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A Study on the performance of multi-outrigger structure subjected to seismic loads

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ABSTRACT : *In the present study a investigation on the performance of a multi-outrigger structure subjected to seismic loads has been carried out. A three dimension model has been developed using the software ETABS. The relative height of the outrigger is varied and the performance of outrigger is then studied based on lateral displacement, storey drift, shear force and bending moment in the core wall for different values of relative axial rigidity (ratio of axial rigidity of the columns to the axial rigidity of core wall). When the displacement criteria is considered, a significant reduction in lateral displacement at top has been observed for the multi-outrigger structure for a relative height of 1.5 when compared with a structure without outrigger. When bending moment criteria is taken into account, there has been a considerable reduction in bending moment when the multi-outrigger structure with a relative height of 6.67 is compared with a model without outrigger .*

Keywords- *Bending Moment, Lateral Displacement, Multi-outrigger, Relative Axial Rigidity, Relative Height.*

I. INTRODUCTION

In modern tall buildings, lateral loads induced by wind or earthquake forces are often resisted by a system of multi-outriggers. An outrigger is a stiff beam that connects the shear walls to exterior columns. When the structure is subjected to lateral forces, the outrigger and the columns resist the rotation of the core and thus significantly reduce the lateral deflection and base moment, which would have arisen in a free core. Bayati et al. [1].In general, earthquake ground motion can occur anywhere in the world and the risk associated with tall buildings, especially under severe earthquakes, should be given particular attention, since tall buildings often accommodate thousands of occupants. It is conceivable that structural collapse of such buildings can lead to disasters of unacceptable proportions. Hearth et al. [2]. The behavior of various alternative 3D models using ETABS software for RCC structure with central core wall with single outrigger and without outrigger by varying the relative flexural rigidity from 0.25 to 2.0 with step of 0.25 has been already studied by Kamath et al. [3].Wu and Li studied the optimum designs of multi-outriggers in tall building structures through the analysis of structural performance of outrigger-braced frame-core structures [4].Smith and Willford presented a new concepts for the structural design of high-rise buildings, in which a damped outrigger concept was introduced to increase the dependable structural damping by a factor of 5–10 [5]. Hoenderkamp et al. described a graphical method of analysis for the preliminary design of tall building structures comprising braced frames with outrigger trusses subjected to horizontal loading [6].

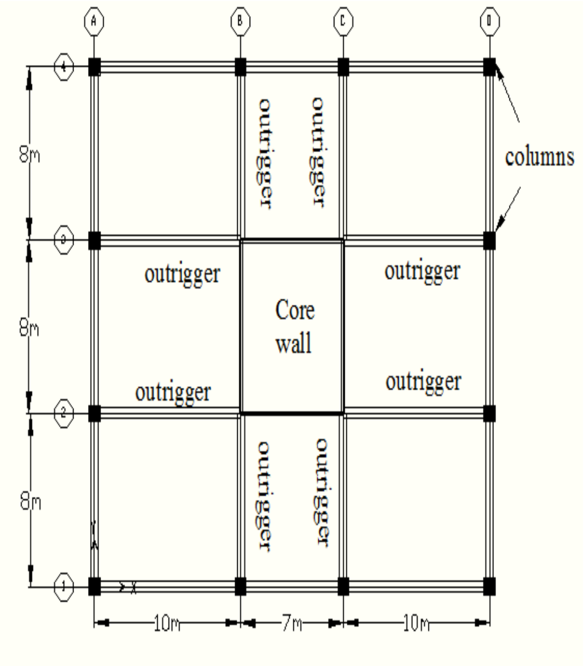
1.1 Objective of study

The study focuses on the performance of multi-outrigger structural system based on location of outrigger and also the performance of the system in terms of lateral displacements at the top, storey drift , shear force and bending moment in the core wall is obtained based on relative axial rigidity.

II. METHODOLOGY

A three-dimensional structure has been modelled having 40 stories, each storey height is of 3.5 m and the total height of the building is 140 m [3]. Figure 1 shows plan of the structure. Multi-outriggers system is modelled with two outriggers at different storey levels. The depth of outrigger is kept equal to one storey depth as shown in Figure 2 .Column size and beam size considered in the analysis are 0.75 m X 0.75 m and 0.45 m X 0.75 m respectively. The thickness of outrigger is kept constant as 500mm and the core wall considered is 200mm thick.

The core wall and the outrigger have been modelled as shell element with meshing.



