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A PERFORMANCE STUDY OF HIGH-RISE BUILDING UNDER LATERAL LOAD WITH RIGID FRAME, CORE AND OUTRIGGER STRUCTURAL SYSTEMS

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Abstract

In this study considered, Performance of 20 storey building under lateral load with different structural systems, such as Rigid frame, Core and Outrigger structural systems under seismic loading with seismic zone V at soil type III (soft soil) and reduction factor 5 for special RC moment-resisting frame. It is evaluated by Response Spectrum analysis for different load combinations as per IS: 1893:2002. Analysis of above mentioned structural systems are carried-out using E-TABS 2015 software. To check the performance of the building by considering following parameters such as, roof displacement, base bending moment of inner and edge columns and base core moment for core structural system and outrigger structural systems. The object of the study is to determine the degree of effectiveness of different locations of outrigger structural system to increase the performance and sustainability of the building.

***Keywords: -** Rigid frame system, core system, outrigger system, Response spectrum analysis and E-TABS 2015*

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1. INTRODUCTION

The increase in population and shortage of land in urban areas, leads to development of tall buildings. Such buildings are subjected to lateral loads such as seismic and wind loads play a dominant role due to their height and terrain characteristics and show greater sensitivity. By using different types of structural systems such as rigid frame system, flat slabs system, braced-frame system, shear wall system, core system, mega column, outrigger frame system, tube system etc. the lateral load resisting capacity is increased to a certain extent.

Many researchers focused on to obtain position of outrigger to control lateral displacement but, secondary needs of research like, controlling core moment and column reaction are need to studied[7]. So, an attempt is made in this paper to include column reaction and core moment which is discussed below.

1.1 Core and Outrigger Structural System

Core system is used in RC buildings. This system consists of a RC core shear wall resisting all the vertical and lateral loads, Fig – 1.

The outriggers are structural elements connecting the core to the perimeter columns at one or more levels throughout the height of the building to stiffen the structure, Fig – 1. An outrigger consists of a horizontal shear truss or shear wall or deep beams. Because the outrigger affects the interior space, they generally located at mechanical equipment floors in order not to hinder the use of normal floors.

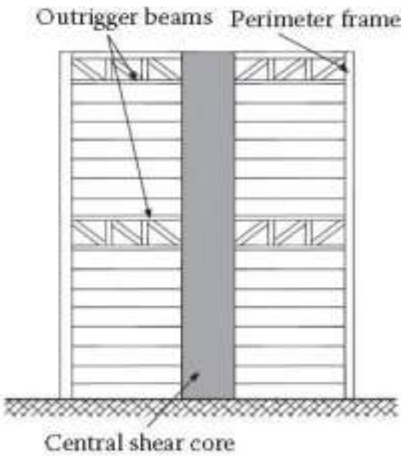

Fig 1: Core and Outrigger frame system adopted in present study (diagonal bracing type)

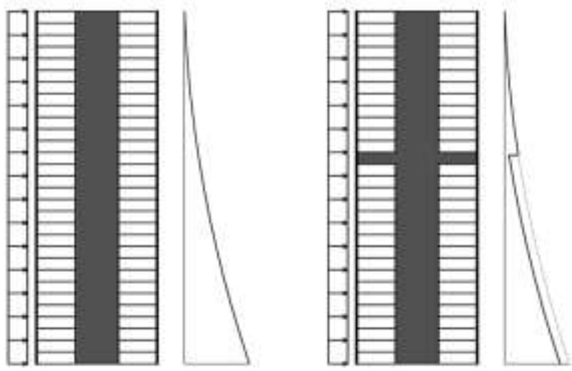

Fig 2: Effect of Outrigger on the moment when compared with core system

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Outriggers are one of the most effective structural system in reducing the lateral deflection, shear and moment in tall buildings, Fig 2.

Several factors affect the performance of outrigger system are, number of outrigger, type of outrigger, depth of outrigger, height of the building, type of material used to outrigger beam, shape of building, shape of the shear wall at center, intensity of lateral loads etc.

