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Influence of Outrigger system in RC Structures for Different Seismic Zones

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Abstract - *Construction of tall structures having residential and commercial purposes has improved in conjunction with the growth of construction technique. In general, earthquake (EQ) ground motion is unpredictable and the problem considered with tall buildings, especially under heavy earthquakes, it should be extensively studied. Construction of tall buildings has laid more challenges for engineers to meet the requirements with respect to the demand growth. In the recent trend of tall buildings, horizontal loads due to seismic or wind action are resisted by arrangement of coupled shear walls. When the structure increases in height, the structural stiffness becomes more significant and introduction of outrigger beams between the exterior columns and shear walls is more commonly used to give lateral stiffness to the structure. The outrigger system is the most commonly used structural lateral load resisting system as to mitigate the excessive drift due to lateral load in an effective manner. The analysis has been carried out to study the effect and performance of outrigger system in a 35 story building. The outrigger system is provided at different levels along the height of the building by varying the relative stiffness. Loads are considered as per Indian Standards IS: 875(Part1)-1987 and IS: 1893(Part-1): 2002. The analysis is done with Equivalent static method for different seismic zones. The modeling and analysis were performed using finite element software ETABS 9.7.4. It is found that, with the increase in relative stiffness of the outrigger system, there is a decrease in lateral displacement and inter-story drift. Further there is increase in base shear of the structure with higher relative stiffness in all seismic zones.*

Key Words: Influence of Outrigger System, RC Structures for Different Seismic Zones.

1. INTRODUCTION

The main core in connection with the columns located at the exterior portion of the building by outriggers (stiffer horizontal members) forms the structural arrangement of an outrigger system. The core is centrally located with outriggers spreading on both sides (Fig.1) or one side of the building with outriggers (Fig.2) and it may consist of reinforced concrete shear walls.

When Horizontal load is applied to the structure, the column with outriggers controls the core rotation. The main objective is to increase the structure's effective depth when it acts like a vertically cantilever, which is done by inducing tension in the windward columns and Compression in the leeward columns. The peripheral columns are utilized to assist the columns located at the ends of the outriggers. A deep spandrel girder or a belt truss, around the structure is used to achieve it the outrigger levels.

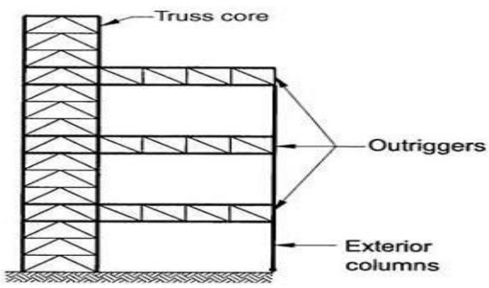

Fig -1: Outrigger system with a central core

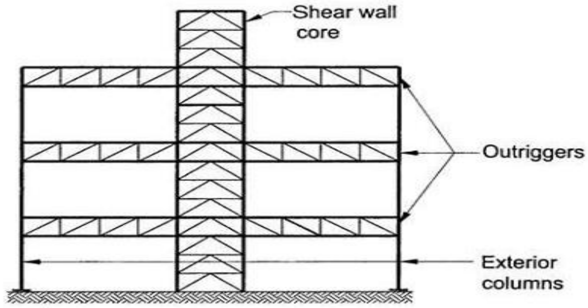

Fig -2: Outrigger system with a central core

The use of Outriggers in High-rise buildings to control the Forces:

- The incorporation of an outrigger connecting the two elements together gives rise to stiffer component acting along with the core to resist the overturning forces.
- When an outrigger building undergoes deflection due to under wind or earthquake load, the outrigger which connects in between the core wall and the external columns, makes the whole system to act as a single unit in resisting the lateral load.

2. MODELING

Table 1 below shows the details of the models considered in the study.

Table -1: Details of the models considered in the study

Details of the models considered in the study	
Plan of 35 storey building	(60X48) m
Building Type	SMRF
Center to Center distance of Column	6.0 m
Storey Height	3.05 m
Intensity of Live Load on each floor	3 kN/m^2
Weight of floor finish	2 kN/m^2
Intensity of roof live load	1.5 kN/m^2
Soil type	Medium
Importance factor	1.0
Response reduction factor	5.0
Grade of steel	Fe 500 for Beam Fe 550 for Column
Grade of concrete	M30 for Beam M50 for Column
Beam details	(300X600) mm
Column details	(900X900) mm
Slab details	150 mm thick M30 throughout
Wall details	200 mm thick M30 throughout

Outrigger system are considered at different locations along the height of the building (H), such as 0.25H, 0.5H, 0.75H and 1H. The dimensions of outrigger beam for different do/d ratio as shown in below Table 2

Table -2: Dimension of Outrigger beam for different do/d

do/d ratio	Size of Outrigger Beam
1	(300X600) mm
2	(300X1200) mm
3	(300X1800) mm
4	(300X2400) mm
5	(300X3000) mm

In the present study there are 6 different models are considered for the analysis.