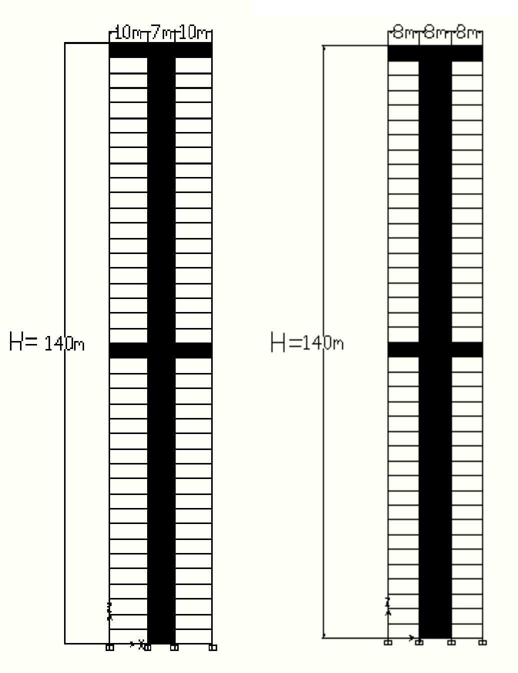


Figure 1: Plan of model considered Figure 2: Elevation of model in X-Z and Y-Z direction

For multi-outrigger structure outrigger location has been varied in two different ways as shown in Table 1 and Figure 3.

Table1: Relative height variation of outrigger

H_2=H is kept constant and H_1 is varied.		H_1=H/2 is kept constant and H_2 is varied.	
H_2/H_1	Location of outrigger	H_2/H_1	Location of outrigger
6.67	Storey 6	1	Storey 20
4	Storey 10	1.3	Storey 26
2.5	Storey 16	1.5	Storey 30
2	Storey 20	1.8	Storey 36

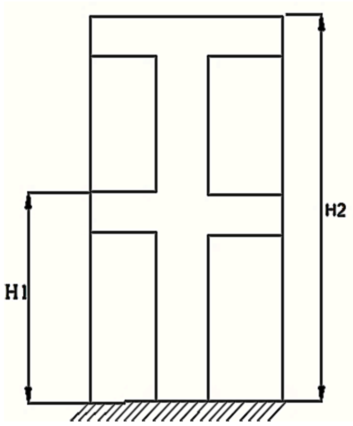


Figure 3:Relatiive height of outrigger

2.1 Models formed based on relative axial rigidity

Relative axial rigidity, $\alpha = \frac{A_c\ E_c}{A_{cw}\ E_{cw}}$ …. Eqn (1)

Where A_c and A_{cw} are the area of columns and core wall respectively. E_c is modulus of elasticity of columns and E_{cw} is the modulus of elasticity of core wall. The value of relative axial rigidity Eqn(1) is varied from 0.25 to 2.0 with a step of 0.25 as shown in Table 2.

Table 2: Models based on relative axial rigidity

Models	$\alpha = \frac{A_c E_c}{A_{cw} E_{cw}}$	H_2/H_1
1	0.25	ratio is varied as 6.67,4,2.5,2,1 1.3,1.5 and 1.8 For each **α** value
2	0.5	
3	0.75	
4	1	
5	1.25	
6	1.5	
7	1.75	
8	2	

A static analysis on the multi-outrigger structure has been carried out by applying seismic load as per IS 1893 (PART 1):2002 for zone III (Z=0.16) , Medium soil (Type II) , Importance factor (I=1.5), Response reduction factor (R=5) and the time period (T) is program calculated. Analysis is done for one storey depth of outrigger based on relative axial rigidity Eqn (1) for different outrigger locations. Results of lateral displacements, storey drifts, shear forces and bending moments in the core wall are obtained through ETABS analysis.

III. RESULTS AND DISCUSSIONS

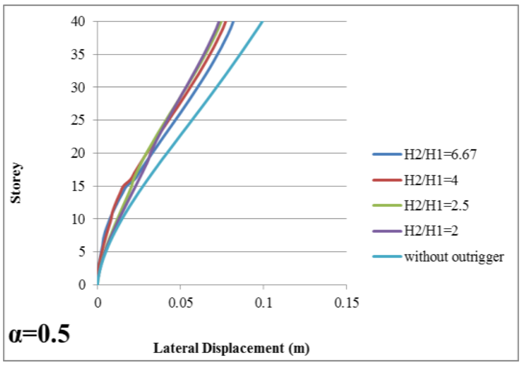
Table 3: Lateral displacement at top of multi-outrigger structure when compared with core wall structure without outrigger.