In the present study, the effect of number of outrigger system in 20 storey buildings under seismic loading as per IS1893 (part-1):2002 are considered. The overall aim is to assess the structural performance 20storeywith seismic zones V at soil type III as per Indian standards. So an attempt is made to controlling roof displacement, core moment and column reactions at edge and inner column. This investigation will serve as a reference for seismic resistant design of rigid frame, core and outrigger structural systems in high-rise RC buildings

2. MODELING OF 20 STOREY REINFORCED CONCRETE BUILDING

Modeling of 20 storey RC building describes the structural configuration of different structural system are as shown in Fig -3. Frame selected for analysis is symmetrical in plan of 42x42m with Centre to Centre column spacing is 6m. Different structural system is introduced in order to minimize the top storey displacement, core moment and column reactions at edge C1 and inner C27 columns for 20 storey building, Fig -3. The structural configuration of buildings like material property (concrete and rebar grade) varied (material property will be same for all structural elements at that floor) i.e. 1 to 5 storey M40, 6 to 10 storey M30 and 11 to 20 storey M25 and sectional property of column 700x1000 mm and beam 400x600 mm and storey height is 3m. Slab, masonry walls and shear wall thickness is assumed to be 150mm, 200mm and 250mm respectively. Diagonal bracing type is adopted as outrigger beam and outrigger beam size 400x600mm.

Each building is subjected to gravity and lateral load. Wall load of 10kN/m on floor throughout beam length, floor finish of 1.5kN/m² and live load of 2kN/m² expect roof, at roof wall load of 4kN/m as parapet wall, floor finish of 3kN/m² and live load of 1.5kN/m². Seismic loading as per IS1893 (part1) – 2002, seismic zone V at soil type III (soft soil).Natural time period of vibration by empiricalexpression as per IS1893 (part-1) – 2002 for 20storey building is 0.833 sec. The results are noted for load combination specified as per IS codes. At present study 1.5(DL+SDL±EQ X) is critical combination which results are obtained.

Table -1: Factors affecting outrigger performance

Factors	**Adopted at present work**
Type of outrigger	Conventional outrigger without belt truss
Number of outrigger	1, 2, 3 and 4
Position of outrigger	0.25H, 0.5H, 0.75H and H
Depth of outrigger	600 mm
Height of building	60 m
Shape of core wall	Closed / Square
Intensity of lateral load	Zone V as per IS1893: 2002

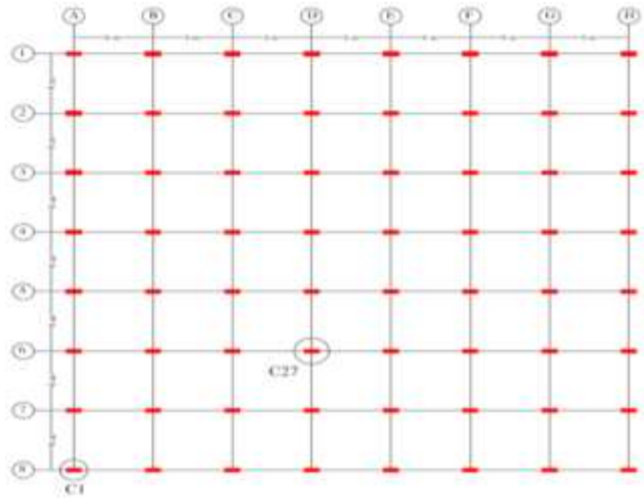
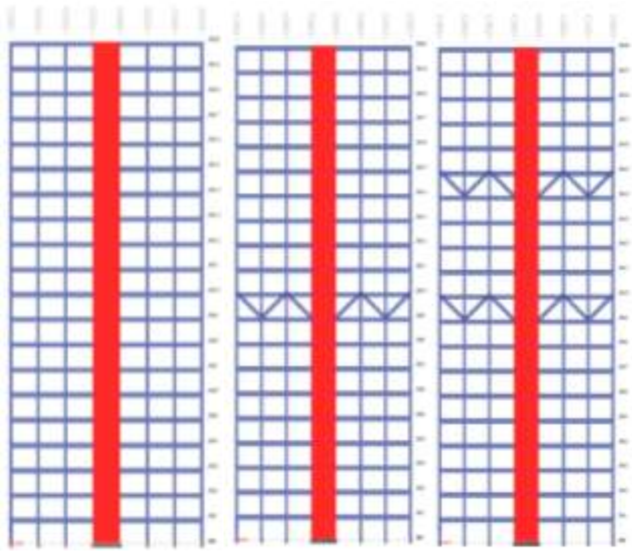


