SEISMIC ANALYSIS OF 20 STORY REINFORCED CONCRETE STRUCTURE UNDER CORE, OUTRIGGER SYSTEM AND BELT-TRUSS

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Abstract : It is a well known fact that earthquake is a disaster causing event. Recent trend of buildings are slender in nature and hence their behavior under lateral loads are quite random or probabilistic. Hence there is a need to improve lateral stiffness of the structure. With many practical studies, it is evident that use of structural systems improves the stiffness of the building. Considering 20 story building(60m in height), an attempt is made to analyse and stiffen the structure with Rigid Frame system, Core system and Outrigger structural system for different zones at soil type III. Models are analysed using Response Spectrum Method in E-TABS V18.0.0 software package as per IS 1893(Part 1):2016 code provisions. Rigid frame, Core system and Outrigger structural systems at various positions are modeled and analysed and the results of top story displacement, Base shear, and time period are obtained and compared at all the seismic zones to arrive at the structurally efficient lateral load resisting system for the plan considered.

Keywords - Core system, Outrigger structural system, Response Spectrum Method, Rigid Frame system and Structural systems.

I. INTRODUCTION

Population increase and land shortage are major threats in present cities that leads to the development of tall buildings. The narrow tall buildings is generally considered to act as a beam cantilevering from the earth and their behavior are majorly governed by lateral loads such as wind and earthquake load. In order to strengthen the structure, efficient structuralsystems must be used in the buildings. At present there are wide variety of structural systems that are being used such as Rigid frame system, core system, base isolation, outrigger system, bracing system etc., but the optimum usage among the available structural systems provides better resistance against lateral loads. Bare Frame case produces larger lateral displacements and drifts. Lateral displacements and drift is significantly lower after inserting shear wall and bracings in the bare frame[6].As the stiffness of outrigger is generally very high, a small vertical deflection will induce very large force in outrigger elements. A belt truss system is adopted to evenly distribute the outriggers vertical force to perimeter columns and reduce story displacement [2].The permissible lateral top story displacement is $H/_{500}$ [13], i.e.,ratio of height of the building from base to 500. [9] compared Fe415 and Fe500 and on comparing them in terms of percentage of steel requirements, Fe500 grade results in low consumption of steel apart from providing higher tensile strength.[10] stated that the performance of the outrigger was efficient and the optimum position for 1 number of outrigger has been found i.e. at mid height of building. The use of outrigger structural systems in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load. In the present study, analysis is carried out using E-TABS V18.0.0 evaluation version as per IS 1893-2016 with different types of structural systems that are Rigid frame, Core system ,Outrigger structural system placed at various positions and belt truss. Many studies have been carried out to find out the efficiency of these systems individually but a comparison of results of this kind all in one at all seismic zones to arrive at the efficient lateral load resisting system and also to decide the optimum positioning of outrigger system is the scope for this project.

1.1 Core system, outrigger structural system and Belt truss:

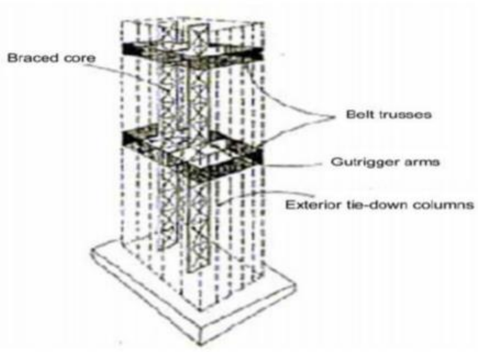


Figure 1: Structural schematic diagram of tall building with core, outrigger and belt truss

Outrigger concept in the building structure is to couple the perimeter and the internal structure like core wall as a whole to resist lateral load. By connecting these outrigger beams rigidly from central shear wall to exterior columns the resistance to applied lateral loads can be achieved. To brace medium high-rise structures, general method is bracing around the core and stair wells. Lateral bracing system is employed as an effective solution which consists of joined shear walls with outriggers that are able to restrain inter-story drift under earthquake loads.

II. MODELING DETAILS

2.1 General Considerations:

The frame selected for analysis is symmetrical in plan with plan size 42mx42m and floor to floor height is 3m.Centre to centre spacing of column is 6m.