(a) For H_2=H

H_2/H_1	6.67	4	2.5	2
α	Percentage reduction (%)			
0.25	10.86	12.90	15.58	18.52
0.5	17.64	22.28	25	26.31
0.75	15.87	21.10	24.98	24.80
1	14.42	19.56	23.27	22.93
1.25	13.35	18.42	21.80	21.32
1.5	12.64	17.44	20.54	20.08
1.75	11.90	16.57	19.43	18.9
2	11.32	15.88	18.53	17.94

(b) For H_1=H/2

H_2/H_1	1	1.3	1.5	1.8
α	Percentage reduction (%)			
0.25	12.77	18.52	19.80	18.92
0.5	22.58	28.43	29.74	28.63
0.75	23.26	31.11	31.74	28.49
1	21.92	29.68	30.27	26.81
1.25	20.76	28.48	28.96	25.34
1.5	19.84	27.44	27.83	24.19
1.75	19.05	26.51	26.81	23.04
2	18.31	25.66	25.96	22.06



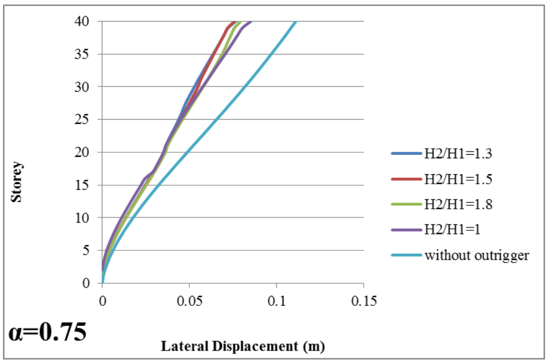


Figure 4: lateral displacement variation of multi-outrigger structure and core wall structure without outrigger for α=0.5 and α=0.75.

It can be observed from Table 3 and Figure 4 that the lateral displacement at top of multi-outrigger structure has been reduced to 31.74% when compared to the structure without outriggers for α=0.75 and H_2/H_1=1.5. And the corresponding values of storey drift have been reduced to 30.73% ,also the shear force has been increased to 8.98% and bending moment has been reduced to 8.98%. Figure 4 shows the lateral displacement variation for maximum value of percentage reduction of lateral displacement from the Table 3 for both cases (a) and (b).

Table 4: Storey drift of multi-outrigger structure when compared with core wall structure without outrigger

(a) For H_2=H

H_2/H_1	6.67	4	2.5	2
α	Percentage reduction (%)			
0.25	3.04	4.06	9.28	14.20
0.5	7.33	11.40	18.02	25
0.75	4.48	9.17	17.92	24.27
1	2.53	7.30	16.34	23.25
1.25	1.39	6.02	15.19	22.41
1.5	0.53	4.99	14.17	20.41
1.75	-0.17	4.24	13.40	18.50
2	-0.59	3.62	12.72	16.93

(b) For H_1=H/2

H_2/H_1	1	1.3	1.5	1.8
α	Percentage reduction (%)			
0.25	8.12	23.04	22.17	18.55
0.5	20.24	30	31.86	28.60
0.75	22.92	31.56	30.73	29.17
1	22.96	27.92	27.14	26.07
1.25	23.06	25	24.26	23.24
1.5	22.99	22.55	21.84	20.94
1.75	21.52	20.48	19.79	19.01
2	20.05	18.79	18.20	17.44

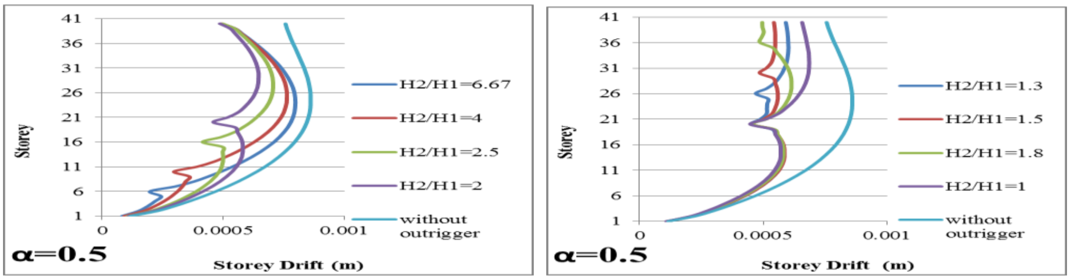


Figure 5:Storey drift variation of multi-outrigger structure and core wall structure without outrigger for α=0.5.

