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Analysis of Multi-Story Building with Different Outrigger System and Locations

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Abstract

Designing and constructing high-rise buildings necessitates structural systems that can effectively resist lateral forces generated by wind and seismic activity. Outrigger systems are commonly used in tall structures to increase lateral stiffness, minimize building drift, and optimize the use structural materials. This research examines the performance of multi-story buildings incorporating various outrigger configurations, including traditional outriggers, belt trusses, deep beams, and shear wall systems. A response spectrum analysis is carried out to assess how different setups influence structural behavior. Key parameters, such as the number, placement, and type of outriggers, are analyzed concerning their impact on lateral displacement, base moment at the core, and the redistribution of loads. Multi-objective optimization methods, such as Pareto front techniques, are applied to determine design strategies that balance structural performance and architectural limitations. The findings show that strategically positioned outriggers significantly enhance stiffness and reduce drift, while also acknowledging the compromises required for integrating elements, like mechanical floors or refuge areas. Overall, the study offers practical recommendations for optimizing outrigger systems to improve high-rise building performance under lateral loading conditions.

Keywords: Lateral load resisting system, outrigger system, multi-story building, braced frame, deep beam, shear wall

INTRODUCTION

A primary structure receives increased stability and functionality through the structural or mechanical configuration of an outrigger system. These structures have a basic concept of projecting exterior supports from the primary structure with adjustable lengths. The function of outrigger systems depends on their usage, but they primarily serve as stability, balance enhancers, and space extenders. High-rise buildings depend on outrigger systems to make their structures more resistant against natural disasters and wind-driven forces. The system consists of multiple structural elements attached to building cores that reach exterior walls to extend the building's lateral resistance. Extreme conditions are made safer through this system, which stops buildings from excessive movement.

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AIM AND OBJECTIVES

The research on outrigger systems intends to optimize the design and performance while studying the behavior of these systems in tall buildings for increased stability, reduced lateral movement, and reduced effects of wind and seismic forces with different types.

- To understand the structural behavior of outrigger systems.
- To compare different outrigger configurations.
- To investigate the impact of building height and geometry on outrigger design.
- To assess the influence of dynamic and seismic loads on outrigger performance.
- To study the future potential and innovations in outrigger systems.

LITERATURE REVIEW

A structural concept called amplified viscously-damped outrigger emerged through the combination of traditional viscously-damped outriggers with steel amplification devices to maximize energy dissipation. Two innovative amplified viscously damped outrigger configurations were developed and subjected to dynamic cyclic loading tests, with results compared against the performance of standard outrigger systems [1]. The best placement locations and damping performance of single-outrigger systems within tall buildings that experience wind force and seismic motions. The study considered three system types: The authors studied three different outrigger types, including a conventional outrigger alongside a viscous-damper outrigger, as well as, a buckling-restrained brace outrigger. Simplified analytical models were formulated to estimate top displacement, inter-story drift, and core base moment under these dynamic loads [2]. Computer modeling methods for skyscrapers outfitted with outrigger systems which substantially streamlined the modeling process. A MATLAB-based implementation of the super-element and dominant degree-of-freedom principles validated results against a detailed ETABS model. Static, modal, and dynamic analyses confirmed the accuracy of the method, which was also tested through a parametric study on various building configurations [3].

Research performed static and dynamic structural analyses on buildings with multiple stories that experienced lateral forces. The research study examined three different structural frameworks through static load-testing: moment-resisting frames and building frames, together with outrigger braced frames. Statistical indicators showed that outriggers within the braced frame system allowed better control of lateral movement in the structure. Dynamic analysis further supported the effectiveness of the bracing system in minimizing structural vibrations [4]. A new lateral force-resisting system called distributed belt walls for reinforced concrete high-rises. Belt trusses from the standard repertoire do not appear in these distributed walls that span from outside columns at various heights of the structure. The study examined their load transfer behavior and effectiveness in acting as virtual outriggers when resisting lateral forces [5]. A multi-objective genetic algorithm to optimize the design of structures supported by outrigger systems. The optimization targeted two competing objectives: The optimization approach worked to minimize top-level drift and decrease core base moment. Researchers implemented MATLAB software to create an automated system that identified optimal outrigger designs based on wind forces through a multi-objective design method. The results confirmed the practicality and efficiency of the proposed method [6]. A suitable design approach for steel plate shear walls, which include outrigger systems (SPSW-O) was presented by the research. The methodology derives from plastic analysis and capacity design principles. The installation of SPSW-O systems creates enhanced overturning stiffness alongside architectural design freedom. However, the inclusion of rigid outrigger beams introduces additional lateral stiffness, which needs to be accounted for to ensure a balanced and efficient design [7].