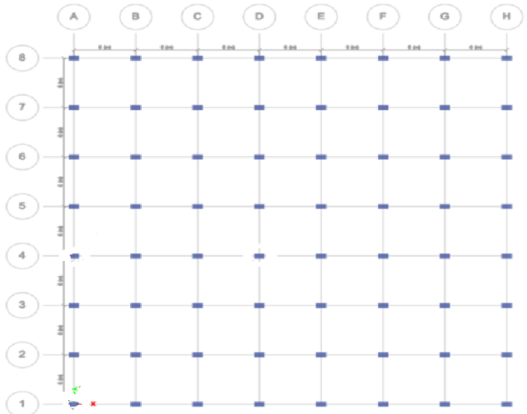
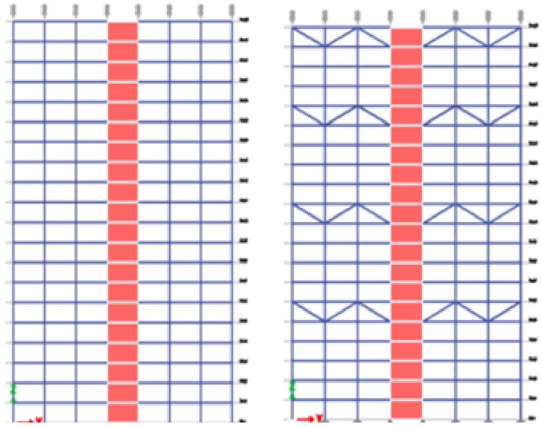


Figure 2: E-TABS plan considered for the study



(a) (b)

Figure 3: Elevational view of 20 story Core system(a) and outrigger system(b)

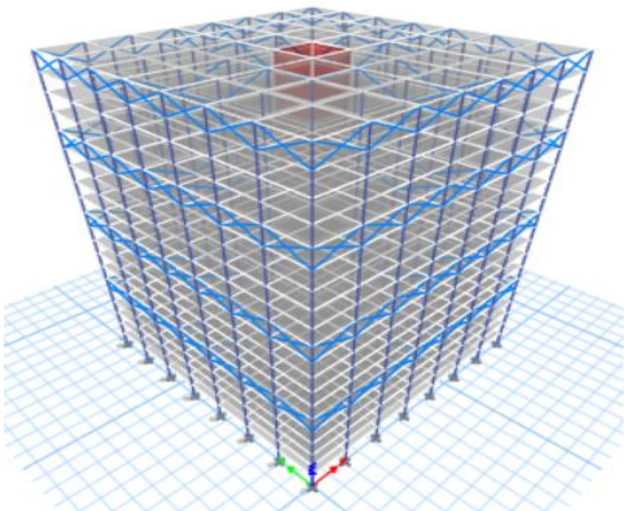


Figure 4: 3D view of outrigger system with belt truss

2.2 Material property:

During modeling, the sizes of each member were fixed by trial and error. The sizes were first randomly chosen as per the literature and was checked in E-TABS v18.0.0, hence if the sizes failed, then higher section was analysed and was fixed after a lot of iterations.

Table 1: Material properties

Story	Structural component	Material property	
		Concrete	Rebar
1 to 5	Beam, Column, Slab, Shear wall	M40	Fe500
6 to 10		M30	
11 to 20		M25	

2.3 Geometrical data:

Table 2: Property of structural components

Section	Story	Zone	Size
Beam	1 to 20	II and III	300x600
		IV and V	400x600
Column		II and III	500x1000
		IV	600x1000
		V	700x1000
Outrigger		II, III, IV and V	400x600
Slab thickness			150
Wall thickness			200
Shear wall thickness			250

2.4 Mass source consideration:

Table 3: Mass source consideration

Load type	Factors
Dead Load	1
Live Load	0.5(>3 kN/m^2)
	0.25(≤3 kN/m^2)
Super Dead Load	1

2.5 Load Definition:

Table 4: Load definition

Gravity load	
Dead load	Weight of structure
Live load on floor	2 kN/m^2
Live load at roof	1.5 kN/m^2
Floor finish	1.5 kN/m^2
Roof floor finish	3 kN/m^2
Seismic load	
Soil condition	Soft soil (Soil type III)
Importance factor	1.2
Response reduction factor	5(SMRF)

2.6 Properties of outrigger

Table 5: Properties of outrigger

Factors	Adopted at present work
Type of outrigger	Conventional outrigger with belt truss
Number of outrigger	1,2,3, and 4
Position of outrigger	0.25H, 0.5H, 0.75H and H
Shape of core wall	Square/Closed

III. RESULTS AND DISCUSSION

For 20 story building, the permissible top story displacement is 120mm [13]. Based upon this criteria, the lateral load resisting systems such as rigid frame, core system and outrigger structural system are analysed and checked. Time periods of mode M1, M2 and M3 defines translation along Y axis, translation along X axis and rotation of the structure.

3.1 Zone II and soil type III

Table 6: Summary of results for 20 Story building at seismic zone II.