Model 1: In this model only bare frame is considered with no shear wall and outrigger beams. The plan of the Model 1 has been shown in Fig.3.

Model 2, Model 3, Model 4, Model 5 and Model 6 are considered with different do/d ratio as 1, 2, 3, 4 and 5 respectively. These models are considered with shear wall and outrigger beams. The plan, elevation and 3D view of these models are shown in Fig.4, Fig.5 and Fig.6 respectively.

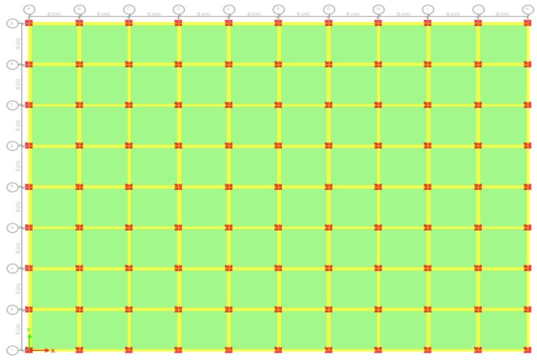

Fig -3: Plan of Model 1

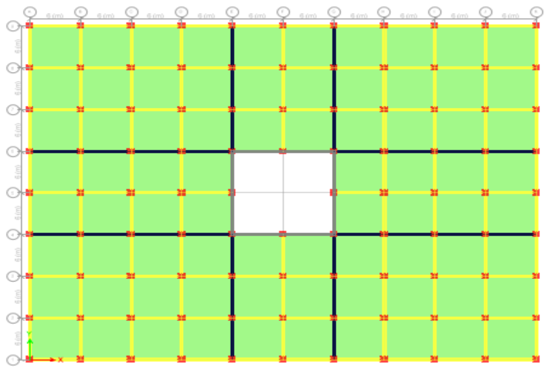

Fig -4: Plan of Outrigger system model

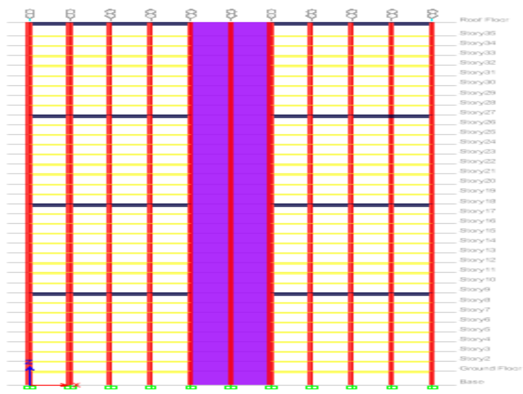

Fig -5: Elevation of Outrigger system model

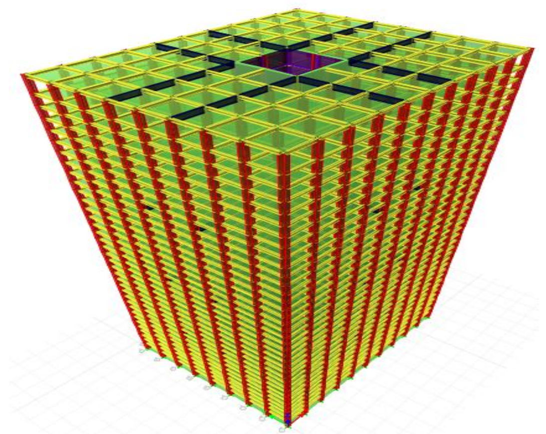

Fig -6: 3D view of Outrigger system model

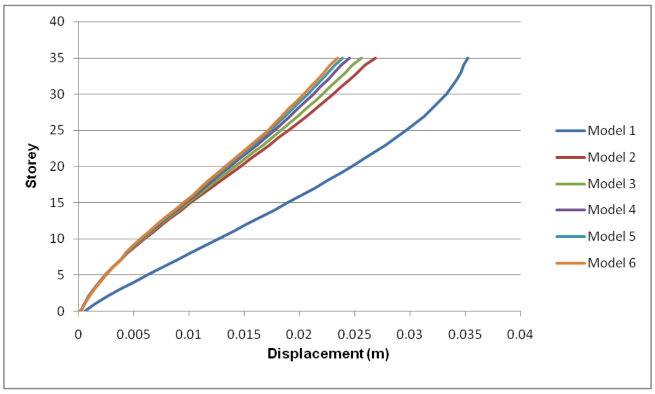

Fig. 7: Variation of lateral displacement for different models at Zone 2.

A Similar variation in lateral displacement for different seismic zones has been observed and the maximum lateral displacement for different seismic zones is tabulated in the table 3.