The study analyzed a new damping technique using specially designed outriggers to dissipate energy. Vertical viscous dampers act as the dampers between outrigger beams and perimeter columns in setups where these components remain structurally apart. The research examined how a semi-active damping arrangement with magneto-rheological damper technology functioned for seismic management control. These devices offer adaptable damping properties, improving the structure's response under earthquake loading [8].

The research team studied how to optimize outrigger designs through a comparison between mixed-integer and continuous nonlinear programming methods. A piecewise quadratic interpolation method transformed finite element data into semicontinuous differential constraints for use in modeling. The study evaluated three different high-rise models with outriggers and optimized them with respect to lateral displacement limits [9].

Nonlinear static pushover analysis enabled researchers to study the seismic behavior of steel high-rise buildings when outfitted with outriggers positioned in different locations. Researchers built four models consisting of buildings with 20, 25, 30, and 35 floors to evaluate how shifting outriggers upwards or downwards affected the structures' responses. The seismic performance of buildings depends heavily on outrigger placement as well as the distribution of lateral loads and overall building height [10]. A simplified skyscraper model (SSM) featuring dominant degrees of freedom and super elements for conducting initial structural analyses on high-rise buildings fitted with outrigger and belt truss. The development team created a spreadsheet-based SSM which underwent testing for a 100-story high-rise building under loads from the weight of construction and wind pressure plus earthquake forces. The stress evaluation of the SSM matched closely with the detailed finite element model results with 6% divergences and 1% variations in calculated displacements [11].

METHODOLOGY

The structural design of multi-story buildings face significant challenges due to the impact of lateral loads, such as wind and seismic forces. These forces can lead to excessive lateral drift, increased core base moments, and compromised stability, which may affect the functionality, safety, and comfort of high-rise structures. Outrigger systems are a widely used solution to enhance lateral stiffness and control structural deflections in tall buildings.

However, the design and analysis of outrigger systems involve complex decisions, such as selecting the optimal type (e.g., belt trusses or virtual outriggers), determining the number of outriggers, and identifying their optimal placement along the height of the structure. Additionally, these decisions must account for architectural constraints, functional requirements, like plant rooms and refuge levels, and cost-effectiveness, creating a multidimensional design challenge.

Building Specification

A 26-story structure was analyzed to evaluate the performance of the outrigger-braced frame system in combination with various lateral load-resisting mechanisms. A total of 15 distinct models were developed using ETABS 22 for this purpose. The building layout consists of seven bays in both directions, with a spacing of 5 meters between columns. A central shear core wall with a thickness of 450 mm was incorporated into all models. All structural systems were subjected to identical loading conditions for consistency during preliminary analysis.

The analysis focused on displacement and drift as the primary response parameters to assess the lateral load performance of each configuration. Dynamic analysis was conducted by introducing outrigger elements in multiple forms: 400 mm thick shear walls, deep beams sized 400 mm × 3200 mm, and bracing systems with dimensions of 400 mm × 600 mm. Various configurations were explored by altering the number and vertical positions of these outriggers to determine their effectiveness in enhancing lateral stability.

Additionally, a bracing with dimensions of 300 mm × 600 mm was used to connect exterior columns at the outrigger levels. Through a comparative study of different arrangements, the most effective location and number of outriggers were identified for optimal performance under dynamic loading conditions (Table 1 and Figures 1–5).

RESULTS AND DISCUSSION

The result and discussion section presents the analysis of the outrigger structure for outrigger at height H, H/2, H & H/2, H & 2H/3 compared with the conventional building. The data includes story displacement, story drift, and base shear. The presented graphs illustrate the differences in structural responses between conventional and outrigger buildings across different story levels.

Table 1. Data and design criteria for structures.

