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Effective Location of Different Outrigger System in Seismic Respond RCC High Rising Building Using ETABS

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Abstract: The rapidly growing number of high-rise structures around the world poses new obstacles, and lateral stiffness becomes one of the most critical issues as building height rises. The lateral stiffness and resistance capacity of high-rise buildings have a significant impact on structural efficiency, and structural engineers have introduced numerous capable constructions. The outrigger system is one of the most frequent and effective lateral loads resisting structural systems for improving structural stiffness and stabilizing the structure. The core shear wall provides structural strength in the main structural system, while the outrigger like X bracing adds lateral stiffness. In this study building with the outrigger and shear wall system has been analysed by Response Spectrum Analysis, The concept of illumination of outrigger structural systems is evaluated by comparing multiple X braced outrigger system and shear wall system models types utilizing a 25-story reinforced concrete building using ETABS software under seismic load to better understand the performance and load transferring mechanism of outrigger system.

Keywords: Highrise structure, Outrigger system, Response spectrum analysis, displacement, base shear

I. INTRODUCTION

The seismic action of the earth on multi-storey building located around the area of epicentre, the wave creates severe harmful effect on structure. As height of the building increase, building becomes more crucial to provide sufficient stiffness against the lateral loads. In modern tall building lateral load is caused by wind load and seismic/earthquake load. The parameter that to check are strength of structure, resistance against the lateral deflection of structure. These wind load & seismic load action are often resisted by different types of system, that is braced frame structure system, rigid frames structure system, shear wall structure system, couple wall system, core and outrigger structure system etc. Sometime moment resisting frames and braced frame system become inadequate to resist all lateral forces and inefficient to provide stiffness against the wind load and seismic load. The deflections cause by lateral forces should be prevented both structure and non-structural damage to maintain the building strength and also the building stiffness against the lateral forces in the analysis of RCC tall building and also for design In this paper seismic load is resisted by shear core with outrigger-braced system. Stiff shear core is provided in mid of the structure by stiff truss arm that will help in resisting the complete structure and transfer its all the lateral load to the beam and column connection with stiff shear core.

Outrigger systems are lateral load-resisting systems that successfully reduce lateral loads while also strengthening tall structures. The external and interior structures in this system work together to with stand lateral stress. Outrigger trusses serve as stiff arms that connect the building's core to the exterior columns (Fig.1). When all the lateral loads are act on the face of the building, the core tries to rotate generating force to the outrigger trusses, which cause tension in force acting on columns side and cause compression in another columns. As a result of this response, a restoring moment operates on core at the position of outriggers, increasing the effective depth of the structure to resist the bending moment. To further strengthen outrigger truss rotation constraint, all outside columns can be mobilized with a one or two storey deep wall around the structure known as a "belt wall."

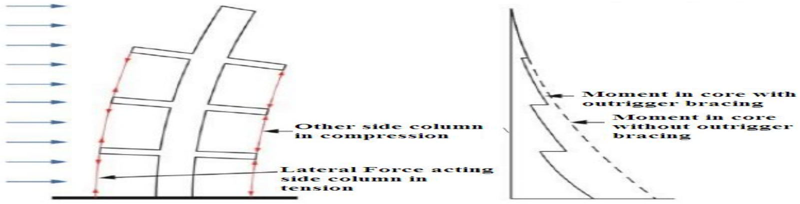

Fig1: Outrigger and Core Interaction

Due to the rotation of the core and the overturning moment, floor diaphragms above and below the belt truss will try to shift right and left. The belt truss or braced system connected to the floors will move in return & rotate itself by one face-up and one face-down. The exterior columns of structure will constrain this movement by developing opposing forces.

II. TYPE OF OUTRIGGER SYSTEM

They are classified into two groups depend on how the outrigger systems connect to the core. The conventional or direct outrigger system is the first. These outriggers are directly attached to the braced shear core or shear walls to the outer columns, as the name implies. On the other hand, virtual or indirect outrigger and the belt truss system eliminate the direct connections to the building core walls with outer columns. As shown in figure (Fig.2) below.