Parameter	Zone II and soil type III					
	Top story displacement (mm)		Time Period (sec)			Base shear (kN)
Model	X	Y	M1	M2	M3	
Rigid Frame	174	207	4.78	4.3	3.95	6950
Core System	85	88.9	3.21	3.1	2.74	6880

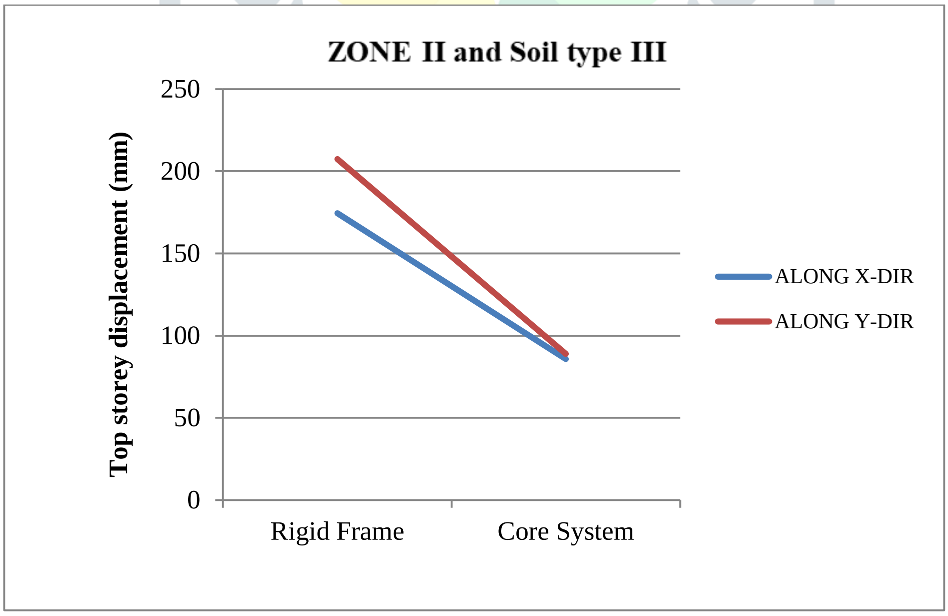


Figure 5: Top story displacement along X and Y direction for rigid frame and core system.

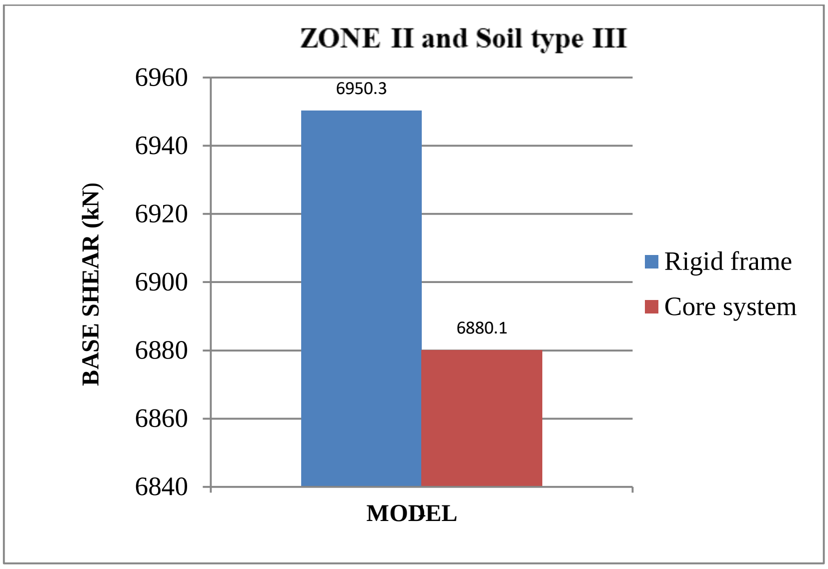


Figure 6: Base shear for rigid frame and core system.

From the tabulated results, it can be inferred that, top story displacement of rigid frame system exceeds permissible displacement limit and hence core system is analysed and adopted so that it performs effectively for zone II and soil type III. Top storey displacement reduces by 50.80% and 57.12% along X and Y direction respectively when rigid frame is replaced by core system. Time period is reduced when rigid frame is replaced by core system. Base shear got reduced by only 1.01% when core system is introduced.

3.2 Zone III and soil type III

Table 6: Summary of results for 20 Story building at seismic zone III

Parameters	Zone III and soil type III					
	Top story displacement (mm)		Time Period (sec)			Base shear (kN)
Model	X	Y	M1	M2	M3	
Rigid Frame	279.1	331.7	4.78	4.39	3.95	11120
Core System	157.3	164.9	3.21	3.11	2.74	11008
Outrigger at 0.25H	132.4	145.6	2.91	2.57	2.15	11676
Outrigger at 0.5H	130.6	142.8	2.89	2.54	2.13	11680
Outrigger at 0.75H	137.8	147.3	2.94	2.61	2.18	11693
Outrigger at H	149.6	154.1	2.97	2.73	2.23	11700
Outrigger at (0.5H and 0.25H)	115.4	120.5	2.51	2.32	2.08	11705
Outrigger at (0.5H and 0.75H)	119.6	122.9	2.53	2.33	2.1	11708
Outrigger at (0.5H and H)	124.2	129.8	2.57	2.36	2.11	11774
Outrigger at (0.5H, 0.25H and 0.75H)	77.7	83.6	2.37	2.13	2.05	12284
Outrigger at (0.5H, 0.25H and H)	84.6	90.7	2.39	2.16	2.06	12297