Fig – 3: Plan considered for the study and marked critical column C1 and C27



(a) (b) (c)

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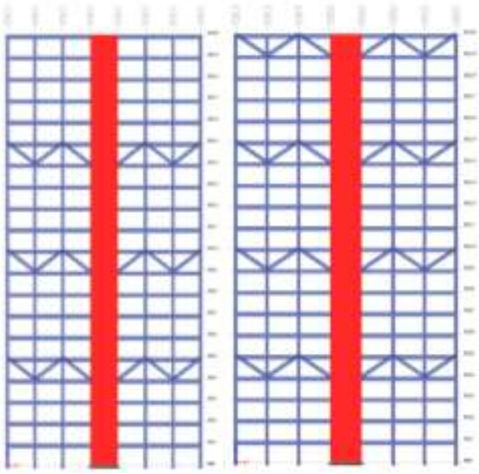

(d) (e)

Fig – 4 : Section view at E for 20 storey core wall (a) with outrigger at 0.5H (b), 0.5H and 0.75H (c), 0.25H, 0.5H and 0.75H (d) and 0.25H, 0.5H, 0.75H and H (e).

2.1 Method of Analysis

Generally following four types of analysis are used for seismic design and performance of buildings, viz linear equivalent static analysis, linear response spectrum analysis, nonlinear static pushover analysis and nonlinear time history analysis. In present study, Response spectrum analysis is used. Dynamic analysis are performed as per clause no 7.8.1 (a), IS1893 – 2002[12]. Response of building from earthquake considered by load combination as per IS456: 2000, Table 18. Modeling and analysis are carried out by ETABS-2015 software.

3. RESULTS AND DISCUSSIONS

In the present study roof displacement, base bending moment of inner and corner column and base moment of core in core structural system and outrigger structural system under seismic load as per IS1893 (part – 1): 2002 for seismic zone V and soil type III.

3.1 Rigid frame System and Core System

Table -2: summary of results from rigid frame and core system

Structural system	Roof displacement (mm)		Base bending moment of column (kN-m)		Base core moment (kN-m)
	X	Y	C27	C1	
Rigid frame	242.8	261	2937.1	2797.8	-
Core	191	199.2	1717.3	1624.9	422879.1

3.2 1ST Outrigger

For first outrigger location is at 0.25H, 0.5H, 0.75H and H. Where H - height of the building from base

Table -3: summary of results from 1st outrigger system at different location

Position of outrigger	Roof displacement (mm)		Base bending moment of column (kN-m)		Base core moment (kN-m)
	X	Y	C27	C1	
0.25H	168.9	175.8	1617.8	1531.1	346916.2
0.5H	165.5	173.8	1700.5	1609.3	406644
0.75H	170.5	178.3	1724.7	1632	425639
H	179.5	187.3	1721.3	1628.6	423929.9