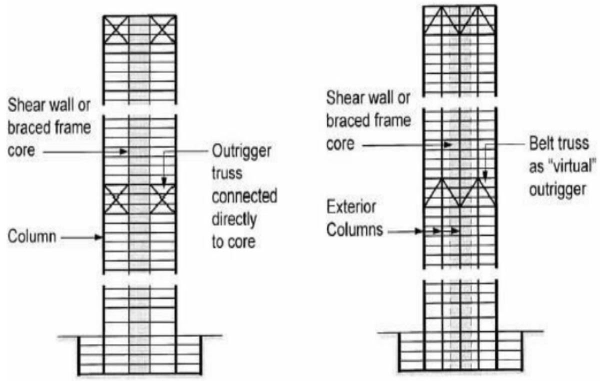

Fig.2: Conventional outriggers (left) and virtual outriggers (right).

The decision between these two sorts is based on the building's current state. Without a doubt, conventional outriggers are stiffer and more efficient than virtual or indirect outriggers due to the shorter load paths from columns to core. More indirect outriggers on more levels are necessary to get the same benefits as direct outriggers. It's also feasible that the two types of outriggers are used by the same structure. To prevent complexity in connections between the core and the outside column, virtual outriggers can be chosen. In fact, in some contexts, some levels with a building are not suited for direct outriggers, and the differential shortening is more problematic in direct outriggers than indirect outriggers at particular floors.

III. TYPES OF CASES USED FOR ANALYSIS OF STRUCTURE

A. Type of Case

There are seven different cases considered to analysis 25-storey structure.

1) Model 1: Building Model without any Outrigger system, Building has no outrigger system incorporated.
2) Model 2: Building Model with External X brace at 11th& 22ndStorey: Building model has X Bracing as an outrigger system at periphery at 11th and 22ndfloor.
3) Model 3: Building Model with External Shear Wall at 11th& 22ndStorey: Building model has Shear Wall as an outrigger system at periphery at 11th and 22nd floor.
4) Model 4: Building Model with External X brace at 11th, 17th& 22ndStorey: Building model has X Bracing as an outrigger system at periphery at 11th, 17thand 22ndfloor.
5) Model 5: Building Model with External Shear Wall at 11th, 17th& 22ndStorey: Building model has Shear Wall as an outrigger system at periphery at 11th, 17th and 22ndfloor.
6) Model 6: Building Model with X Bracing as an outrigger system at Centre core position, Building model has X Bracing as an outrigger system at Centre core position of all floors of considered building.
7) Model 7: Building Model with Shear Wall as an outrigger system at Centre core position, Building model has Shear Wall as an outrigger system at Centre core position of all floors of considered building.

B. Structural Data

Building consists of 12 m X 12 m in both direction, Brick masonry wall is provided with 230 mm thickness for all models. And 1.5m height parapet wall is also considered. Storey height is kept as 3m for bottom storey and all upper floors.

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Grade Fe-500 hot rolled deformed steel is used. Concrete having M-30 (E=5000√fck as per IS456) strength for columns, beams and slabs is to be employed. Columns were kept of 500mm X 500mm size for overall structure. All beams are of uniform size of 300mm X 450mm having 125 mm thick slab for all the spans. All Bracing are of uniform size of 300 X 300 mm for all the building models And 230 mm thick shear walls are used for different building models.

1) Gravity loading

Gravity loading consists of dead and live loading. Dead loading can be predicted reasonably accurately from the designed member sizes and material densities. Dead load due to structural self-weights and superimposed dead loads are as follows:

Dead Load (DL):

Intensity of wall (External wall) = 11.84 KN /m (for 3m height)
Intensity of wall (Internal wall) = 5.97 KN /m (for 3m height)
Intensity of parapet wall = 6.96 KN /m (for 1.5m height)
Intensity of floor finish load =1.5 KN /m2

Live load (LL):