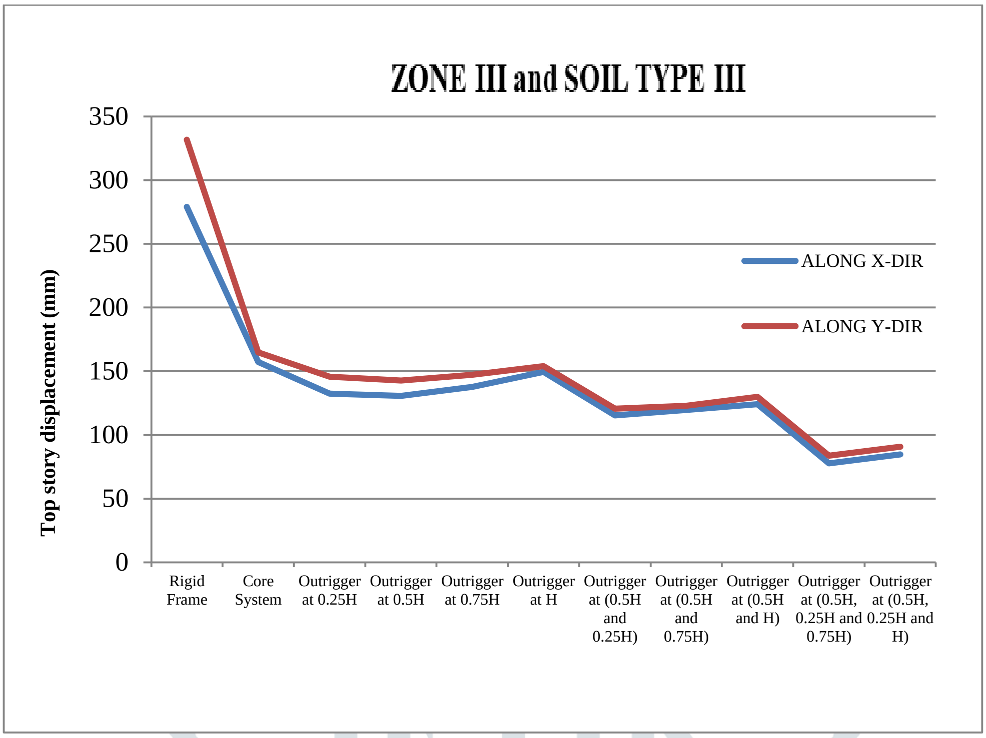


Figure 7: Top story displacement along X and Y direction for rigid frame, core system and outrigger structural system.