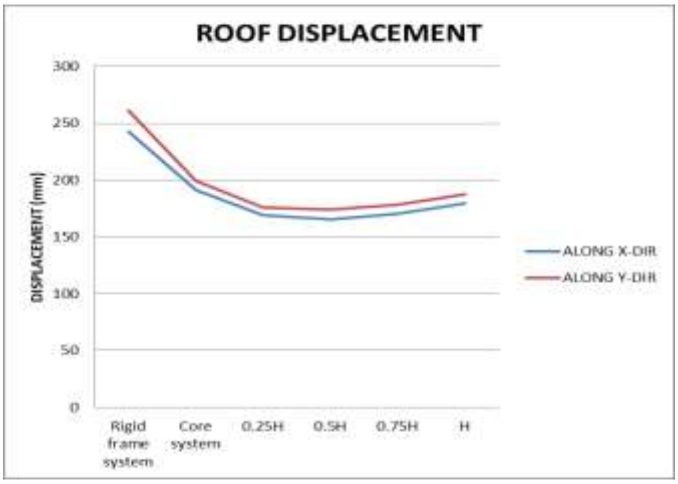

Chart -1: Roof displacement along X and Y direction for rigid frame system, core system and 1st outrigger at 0.25H, 0.5H, 0.75H and H

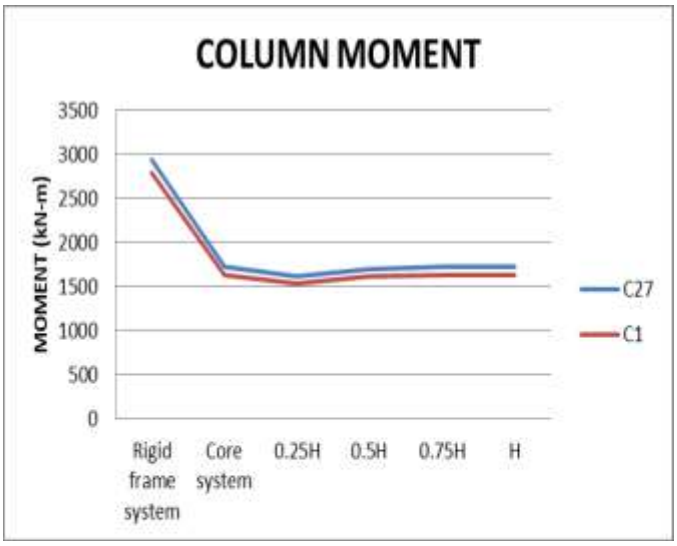

Chart -2: Column moment for C27 and C1 columns

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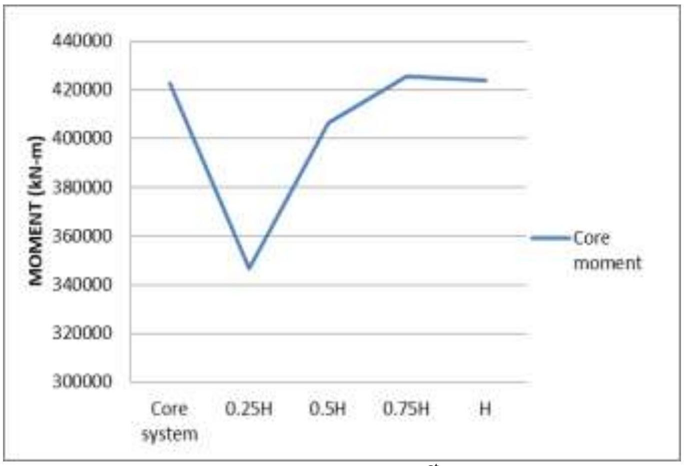

Chart -3: Core moment for Core and 1st outrigger at 0.25H, 0.5H, 0.75H and H

1. From chart -1, about 21.33%, 30.43%, 31.83%, 29.77% and 26.07% reduction in roof displacement along X direction and 23.67%, 32.64%, 33.4%, 31.68% and 28.23% % reduction in roof displacement along Y directionis observed for core, 1st outrigger at 0.25H, 0.5H, 0.75H and H respectively when compared with rigid frame system.
2. For C27 column, 41.53%, 44.91%, 42.1%, 41.27% and 41.39% reduction in base column moment is observed core, 1st outrigger at 0.25H, 0.5H, 0.75H and Hrespectively when compared withrigid frame system.
3. For C1 column, 41.92%, 45.27%, 42.47%, 41.66% and 41.78% reduction in base column moment is observed core, 1st outrigger at 0.25H, 0.5H, 0.75H and H respectively when compared with rigid frame system.
4. 17.96% and 3.83% reduction in base core moment at 1st outrigger at 0.25H and 0.5H. But by providing outrigger at 0.75H and H the core moment is increased by 0.65% and 0.24% when compared to core system.