Intensity of live load =3 KN /m2

2) Lateral loading

Lateral loading consists of earthquake loading. Earthquake loading has been calculated by the program and it has been applied to the mass centre of the building. Since the building under consideration has in ZonesV with standard occupancy so the total base shear was computed as follows:

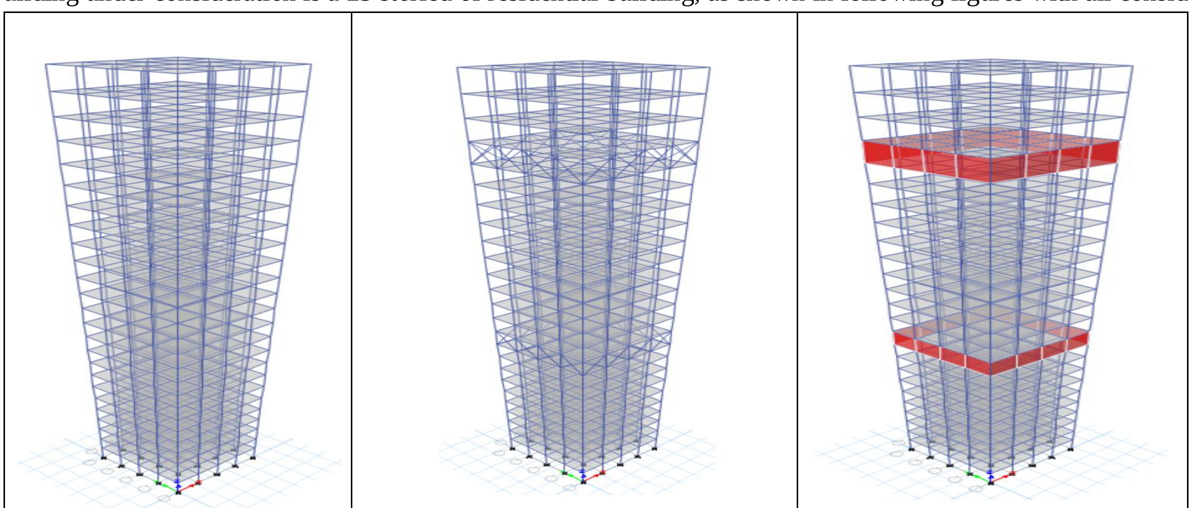
Load Case:

- SPECX
- SPECY

Period Calculation: Program Calculated
Top Storey: Storey- 25
Outrigger provision at storey: Storey -11th ,17th and 22ndStorey and Centre Core of all storeys.
Bottom Storey: Base
Response reduction factor, R = 5
Importance factor, I = 1
Building Height H = 75 m
Soil Type = II (Medium Soil)

3) Building under Consideration

The building under consideration is a 25 storied of residential building, as shown in following figures with all considered cases.