1	Size of Buildings	35 x 35 m.
2	Building Height	83.2 m.
3	Floor to Floor Height	3.2 m.
4	Bottom story Height	3.2 m.
5	No. of Stories	26
6	Thickness of Shear Wall	450 mm, 400 mm.
7	Thickness of Slab	200 mm.
8	Beam Size	500 x 1000 mm.
9	Column size	1000 x 1000 mm.
10	Material Property	M30.
11	Grade of steel	HYSD 415, HYSD 500
12	Density of concrete	25 KN/m.
13	Density of brick	18 KN/m.
14	Support Condition	Fixed Support

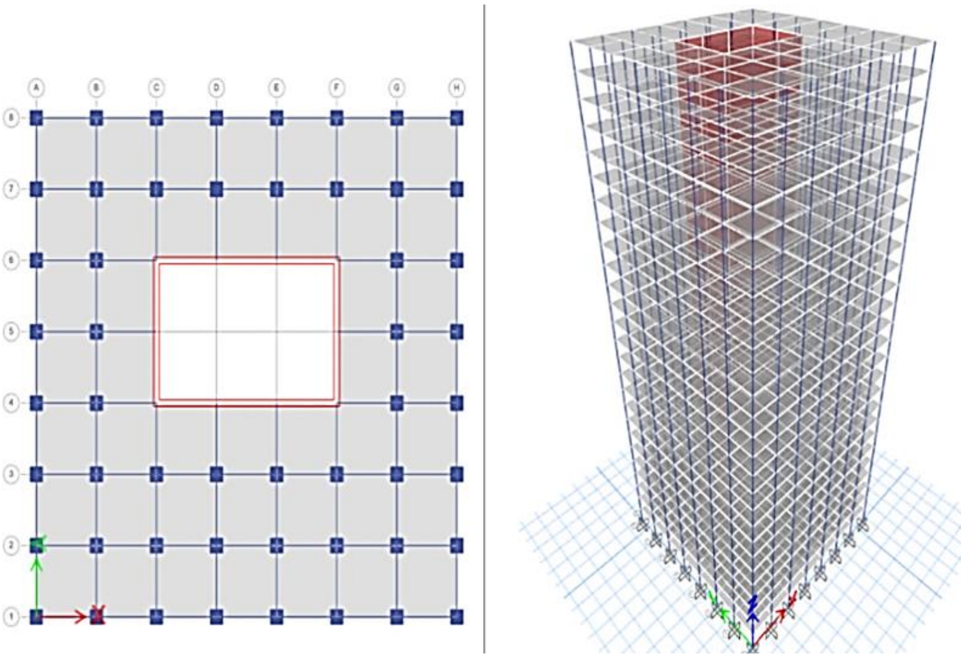

Figure 1. Building plan view and 3D view.

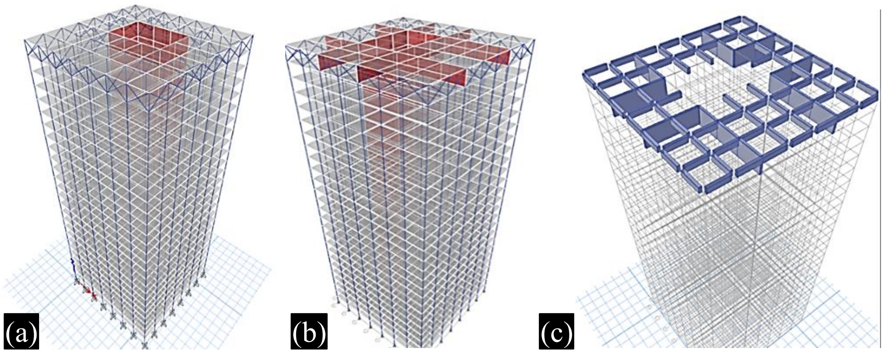

Figure 2. 3D view of outrigger at top: (a) bracing, (b) shear wall, and (c) deep beam.

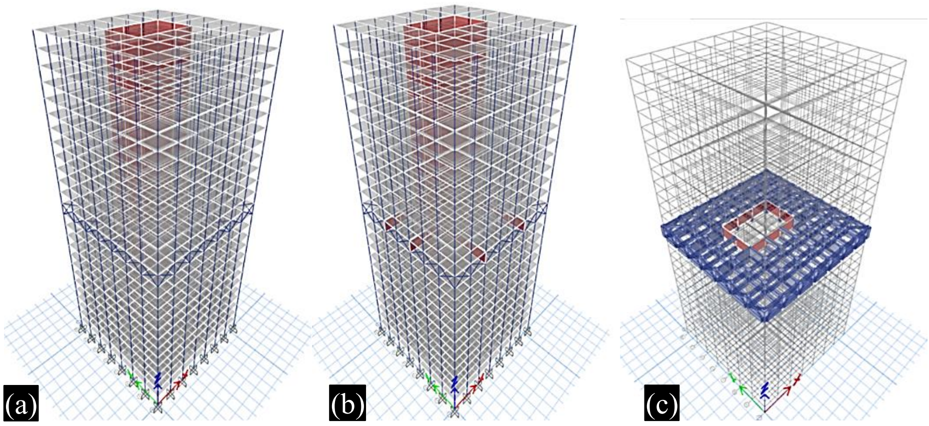

Figure 3. 3D view of outrigger at middle: (a) bracing, (b) shear wall, and (c) deep beam.