3.3 2nd Outrigger

From keeping in view of max reduction in roof displacement the 1st outrigger placed at 0.5H. so, by keeping 1st as constant 2nd outrigger positions are varied i.e. 0.5H+0.25H, 0.5H+0.75H, 0.5H+H.

Table -4: summary of results from 2nd outrigger system at different location

Position of outrigger	Roof displacement (mm)		Base bending moment of column (kN-m)		Base core moment (kN-m)
	X	Y	C27	C1	
0.5H+0.25H	148.1	154.9	1610.1	1524.2	338290.7
0.5H+0.75H	148	155.4	1707.4	1616	409577
0.5H+H	155.6	162.4	1704.7	1613.4	407958.5

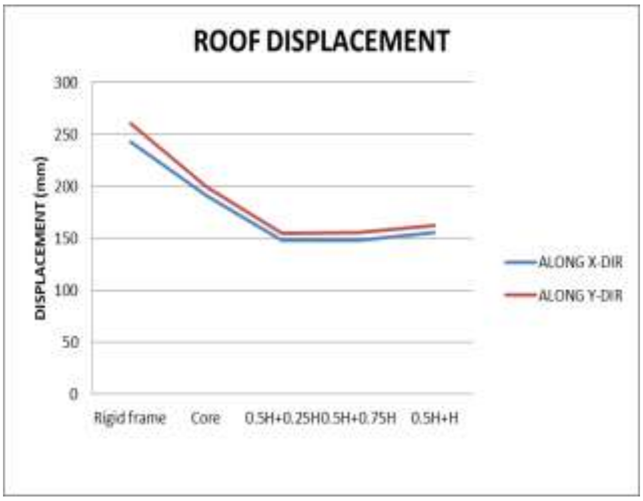

Chart -4: Roof displacement along X and Y direction for rigid frame, core and 1st outrigger at 0.5H as constant position and 2nd at 0.25H, 0.75H and H