Model 1 Model 2 Model 3

Fig. 3 Considered Model 1, Model 2 & Model 3

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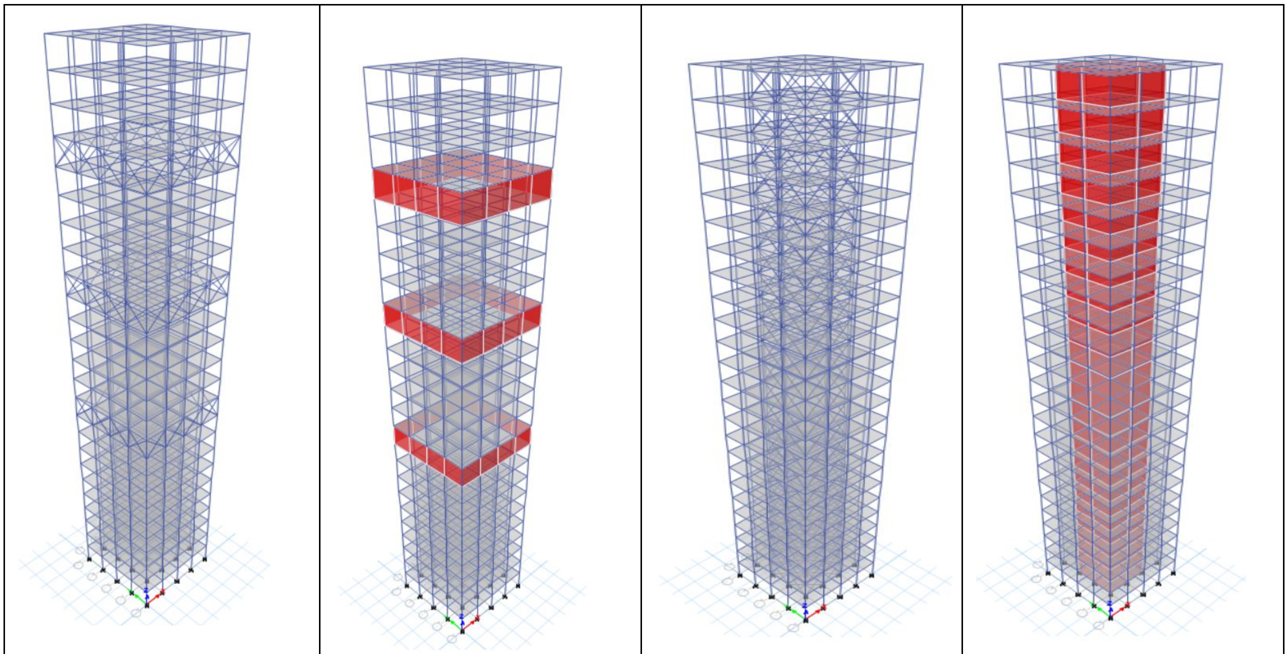


Model 4 | Model 5 | Model 6 | Model 7

Fig. 4 Considered Model 4, Model5, Model 6 & Model 7

IV. RESULTS

A. Result obtained using Response Spectrum method

1) Maximum Lateral Displacement

TABLE I

COMPARISON MAXIMUM DISPLACEMENT FOR SPEC-X OF MODELS 1,2, 3, 4, 5, 6 & 7

		Models Maximum displacement (mm) in X-direction						
Storey No's	Storey Height (m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Story25	75	93.509	86.715	86.743	83.625	83.716	46.925	35.887
Story24	72	91.295	84.567	84.609	81.487	81.591	44.997	34.167
Story23	69	88.841	82.222	82.29	79.152	79.281	43.009	32.424
Story22	66	86.131	79.859	80.002	76.8	77.003	40.98	30.67
Story21	63	83.19	77.782	78.028	74.723	75.031	38.913	28.905
Story20	60	80.047	74.922	75.249	71.887	72.278	36.814	27.133
Story19	57	76.728	71.687	71.985	68.701	69.072	34.692	25.357
Story18	54	73.254	68.259	68.513	65.414	65.78	32.554	23.581
Story17	51	69.644	64.69	64.899	62.45	62.937	30.41	21.812
Story16	48	65.914	61.004	61.169	60.352	61.021	28.264	20.053
Story15	45	62.079	57.22	57.342	57.033	57.813	26.125	18.312
Story14	42	58.151	53.356	53.441	53.251	53.961	23.996	16.593
Story13	39	54.141	49.443	49.501	49.351	49.979	21.883	14.902
Story12	36	50.058	45.586	45.661	45.496	46.083	19.788	13.247
Story11	33	45.911	42.347	42.623	42.257	43.002	17.716	11.634
Story10	30	41.707	40.509	41.05	40.41	41.4	15.673	10.071
Story9	27	37.452	36.973	37.688	36.878	37.998	13.663	8.568
Story8	24	33.152	32.826	33.474	32.734	33.735	11.697	7.133
Story7	21	28.807	28.532	29.084	28.445	29.295	9.785	5.78