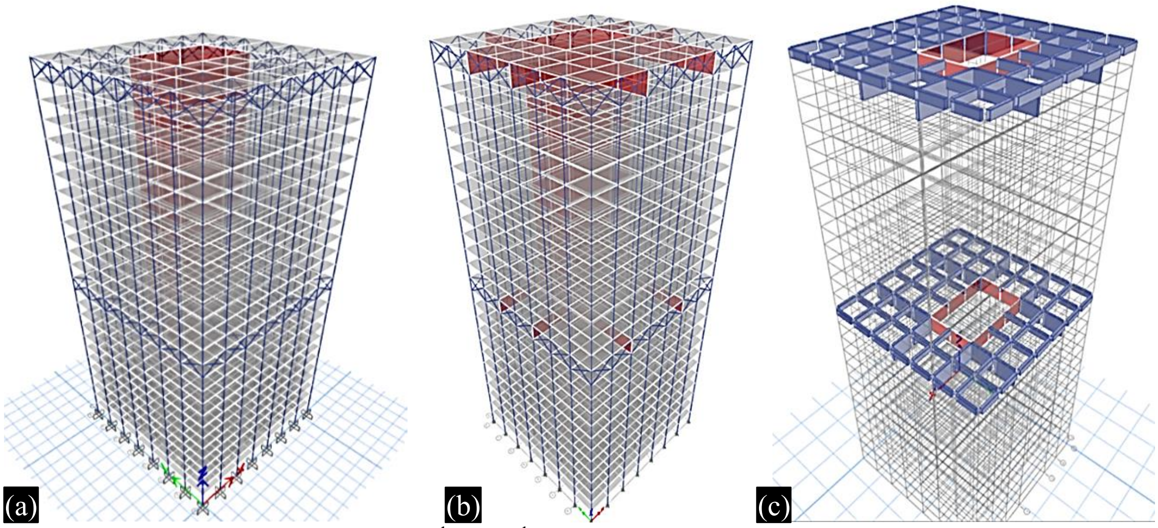

Figure 4. 3D view of outrigger at 13th & 26th: (a) bracing, (b) shear wall, and (c) deep beam.

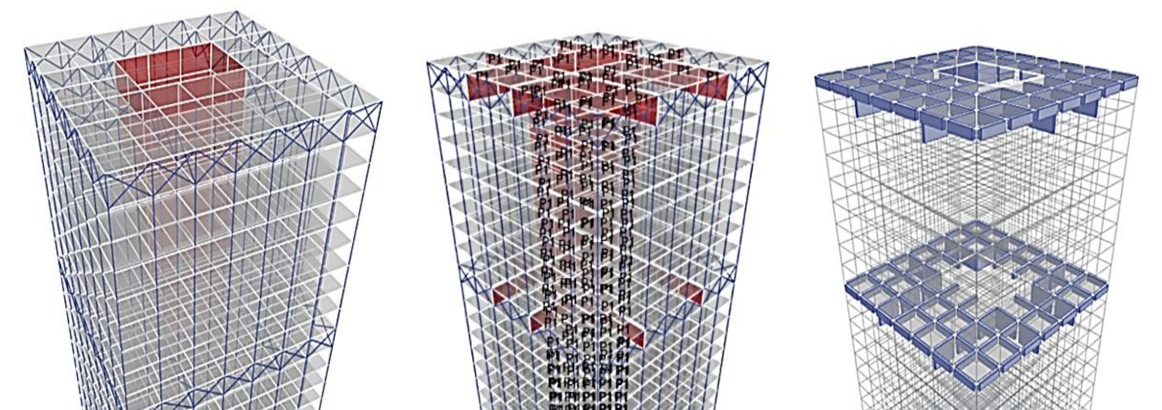

Figure 5. 3D view of outrigger at 17th & 26th: (a) bracing, (b) shear wall, and (c) deep beam.