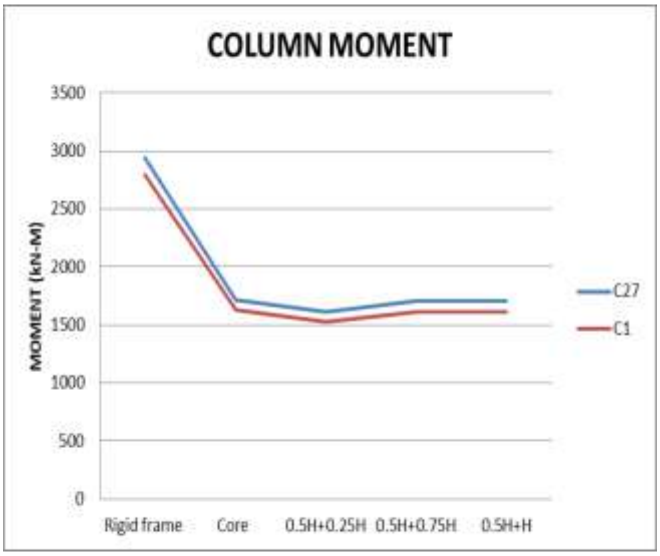

Chart -5: Column moment for C27 and C1 columns

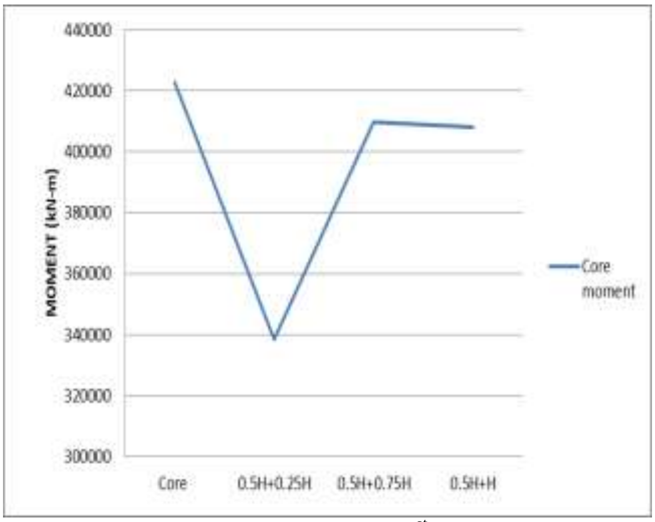

Chart -6: Core moment for core and 1st outrigger at 0.5H as constant position and 2nd at 0.25H, 0.75H and H

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1. From chart -4, 39%, 39.04% and 35.91%reduction in roof displacement along X direction and 40.65%, 40.45% and 37.77% reduction in roof displacement along Y direction for 1st outrigger at 0.5H and 2nd outrigger varied at 0.25H, 0.75H and H.
2. For C27 column, 45.18%, 41.86% and 41.95% and for C1 column 45.55%, 42.24% and 42.33% reduction of base column moment is noticed when compared with rigid frame system, chart -5.
3. 20%, 3.14% and 3.52% reduction in base core moment at 1st outrigger at 0.5H and 2nd outrigger at 0.25H, 0.75H and H respectively when compared to core system, chart -6.

3.4 3rd Outrigger

From keeping in view of reduction in roof displacement, reduction in column moment and core moment it's clear that the 1st outrigger placed at 0.5H and 2nd outrigger positions at 0.25H are effective position. So, by keeping 1st and 2nd as constant 3rd outrigger is varied i.e. 0.5H+0.25H+0.75H and 0.5H+0.25H+H.

Table -5: summary of results from 3rdoutrigger system at different location

Position of outrigger	**Roof displacement (mm)**		**Base bending moment of column (kN-m)**		**Base core moment (kN-m)**
	X	**Y**	**C27**	**C1**	
0.5H+0.25 H+0.75H	132.6	139.1	1617.8	1531.6	341840
0.5H+0.25 H+H	138.8	145.2	1614.4	1528.3	339564

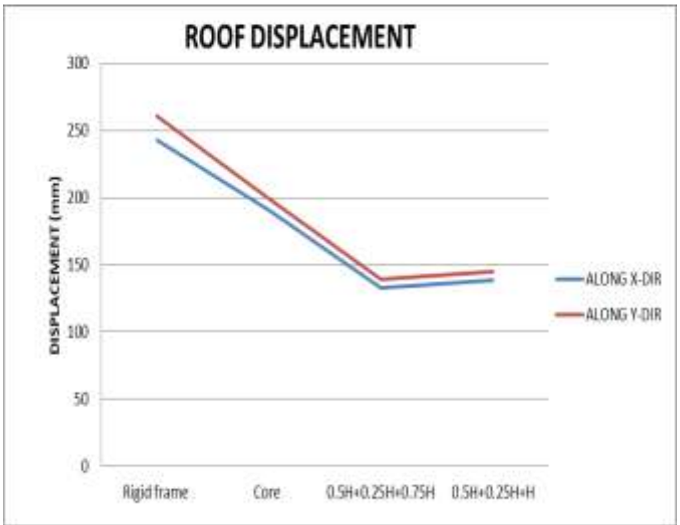

Chart -7: Roof displacement along X and Y direction for rigid frame, core, 1stoutrigger at 0.5H, 2nd at 0.25Has constant position and 3rd outrigger at 0.75H and H