Story6	18	24.417	24.18	24.634	24.099	24.798	7.942	4.522
Story5	15	19.98	19.784	20.145	19.713	20.268	6.189	3.373
Story4	12	15.503	15.353	15.626	15.294	15.712	4.551	2.353
Story3	9	11.008	10.905	11.095	10.861	11.151	3.061	1.482
Story2	6	6.57	6.511	6.623	6.485	6.654	1.76	0.782
Story1	3	2.464	2.442	2.484	2.432	2.495	0.691	0.278
Base	0	0	0	0	0	0	0	0

TABLE II

COMPARISON MAXIMUM DISPLACEMENT FOR SPEC-Y OF MODELS 1,2, 3, 4, 5, 6 & 7

		Models Maximum displacement (mm) in Y-direction						
Storey No's	Storey Height (m)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Story25	75	93.509	86.715	86.743	83.625	83.716	46.925	35.887
Story24	72	91.295	84.567	84.609	81.487	81.591	44.997	34.167
Story23	69	88.841	82.222	82.29	79.152	79.281	43.009	32.424
Story22	66	86.131	79.859	80.002	76.8	77.003	40.98	30.67
Story21	63	83.19	77.782	78.028	74.723	75.031	38.913	28.905
Story20	60	80.047	74.922	75.249	71.887	72.278	36.814	27.133
Story19	57	76.728	71.687	71.985	68.701	69.072	34.692	25.357
Story18	54	73.254	68.259	68.513	65.414	65.78	32.554	23.581
Story17	51	69.644	64.69	64.899	62.45	62.937	30.41	21.812
Story16	48	65.914	61.004	61.169	60.352	61.021	28.264	20.053
Story15	45	62.079	57.22	57.342	57.033	57.813	26.125	18.312
Story14	42	58.151	53.356	53.441	53.251	53.961	23.996	16.593
Story13	39	54.141	49.443	49.501	49.351	49.979	21.883	14.902
Story12	36	50.058	45.586	45.661	45.496	46.083	19.788	13.247
Story11	33	45.911	42.347	42.623	42.257	43.002	17.716	11.634
Story10	30	41.707	40.509	41.05	40.41	41.4	15.673	10.071
Story9	27	37.452	36.973	37.688	36.878	37.998	13.663	8.568
Story8	24	33.152	32.826	33.474	32.734	33.735	11.697	7.133
Story7	21	28.807	28.532	29.084	28.445	29.295	9.785	5.78
Story6	18	24.417	24.18	24.634	24.099	24.798	7.942	4.522
Story5	15	19.98	19.784	20.145	19.713	20.268	6.189	3.373
Story4	12	15.503	15.353	15.626	15.294	15.712	4.551	2.353
Story3	9	11.008	10.905	11.095	10.861	11.151	3.061	1.482
Story2	6	6.57	6.511	6.623	6.485	6.654	1.76	0.782
Story1	3	2.464	2.442	2.484	2.432	2.495	0.691	0.278
Base	0	0	0	0	0	0	0	0