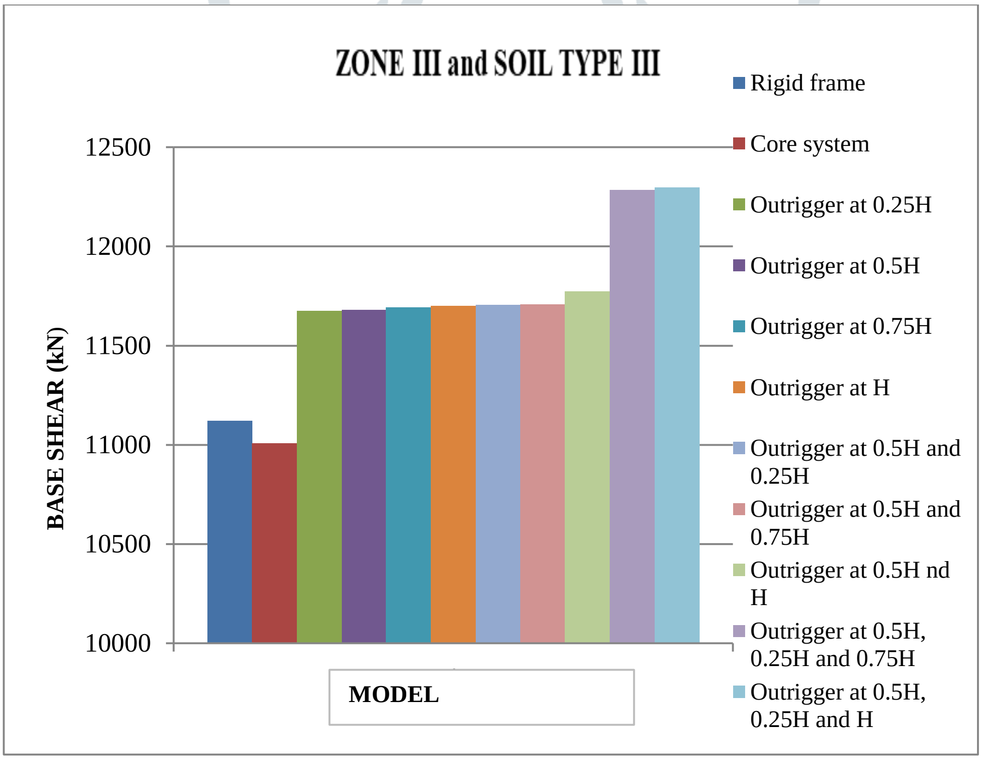


Figure 8: Base shear for rigid frame, core system and outrigger structural system.

From table 6, it is clear that 3 number outrigger placed at 0.5H+0.25H+0.75H is effective and here the roof displacement reduces by 50.6% and 49.31% along X and Y directions core system is replaced by outrigger system.

3.3 Zone IV and soil type III

Table -7: Summary of results for 20 Story building at seismic zone IV

Parameters	Zone IV and soil type III					
	Top story displacement (mm)		Time Period (sec)			Base shear (kN)
Model	X	Y	M1	M2	M3	
Rigid Frame	331.9	376.5	4.78	4.39	3.95	17693
Core System	187.0	194.3	3.21	3.11	2.74	17483
Outrigger at 0.5H	149.2	156.9	2.89	2.54	2.13	17520
Outrigger at (0.5H and 0.25H)	134.1	145.6	2.51	2.32	2.08	17558
Outrigger at (0.5H, 0.25H and 0.75H)	114.6	120.7	2.37	2.13	2.05	17626
Outrigger at (0.5H, 0.25H, 0.75H and H)	95.1	98.9	2.07	1.98	1.67	17632

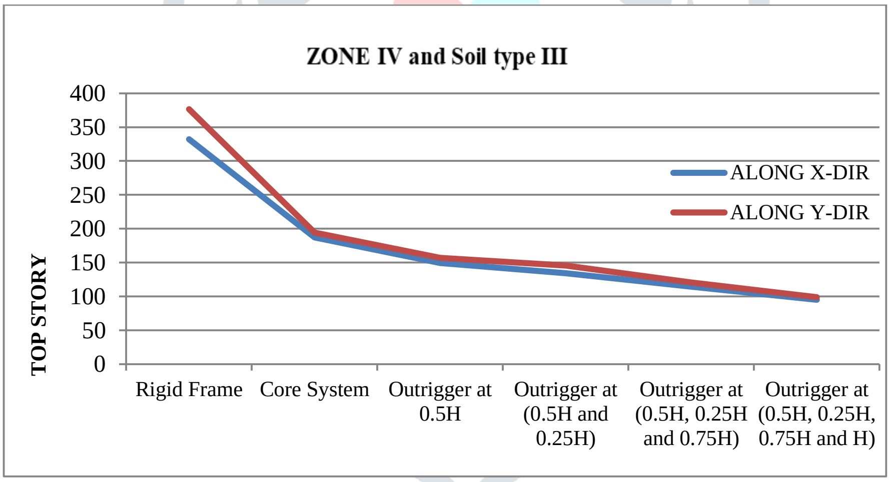


Fig. 9: Top story displacement along X and Y direction for rigid frame, core system and outrigger structural system.

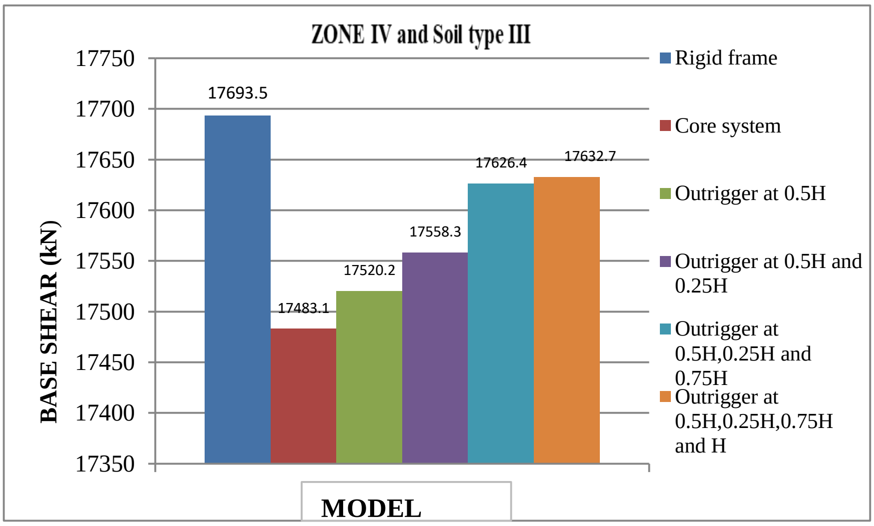


Fig. 10: Base shear for rigid frame, core system and outrigger structural system.

