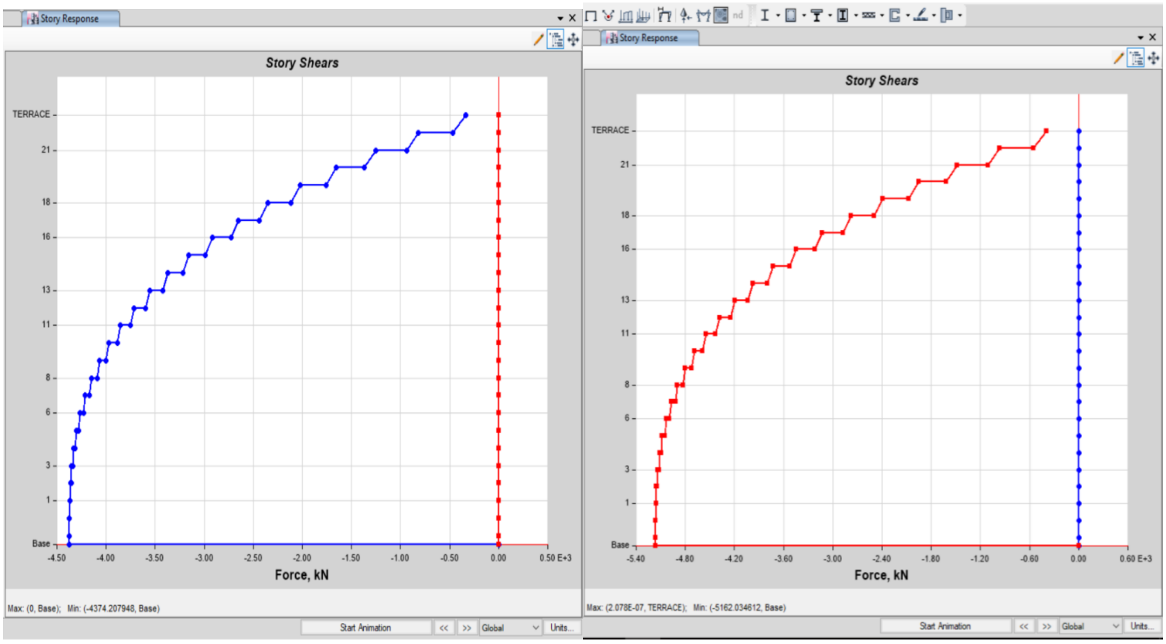


Figure 6a & 6b: Model 2c : Distribution for static base shear in X- direction and Y- direction respectively

A graph of storey height Vs base shear is plotted. The Maximum Base shear in Y-direction after applying scale factor is 4374 kN and 5172 kN respectively.

VII. CONCLUSION

Following conclusions can be drawn based on the results obtained from the analysis:

1. Provision of seismic joint at junctions of different wings that meet each other in plans with irregular configuration in different direction in plans to form simple rectangular blocks helps to reduce the contributions of modal mass in first two modes in torsion.
2. Lateral load carrying capacity of the frame increases significantly if combined with shear walls. However their location in the building governs the overall response of the building.
3. Base shear of model 2b increased by 9.5 % in model 2c by adding coupling beams at periphery.
4. Placing the structural walls towards the center of the building allows flexibility for the building to undergo torsion, which is not desirable.
5. Corner shear walls and the shear walls provided centrally at the outer edge have shown better performance. Hence structural walls are most effective when placed at the periphery of building.
6. Good control over the displacement and storey drift can be achieved if shear walls are located symmetrically in plan.
7. Structural walls, owing to their large lateral stiffness, draw most of the lateral forces and thereby help to reduce demand on columns and beams.
8. Buildings are not made structurally bi-symmetric in two plan directions even though they may be architecturally bi-symmetric in plan, resulting in the same natural period for the two pure horizontal translational modes of oscillation. No two natural periods of pure translational modes of vibration should be within 15% of the larger natural period. This 15% limit is arrived at to ensure that the width of peak response at a certain natural period does not overlap with that at the adjacent natural period.
9. Modal mass participating ratio of model 2b reduced from 2.74% and 56.51% in first two modes to 0.22% and 0.65% in model 2c by adding coupling beams at periphery.

10. It is useful to have one long structural wall than two short ones separated by interconnecting beams. However from practical point of view it is not always feasible to provide one long wall, hence Coupling beams shall be provided which gives a continuity effect to the wall and torsion, displacement and drift are reduced.

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