Top (H) Story Displacement Comparison Between Conventional and Outrigger Structure

In Table 2, the comparison of story displacement for the outrigger at the top of the building is shown, in which it is observed that the shear wall as an outrigger shows minimum displacement as compared to others. Figure 6 shows the graphical representation of the maximum story displacement for outrigger at top story.

Table 2. Comparison of story displacement for outrigger at top story.

Story No.	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story26	83.2	31.793	30.374	27.433	27.732
Story25	80	31.015	29.837	26.864	27.032
Story24	76.8	30.16	29.022	26.103	26.207
Story23	73.6	29.24	28.125	25.259	25.323
Story22	70.4	28.256	27.16	24.361	24.396
Story21	67.2	27.209	26.136	23.411	23.424
Story20	64	26.103	25.056	22.41	22.407
Story19	60.8	24.943	23.922	21.363	21.347
Story18	57.6	23.732	22.739	20.272	20.248
Story17	54.4	22.476	21.511	19.143	19.113
Story16	51.2	21.177	20.243	17.979	17.946
Story15	48	19.842	18.941	16.786	16.751
Story14	44.8	18.473	17.609	15.568	15.532
Story13	41.6	17.076	16.253	14.33	14.294
Story12	38.4	15.655	14.879	13.076	13.041
Story11	35.2	14.216	13.492	11.812	11.78
Story10	32	12.762	12.098	10.544	10.514
Story9	28.8	11.302	10.706	9.279	9.252
Story8	25.6	9.842	9.321	8.024	8
Story7	22.4	8.391	7.953	6.788	6.768
Story6	19.2	6.959	6.611	5.583	5.566
Story5	16	5.561	5.305	4.42	4.407
Story4	12.8	4.21	4.045	3.315	3.305
Story3	9.6	2.928	2.837	2.282	2.275
Story2	6.4	1.74	1.686	1.334	1.33
Story1	3.2	0.689	0.639	0.543	0.541
Base	0	0	0	0	0

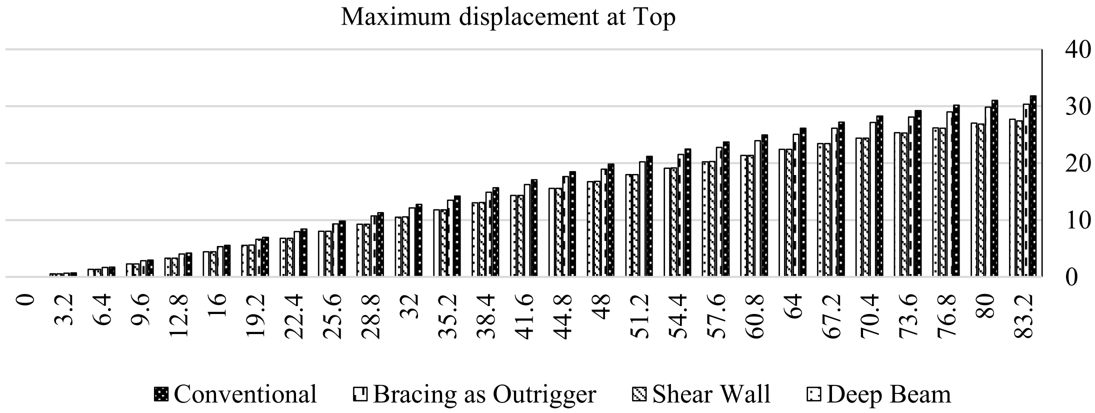

Figure 6. Maximum displacement at top.

Story Drift Comparison Between Conventional and Outrigger Structure

Table 3 shows the comparison of story drift for outrigger at top story. Minimum drift is at the 26th story in the structure of bracing as outrigger. As the drift is minimum it opposes to lateral forces. Below Figure 7 shows graphical representation of story drift at top story.

Table 3. Comparison of story drift for outrigger at top story.