Table 4 and Figure 5 clearly indicates that the storey drift of multi-outrigger structure has been reduced to 31.86% when compared to the structure without outriggers for α=0.5 and H_2/H_1=1.5. And the corresponding values of lateral displacement at top has been reduced to 29.74% ,also the shear force has been increased to 14.51% and bending moment has been reduced to 7.78%. Figure 5 shows the storey drift variation for maximum value of percentage reduction of storey drift from the Table 4 for both cases (a) and (b).

Table 5: Shear force of multi-outrigger structure when compared with core wall structure without outrigger

(a) For H_2=H

H_2/H_1	6.67	4	2.5	2
α	Percentage increase (%)			
0.25	23.38	25.74	26.56	24.1
0.5	14.89	12.96	12.60	9.42
0.75	16.95	13.47	10.29	8.81
1	18.52	14.27	10.37	8.69
1.25	19.78	14.84	10.34	8.54
1.5	20.85	15.25	10.25	8.38
1.75	21.77	15.56	10.14	8.23
2	22.57	15.79	10.02	8.10

(b) For H_1=H/2

H_2/H_1	1	1.3	1.5	1.8
α	Percentage increase (%)			
0.25	23.40	30.86	29.60	26.37
0.5	8.83	15.75	14.51	11.43
0.75	5.74	9.08	8.98	8.87
1	5.64	8.95	8.86	8.75
1.25	5.50	8.79	8.70	8.59
1.5	5.36	8.62	8.53	8.43
1.75	5.21	8.46	8.37	8.28
2	5.08	8.31	8.23	8.14

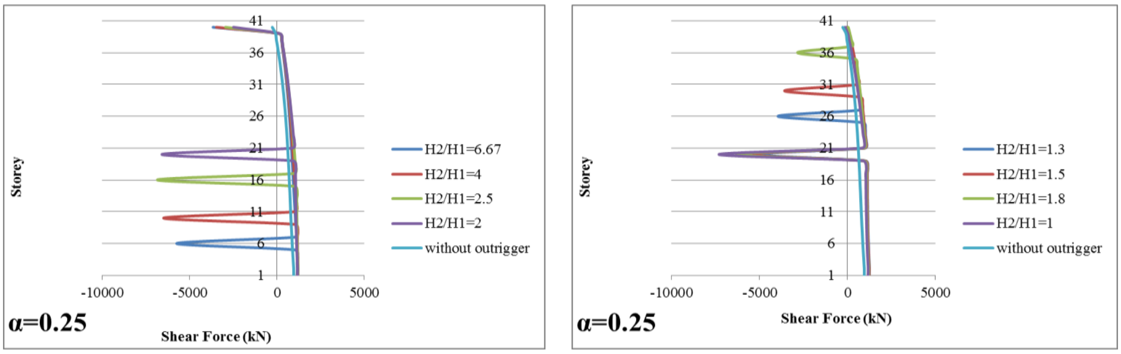


Figure 6:Shear force variation of multi-outrigger structure and core wall structure without outrigger for α=0.25.

It has been clearly seen from Table 5 and Figure 6 that the shear force of multi-outrigger structure has been increased to 30.86% when compared to structure without outriggers for α=0.25 and H_2/H_1=1.3. And the corresponding values of lateral displacement at top has been reduced to 18.52% , also storey drift has been reduced to 23.04% and bending moment has been increased to 0.41 %. Figure 6 shows the shear force variation for maximum value of percentage increase of shear force from the Table 5 for both cases (a) and (b).