At zone IV and soil type III, combination of outrigger placed at 0.5H+0.25H+0.75H+H is tried and roof displacement is within the limit. From the tabulated results roof displacement reduces by 49.14% and 49.15% along X and Y directions when core system is replaced by the outrigger system.

3.4 Zone V and soil type III

Table -8: Summary of results for 20 Story building at seismic zone V

Parameters	Zone V and soil type III					
	Top story displacement (mm)		Time Period (sec)			Base shear (kN)
Model	**X**	**Y**	**M1**	**M2**	**M3**	
Rigid Frame	496	540	4.78	4.39	3.95	28906
Core System	281	290	3.21	3.11	2.74	26164
Outrigger at 0.5H	223	235	2.89	2.54	2.13	26281
Outrigger at (0.5H and 0.25H)	184	196	2.51	2.32	2.08	26336
Outrigger at (0.5H, 0.25H and 0.75H)	153	162	2.37	2.13	2.05	26392
Outrigger at (0.5H, 0.25H, 0.75H and H)	142	150	2.07	1.98	1.67	26835
Outrigger at (0.5H, 0.25H, 0.75H and H) and Belt truss	114	118	1.65	1.42	1.09	29570

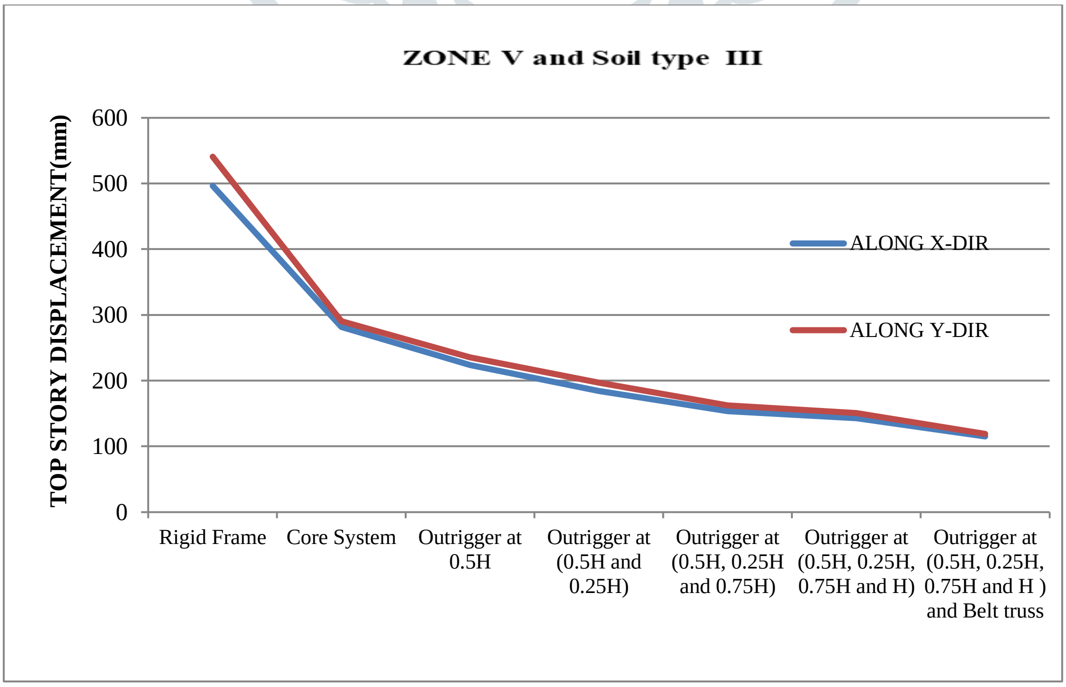


Fig. 11: Top story displacement.