Table3: Variation of maximum lateral displacement in meters for different models at different seismic zones

Seismic Zones	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Zone 2	0.0352	0.0268	0.0256	0.0245	0.0238	0.0234
Zone 3	0.0563	0.0429	0.0409	0.0392	0.0382	0.0375
Zone 4	0.0845	0.0644	0.0614	0.0589	0.0573	0.0563
Zone 5	0.126	0.0966	0.0922	0.0883	0.859	0.0844

3. METHODOLOGY

In the present study, an attempt has been made to evaluate the seismic performance of RC structures with central core wall with Outrigger and without Outrigger by varying the relative stiffness. For this purpose, Outrigger systems are placed at different locations along the height of the building by varying relative stiffness. The relative stiffness is varying by considering the ration of depth of Outrigger beam to depth of Convention beam (do/d) from 1 to 5 with interval of 1. Also the position of outriggers remains same along the height of the building for all models.

Modelling and Analysis are carried out using ETABS finite element software, analysis is carried out using Equivalent Static method and Response Spectrum method. Loads are considered as per Indian Standards IS: 1875(Part 1) -1987, IS: 1875 (Part 2) -1987 and IS: 1893 (Part 1) -2002. The analysis is performed for different seismic zones, results are tabulated and corresponding graphs are plotted.

4. RESULTS AND DISCUSSIONS

Results obtained from the Equivalent static method are tabulated as follows and represented in the form of graphs. Lateral displacement, Inter-storey drift and base shear are parameters used to quantify the performance of RC structures with and without outriggers system for different seismic zones.

I) Lateral displacement in Equivalent Static Method

Fig.7 shows the variation of lateral displacement for different models at Zone 2.

II) Inter-Storey Drift in Equivalent Static Method:

Fig.8 shows the variation of inter-storey drift for different models at Zone 2.

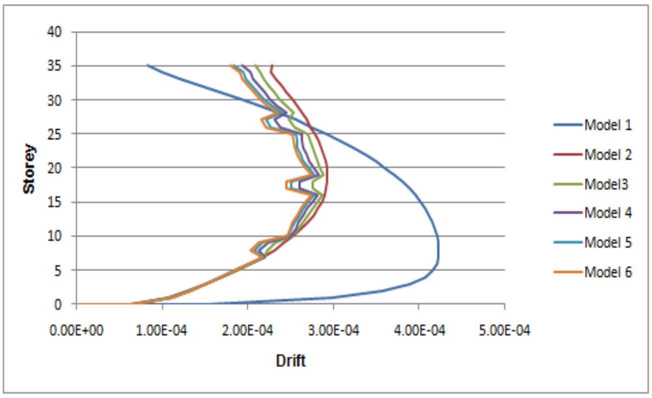

Fig. 8: Variation of Inter-storey for different models at Zone 2.

A Similar variation in Inter-Storey drift for different seismic zones has been observed and the maximum Inter-Storey Drift for different seismic zones is tabulated in the table 4.

Table4: Variation of maximum Inter-Storey Drift for different models at different seismic zones

Seismic Zones	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Zone 2	0.000422	0.000243	0.000233	0.000223	0.000217	0.000213
Zone 3	0.000675	0.000389	0.000372	0.000357	0.000347	0.000340
Zone 4	0.0001013	0.000555	0.000532	0.00051	0.000496	0.000487
Zone 5	0.0015	0.000833	0.000798	0.000765	0.000744	0.000731

III) Base shear in Equivalent Static Method:

Fig.9 shows the variation of inter-storey drift for different models at Zone 2.

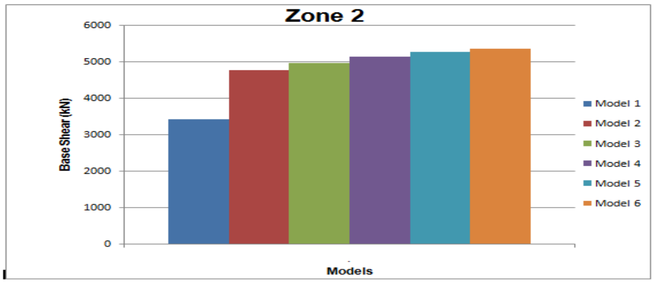

Fig. 9: Variation of Base Shear for different models at Zone 2.

A Similar variation in Base Shear for different seismic zones has been observed and the maximum Base Shear for different seismic zones is tabulated in the table 5.

Table4: Variation of maximum Base Shear in kN for different models at different seismic zones

Seismic Zones	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Zone 2	3402.40	4578.21	4947.6	5132.1	5259.3	8348.1
Zone 3	5443.84	7613.14	7916.2	8211.4	8415.0	8557.0
Zone 4	8165.77	11419.7	11874	12317	12622	12835
Zone 5	12248.6	17129.5	17811	18475	18933	19253

5. CONCLUSIONS

1) The percentage reduction of lateral displacement and inter-storey drift with respect to bare frame (Model1) varies for different model configuration, however this variation is not significant when compared between different seismic zones.
2) Maximum inter-storey drift has been observed at building height in the range of 5 to 15m.
3) Base shear is highest for Model 6 and Model 1 experiences least base shear in all seismic zones.

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