Story No.	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story 26	83.2	0.000254	0.000239	0.00022	0.000256
Story25	80	0.000283	0.000264	0.000255	0.000272
Story24	76.8	0.000308	0.000287	0.000282	0.000295
Story23	73.6	0.000333	0.000306	0.0003	0.000311
Story22	70.4	0.000356	0.000323	0.000319	0.000327
Story21	67.2	0.000378	0.000339	0.000337	0.000343
Story20	64	0.000396	0.000354	0.000352	0.000357
Story19	60.8	0.000413	0.000367	0.000366	0.000369
Story18	57.6	0.000427	0.000378	0.000377	0.00038
Story17	54.4	0.000438	0.000388	0.000387	0.000389
Story16	51.2	0.000448	0.000395	0.000395	0.000396
Story15	48	0.000455	0.000401	0.000401	0.000401
Story14	44.8	0.000461	0.000405	0.000405	0.000405
Story13	41.6	0.000466	0.000407	0.000408	0.000407
Story12	38.4	0.000468	0.000408	0.000409	0.000408
Story11	35.2	0.000469	0.000407	0.000408	0.000407
Story10	32	0.000468	0.000404	0.000405	0.000404
Story9	28.8	0.000466	0.000399	0.0004	0.000399
Story8	25.6	0.00046	0.000392	0.000392	0.000391
Story7	22.4	0.000452	0.000381	0.000382	0.000381
Story6	19.2	0.00044	0.000367	0.000368	0.000367
Story5	16	0.000424	0.000349	0.000349	0.000348
Story4	12.8	0.000402	0.000325	0.000325	0.000324
Story3	9.6	0.000372	0.000296	0.000297	0.000296
Story2	6.4	0.000329	0.000262	0.000262	0.000262
Story1	3.2	0.000215	0.000169	0.00017	0.000169
Base	0	0	0	0	0

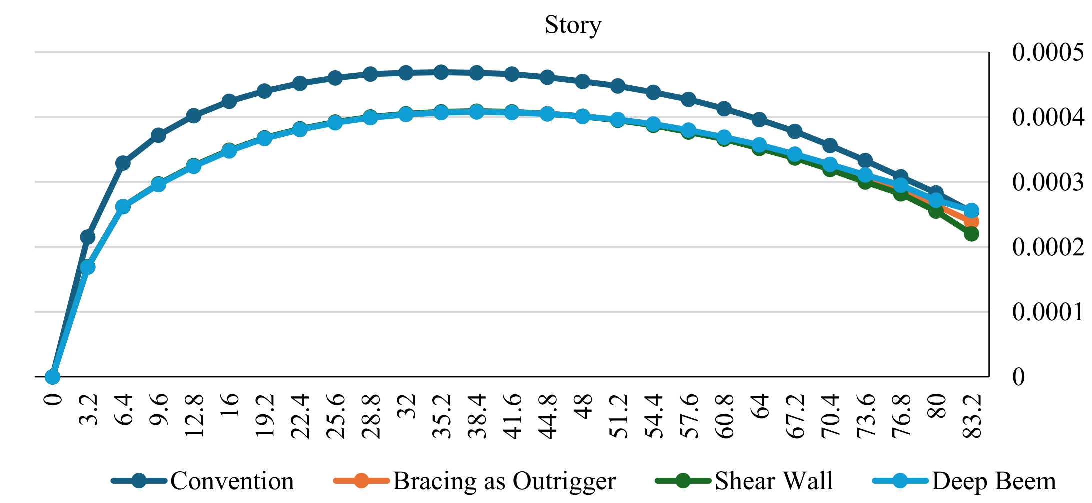

Figure 7. Story drift at top.

MIDDLE (H/2)

Story Displacement Comparison Between Conventional and Outrigger Structure

In Table 4, the comparison of story displacement for the outrigger at middle of the building shown, in which it is observed that shear wall as outrigger shows minimum displacement as compared to others. Figure 8 shows the graphical representation of maximum story displacement for outrigger at middle story.

Table 4. Comparison of story displacement for outrigger at middle story.