Table 6: Bending moment of multi-outrigger structure when compared with core wall structure without outrigger

(a) For H_2=H

H_2/H_1	6.67	4	2.5	2
α	Percentage reduction (%)			
0.25	27.24	20.99	7.40	1.64
0.5	32.60	31.25	15.86	10.16
0.75	29.91	30.75	15.03	7.67
1	27.98	29.54	12.70	5.43
1.25	26.49	28.33	10.80	3.75
1.5	25.23	27.15	9.20	2.43
1.75	24.14	26.05	7.86	1.39
2	23.21	25.04	6.76	0.57

(b) For H_1=H/2

H_2/H_1	1	1.3	1.5	1.8
α	Percentage reduction (%)			
0.25	2.82	-0.41	-0.30	0.86
0.5	11.21	7.52	7.78	9.23
0.75	10.85	9.54	8.98	8.20
1	8.68	7.05	6.55	5.89
1.25	7.04	5.17	4.74	4.15
1.5	5.74	3.70	3.31	2.79
1.75	4.71	2.53	2.18	1.72
2	3.89	1.61	1.30	0.87

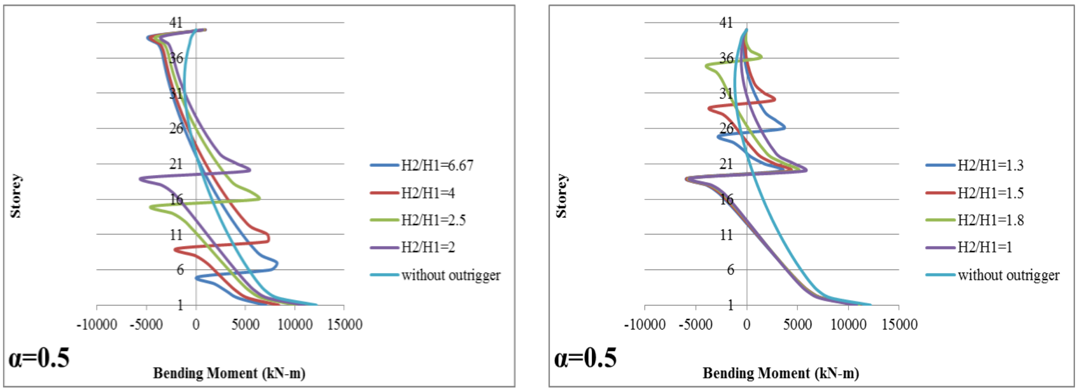


Figure 7:Bending moment of multi-outrigger structure and core wall structure without outrigger for α=0.5.

It has been observed from Table 6 and Figure 7 that the bending moment of multi-outrigger structure has been reduced to 32.60% when compared to structure without outriggers for α=0.5 and H_2/H_1=6.67. And the corresponding values of lateral displacement at top has been reduced to 17.64% ,also the storey drift has been reduced to 7.33% and shear force at core wall has been increased to 14.89%. Figure 7 shows the bending moment variation for maximum value of percentage reduction of bending moment from the Table 6 for both cases (a) and (b).

3.1 Conclusion

From the results and discussion following conclusions can be arrived at,
The performance of multi-outrigger structure considering the lateral displacement at top, the analysis shows that for H_2/H_1=1.5 and α=0.75 there is a considerable reduction in the lateral displacement when it is compared with core wall structure without outriggers and it is found to be 31.74%.

However, if the performance of multi-outrigger structure is considered with respect to bending moment in the core wall, at H_2/H_1=6.67 and α=0.5 there has been a significant reduction of 32.60% in bending moment when its compared with core wall structure without outriggers.

REFERENCES

[1]. Z. Bayati, M. Mahidikhani and A. Rahaei, Optimized Use of Multi-outrigger System to Stiffen Tall Buildings, *The 14th World Conference on Earthquake Engineering, Beijing China,* October 2008, 12-17.
[2]. N. Herath, N. Haritos, T. Ngo and P. Mendis, Behaviour of Outrigger Beams in High-Rise Buildings Under Earthquake Loads, *Proceedings of Australian Earthquake Engineering Society Conference,* 2009.
[3]. Kiran Kamath, N. Divya and Asha U. Rao, A Study on Static and Dynamic Behaviour of Outrigger Structural System for Tall Buildings, *Bonfring International Journal of Industrial Engineering and Management, Vol 2, No. 4,* December 2012,15-20.
[4]. J. R. Wu and Q. S. Li, Structural Performance of Multi-Outrigger Braced Tall Buildings, *The Structural Design of Tall and Special Buildings, Volume 12,* 2003, 155-176.
[5]. Rob J. Smith and Michael R. Willford, The Damped Outrigger Concept for Tall Buildings, *The Structural Design of Tall and Special Buildings 16,* November, 2007, 501-507.
[6]. J. C. D. Hoenderkamp and M. C. M. Bakker, Analysis of High-rise Braced Frame with Outriggers, *The Structural Design of Tall Buildings and Structures, Volume 12,* 2003, 335-350.