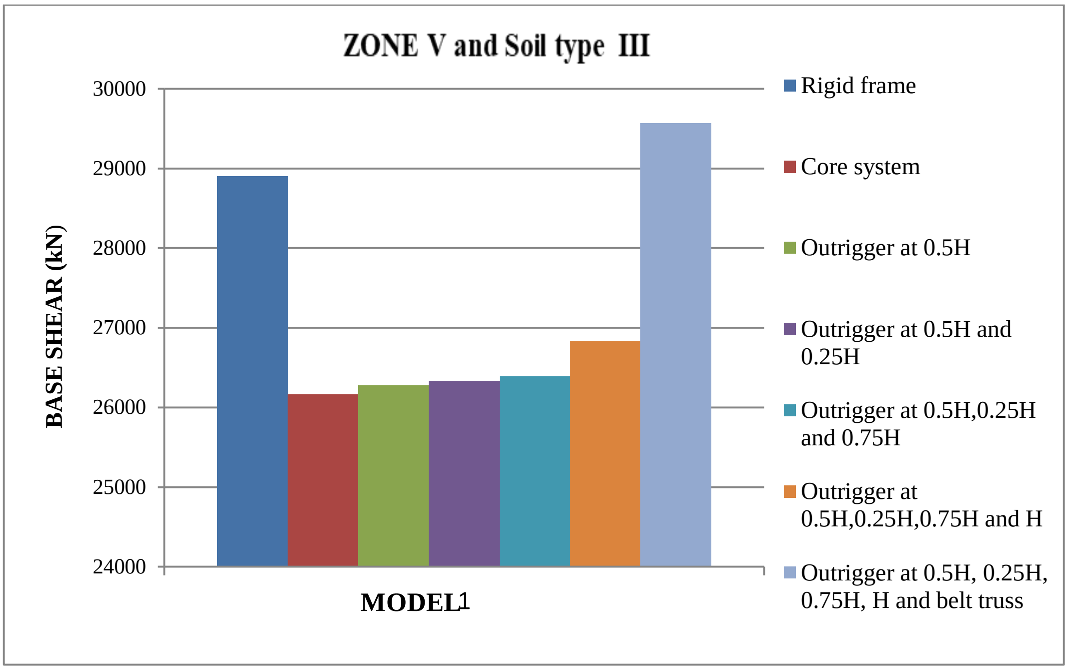


Figure 12: Base shear for rigid frame, core system and outrigger structural system.

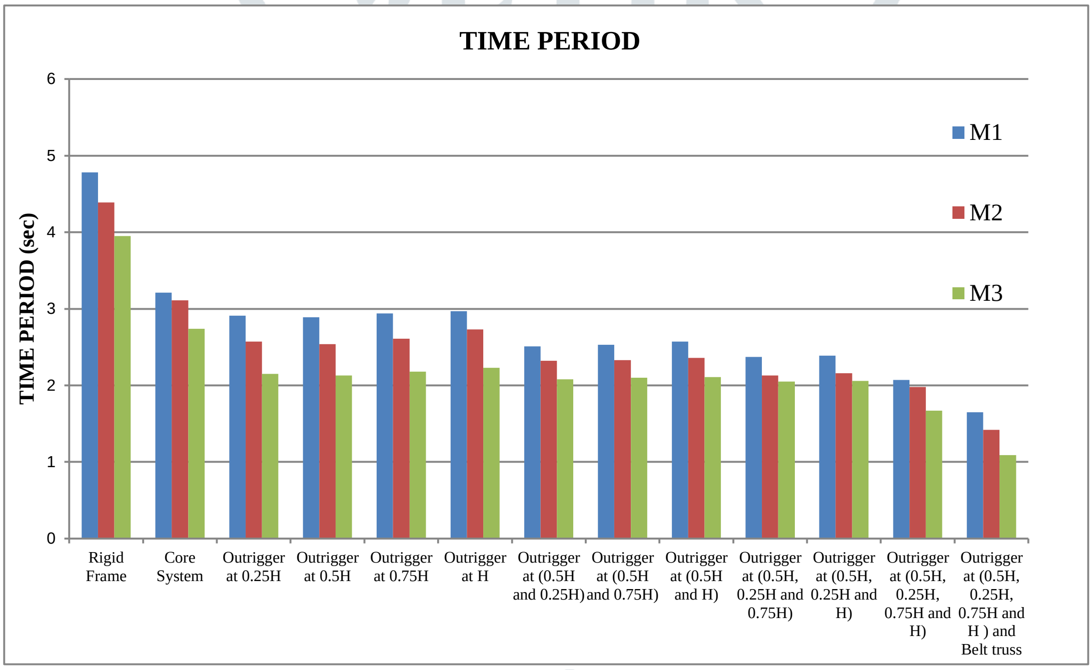


Figure 13: Time period for rigid frame, core system and outrigger structural system.

At zone V and soil type III combination of outrigger placed at 0.5H, 0.25H, 0.75H, H and Belt Truss is tried and the roof displacement is within the limit. A belt truss system is adopted to evenly distribute the outriggers vertical force to perimeter columns and reduce storey displacement. From the tabulated results, roof displacement reduces by 59.18% and 59.13% along X and Y directions when core system is replaced by outrigger system and belt truss. Time period is least and maximum base shear are observed in the above case. Fig 13 represents time period for the considered lateral load resisting systems at all seismic zones.