Story No.	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story26	83.2	31.793	29.592	27.086	27.6
Story25	80	31.015	28.899	26.283	26.805
Story24	76.8	30.16	28.089	25.451	25.982
Story23	73.6	29.24	27.195	24.555	25.096
Story22	70.4	28.256	26.235	23.609	24.161
Story21	67.2	27.209	25.219	22.619	23.18
Story20	64	26.103	24.15	21.587	22.156
Story19	60.8	24.943	23.033	20.519	21.092
Story18	57.6	23.732	21.872	19.419	19.992
Story17	54.4	22.476	20.673	18.293	18.859
Story16	51.2	21.177	19.435	17.149	17.699
Story15	48	19.842	18.156	15.991	16.513
Story14	44.8	18.473	16.833	14.845	15.329
Story13	41.6	17.076	15.6	13.875	14.206
Story12	38.4	15.655	14.816	13.286	13.285
Story11	35.2	14.216	13.493	12.074	11.99
Story10	32	12.762	12.095	10.802	10.672
Story9	28.8	11.302	10.711	9.541	9.389
Story8	25.6	9.842	9.342	8.281	8.126
Story7	22.4	8.391	7.987	7.029	6.882
Story6	19.2	6.959	6.654	5.797	5.664
Story5	16	5.561	5.351	4.601	4.488
Story4	12.8	4.21	4.088	3.457	3.367
Story3	9.6	2.928	2.872	2.384	2.319
Story2	6.4	1.74	1.71	1.395	1.356
Story1	3.2	0.689	0.649	0.57	0.553
Base	0	0	0	0	0

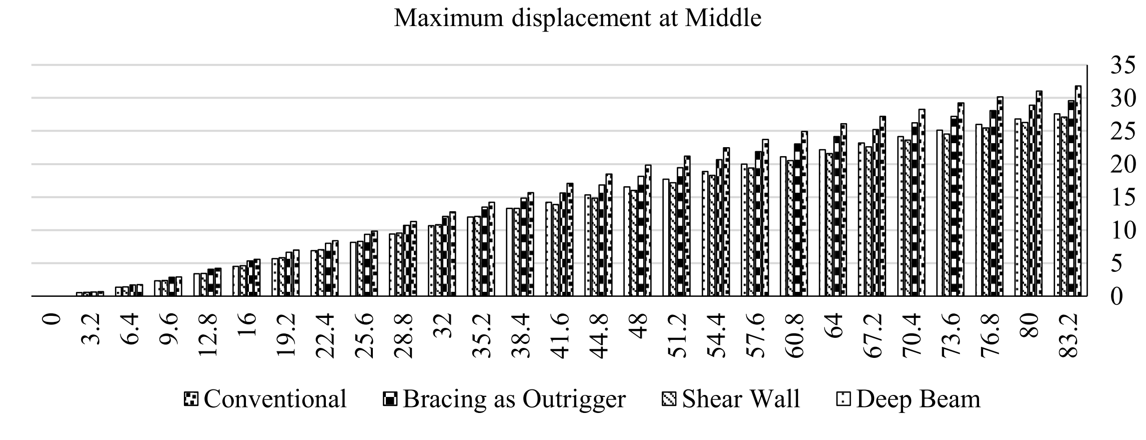

Figure 8. Maximum displacement at middle story.

Story Drift Comparison Between Conventional and Outrigger Structure

Table 5 shows the comparison of story drift for outrigger at middle in which at 13th story of shear wall structure shows minimum displacement as 0.000293. Figure 9 shows graphical representation of story drift at middle story.

Table 5. Comparison of story drift for outrigger at middle story.

Story no	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story 26	83.2	0.000254	0.00027	0.000272	0.000269
Story25	80	0.000283	0.000277	0.000279	0.000276
Story24	76.8	0.000308	0.000296	0.000297	0.000295
Story23	73.6	0.000333	0.000314	0.000315	0.000313
Story22	70.4	0.000356	0.000331	0.000332	0.000329
Story21	67.2	0.000378	0.000346	0.000346	0.000345
Story20	64	0.000396	0.000359	0.000359	0.000358
Story19	60.8	0.000413	0.00037	0.000369	0.000369
Story18	57.6	0.000427	0.000379	0.000377	0.000379
Story17	54.4	0.000438	0.000386	0.000382	0.000387
Story16	51.2	0.000448	0.000395	0.000387	0.000397
Story15	48	0.000455	0.000405	0.000399	0.00041
Story14	44.8	0.000461	0.000403	0.000386	0.000408
Story13	41.6	0.000466	0.00034	0.000293	0.000366
Story12	38.4	0.000468	0.000408	0.0004	0.000422
Story11	35.2	0.000469	0.000414	0.000411	0.000423
Story10	32	0.000468	0.000407	0.000402	0.00041
Story9	28.8	0.000466	0.000401	0.0004	0.000402
Story8	25.6	0.00046	0.000396	0.000398	0.000395
Story7	22.4	0.000452	0.000387	0.00039	0.000386
Story6	19.2	0.00044	0.000374	0.000379	0.000372
Story5	16	0.000424	0.000356	0.000361	0.000354
Story4	12.8	0.000402	0.000332	0.000338	0.00033
Story3	9.6	0.000372	0.000304	0.00031	0.000302
Story2	6.4	0.000329	0.000269	0.000274	0.000267
Story1	3.2	0.000215	0.000174	0.000178	0.000173
Base	0	0	0	0	0