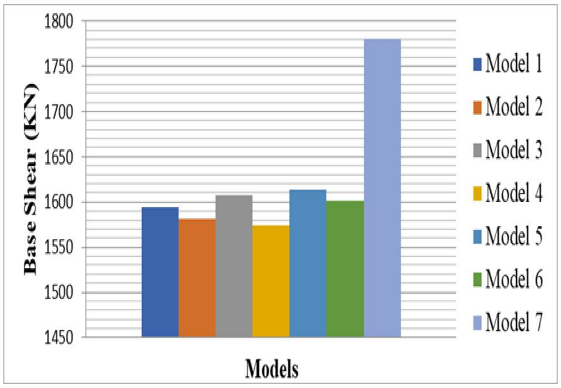
2) Base Shear

TABLE III

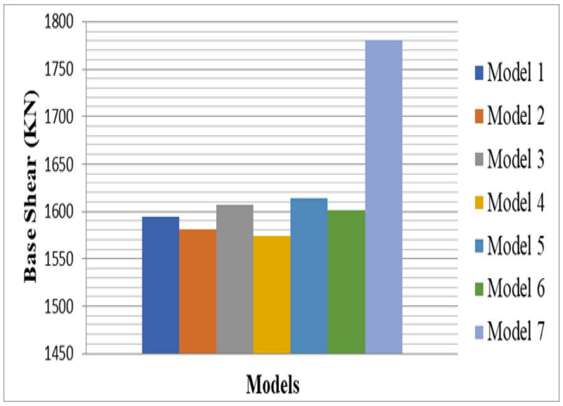
BASE SHEAR OF MODEL 1,2,3,4,5, 6 & 7

Model	SPECX (KN)	SPECY (KN)
Model 1	1594.1362	1594.1362
Model 2	1580.8957	1580.8957
Model 3	1607.2103	1607.2103

Model 4	1574.269	1574.269
Model 5	1613.7218	1613.7218
Model 6	1601.6552	1601.6552
Model 7	1780.7267	1780.7267



Along X-direction



Along Y-direction

Fig. 5 Comparison of Base Shear values of Models 1, 3, 4, 5, 6 &7 for SPECX & SPECY respt.

3) Fundamental Natural period

TABLE VI
FUNDAMENTAL NATURAL PERIODS

Models	Fundamental Natural Period (sec)			
	X-direction		Y-direction	
	Code	Analysis	Code	Analysis
Model 1	1.9485	3.117	1.9485	3.117
Model 2	1.9485	2.998	1.9485	2.998
Model 3	1.9485	3.001	1.9485	3.001
Model 4	1.9485	2.949	1.9485	2.949
Model 5	1.9485	2.959	1.9485	2.959
Model 6	1.9485	2.265	1.9485	2.265
Model 7	1.9485	1.902	1.9485	1.902

V. CONCLUSION

A study has been carried out to determine the optimum configuration of a twenty-five story building by changing outrigger location. Seven different cases of outrigger position for a twenty-five storey building have been analyzed by Response Spectrum analysis as a space frame system using a standard package ETAB subjected to lateral and gravity loading. The typical shear wall and X bracing is also used in considered cases. This study leads to following conclusions:

1) The X-braced and shear wall Outriggers is very much effective; as it shows minimum lateral displacement as compared to without Outriggers provision.
2) The Outriggers provided with X Bracing at core area were less effective in reducing lateral displacement compared with Shear wall by a small margin, hence it can be employed as the cost effective construction. It is observed that 30% more top storey displacement of Model 6 as compared to Model 7.
3) And relatively comparison of all the similarly located outrigger system like in Model 2 with Model 3, Model 4 with Model 5 has experienced less displacement variation. It is observed that 3.5% more top storey displacement of Model 2 and Model 4 as compared to Model 3 and Model 5 respectively.

4) Lateral displacement values obtained from analysis indicate that numbers of outrigger provisions increases along longitudinal and transverse directions are effective in reducing the displacement values in the same directions.
5) The absolute lateral displacement obtained from analysis of regular building Model 1 at respective nodes is found to be greater at less storey stiffness. The reason for high storey displacements in buildings is that the overall stiffness of the building decreases due to attract maximum lateral forces. Due to decreasing stiffness, the flexibility increases and strength decreases resulting in high displacements.
6) Building Models7 with outrigger as an shear wall have maximum base shear about 11% when compared to building Model 6 where outrigger as an X bracing. Similarly all the models having outrigger as an shear wall is found more base shear value as compared to similarly located outrigger as an X bracing. Indicating these models are stiffer than without shear wall model.
7) From analysis, shorter fundamental periods is obtained in the form of seconds for shear wall building models that means to attract higher forces than the without shear wall model. So it concludes that these building models have more strength against the lateral loads to stable the structure.

The analysis proves that without outrigger system structures may exhibit poor performance during a strong shaking, as far as possible without outrigger provision in a high-rise building must be avoided. Therefore building provided with outrigger provision have to be introduced for reducing vulnerable response of building, they must be analyzed and designed properly following the conditions of IS 1893-part-1: 2002 and IS- 456: 2000, and joints should be made ductile as per IS 13920:1993. Now a day, complex shaped high-rise buildings are getting popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behavior.

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