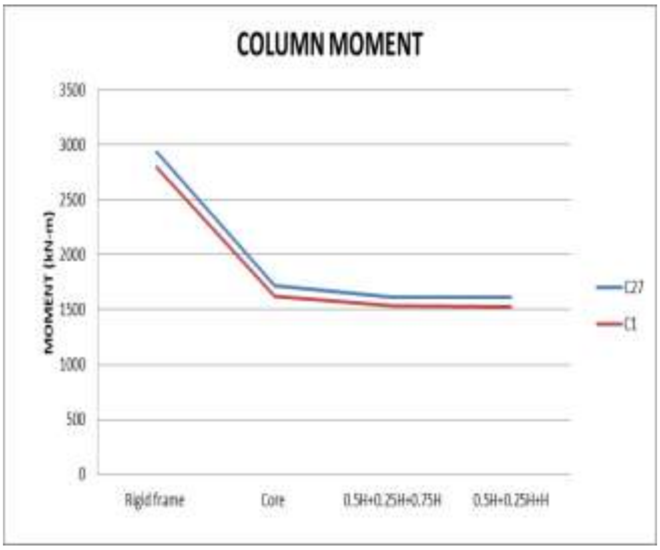

Chart -8: Column moment for C27 and C1 columns

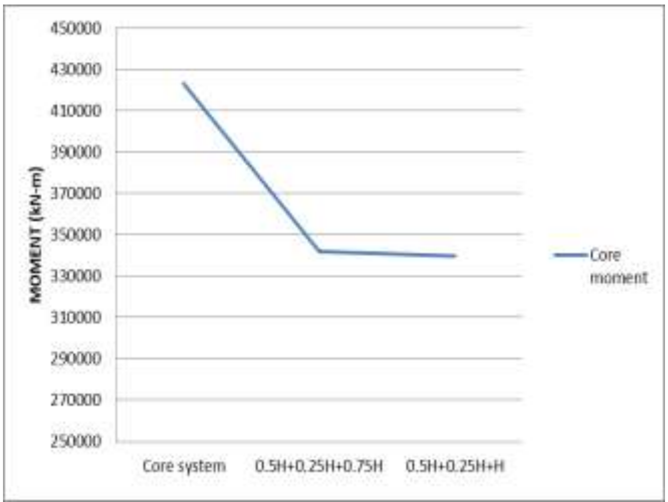

Chart -9: Core moment for core, 1st outrigger at 0.5H, 2nd at 0.25H as constant position and 3rd outrigger at 0.75H and H

1. From chart -5, 45.38% and 42.83% reduction in roof displacement along X direction and 46.7%, and 44.36% reduction in roof displacement along Y direction for 1st, 2nd outrigger at 0.5H, 0.25H and 3rd outrigger varied at 0.75H and H.
2. For C27 column, 44.91% and 45.03% and for C1 column 45.25% and 45.37% reduction of base column moment is noticed when compared with rigid frame system, chart -5.
3. 19.16% and 19.7% reduction in base core moment for 1st, 2nd outrigger at 0.5H, 0.25H and 3rd outrigger varied at 0.75H and H respectively when compared to core system, chart -9.

4. CONCLUSION

In this study an attempt is made to assess the seismic behavior of 20 storey high-rise building of rigid frame, core and outrigger structural system. to control roof displacement with minimum base core moment and base column moment.

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Outrigger system depends on the position and numbers of outrigger throughout the height of the building, in present study an effort is made to know the optimum location of outrigger system to control roof displacement with minimum base core moment and base column moment.

With roof displacement as criteria, the optimum location for 1st, 2nd, and 3rd outrigger are 0.5H, 0.25H and 0.75H.

Base column moment and base core moment as criteria, the optimum location for 1st, 2nd, and 3rd outrigger are 0.25H, 0.5H and H.

The research presented here mainly focus on the seismic behavior of high-rise building of rigid frame, core and outrigger system at different outrigger position. However, future studies should take into account the seismic behavior of different outrigger bracing system for further increase in height of the building.

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