IV. CONCLUSION

Rigid frame system is not suitable in any of the seismic zones for the structure in soft soil when analysed as per IS 1893-2016.Core system is suitable only at seismic zone for 20 story structure with 250mm thick core wall and adopted dimensions of structural components. For minimum top storey displacement, the order of best position for 1 number outrigger is 0.5H, 0.25H and 0.75H respectively. The order of best position for 2 number outrigger is 0.5H+0.25H , 0.5H+0.75H and 0.5H+H respectively. The order of best position for 3 number outrigger is 0.5H+0.25H+0.75H and 0.5H+0.25H+H respectively. By placing outrigger at top story i.e., at position H , there is no much variational effect on parameters like top story displacement. By adopting belt truss along with outrigger system, story displacement can be reduced to a larger extent.

REFERENCES

[1] Reza Kamgar and Reza Rahgozar (2017) "Determination of Optimum Location for Flexible Outrigger Systems in Tall Buildings with Constant Cross Section Consisting of Framed Tube, Shear Core, Belt Truss and Outrigger System Using Energy Method". Springer journal. pp. 1598-2351.

[2] Goman wai-mig ho, Arup (2016) "The evolution of outrigger system in tall building": CTBUH research paper. Volume 5,no 1,21-30.

[3] Suraj Sangtiani , Satyanarayana J (2017) "Performance of tall buildings under lateral loads with different types of structural systems". Scopus Indexed. Volume 8, Issue 3, pp. 1014–1022.

[4] Hemant B. Dahake1 Mohd. Imran, Mohd. Azghar (2019) "Optimum Position of Outrigger Systems in Tall Building by Using Reinforced Concrete Shear Walls and Braces". International Journal of Innovative Research in Science, Engineering and Technology. Vol. 8, Issue 5, pp. 5810-5817.

[5] Narayan Malviya, Sumit Pahwa (2017) "Seismic analysis of high rise building with seismic code IS 1893-2002 and IS 1893-2016". Global Research and Development Journal for Engineering. Volume: 04 Issue: 11. pp. 2115-2119.

[6] Abhijeet Baikerikar, Kanchan Kanagali (2014) "Study of lateral load resisting systems of variable heights in all soil types of high seismic zones". International Journal of Research in Engineering and Technology. Volume: 03 Issue: 10, pp. 109-119.

[7] Anoj Surwase 1, Dr. Sanjay K. Kulkarni 2 & Prof. Manoj Deosarkar 3 (2018) "Seismic analysis and comparison of IS 1893 (Part-1) 2002 and 2016 of (G+4) residential building." Global Journal of Engineering Science and Researches. Volume:05 Issue:07. pp. 330-335.

[8] Mayur R. Rethaliya1, Bhavik R. Patel , Dr. R. P. Rethaliya (2018) "A Comparative Study of Various Clauses of New IS 1893 (Part 1):2016 and Old IS 1893 (Part 1):2002." International Journal for Research in Applied Science & Engineering Technology . Volume 6 Issue I. pp. 1874-1881.

[9] Saloni apporva, Er .Manjit Kaur, Er. Abhishek Sachdeva (2018) "Comparison of Fe415 and Fe500 steel in two storey RC building using STAAD Pro" Volume 7, issue 5.

[10] Shruti B. Sukhdeve (2016) "Optimum Position of Outrigger in G+40 RC Building". International Journal of Science Technology & Engineering. Volume 2, Issue 10.pp. 1051-1055.

[11] Ravikant Singh and Vinay Kumar Singh (2018) "Analysis of Seismic Loads acting on multistory Building as per IS: 1893-2002 and IS: 1893-2016 :- A comparative Study. Journal of Civil Engineering and Environmental Technology. Volume 4, Issue 5; pp. 405-408.

[12] Manoj Kumar M, B. S. Jayashankar Babu (2018) "A performance study of high rise building under lateral load with rigid frame, core and outrigger structural systems". International Journal of Research in Engineering and Technology. Volume: 07 Issue: 05. pp. 108-113.

[13] IS: 456:2000 (Fourth Revision) "Indian Standard code of practice for Plain and Reinforced Concrete ", Bureau Indian Standards, New Delhi.

[14] IS: 1893(part-1)-2002 "Criteria for earthquake resistant design of structures", Bureau of Indian standard, New Delhi.

[15] IS: 1893(part-1)-2016 "Revised code of Practice for criteria for Earthquake Resistant Design of structures", part – 1: General provisions and buildings, Bureau of Indian standards, New Delhi.

[16] [16] IS: 875-1987 – Code of practice for Design Loads (other than Earthquake) for Building and Structures, Part 1: Dead loads, Part – 2: Imposed loads, Part – 5: Special loads and load combinations, Bureau of Indian Standards, New Delhi.

[17] B. Stafford smith and Alex couil "Tall building structures analysis and design", Wiley India Pvt. Ltd.

[18] Pankaj Agarwal and Manish Shrikhande "Earthquake resistant design of structures" PHI learning private limited.