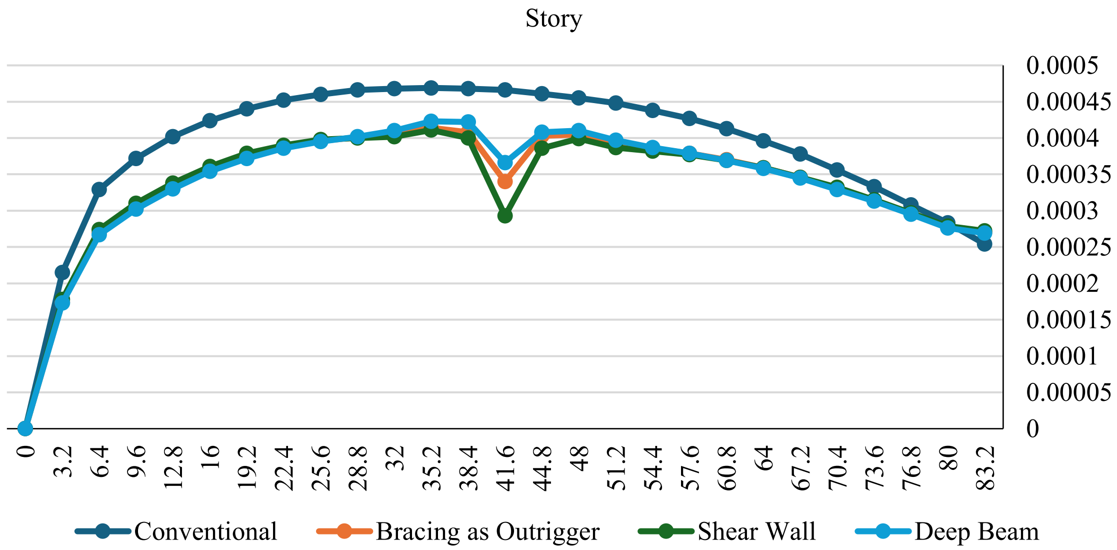

Figure 9. Story drift at middle story.

13th &26th (H & H/2)

Story Displacement Comparison Between Conventional and Outrigger Structure

In Table 6, the comparison of story displacement for the outrigger at 13th and 26th floor of the building shown, in which it is observed that shear as outrigger shows minimum displacement as compared to others. Figure 10 shows the graphical representation of maximum story displacement for outriggers at 13th and 26th story.

Table 6. Comparison of story displacement for outrigger at 13th and 26th story.

Story No.	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story26	83.2	31.793	27.236	26.762	27.543
Story25	80	31.015	26.569	26.167	26.835
Story24	76.8	30.16	25.77	25.387	26.003
Story23	73.6	29.24	24.895	24.517	25.11
Story22	70.4	28.256	23.969	23.597	24.174
Story21	67.2	27.209	22.996	22.626	23.195
Story20	64	26.103	21.977	21.609	22.171
Story19	60.8	24.943	20.915	20.55	21.106
Story18	57.6	23.732	19.816	19.456	20.004
Story17	54.4	22.476	18.685	18.333	18.87
Story16	51.2	21.177	17.528	17.189	17.708
Story15	48	19.842	16.347	16.03	16.521
Story14	44.8	18.473	15.163	14.882	15.335
Story13	41.6	17.076	14.073	13.908	14.21
Story12	38.4	15.655	13.225	13.314	13.287
Story11	35.2	14.216	12.004	12.1	11.991
Story10	32	12.762	10.712	10.826	10.672
Story9	28.8	11.302	9.437	9.561	9.389
Story8	25.6	9.842	8.175	8.299	8.126
Story7	22.4	8.391	6.927	7.044	6.881
Story6	19.2	6.959	5.705	5.809	5.663
Story5	16	5.561	4.522	4.609	4.487
Story4	12.8	4.21	3.395	3.463	3.366
Story3	9.6	2.928	2.339	2.388	2.318
Story2	6.4	1.74	1.368	1.398	1.355
Story1	3.2	0.689	0.558	0.571	0.552
Base	0	0	0	0	0

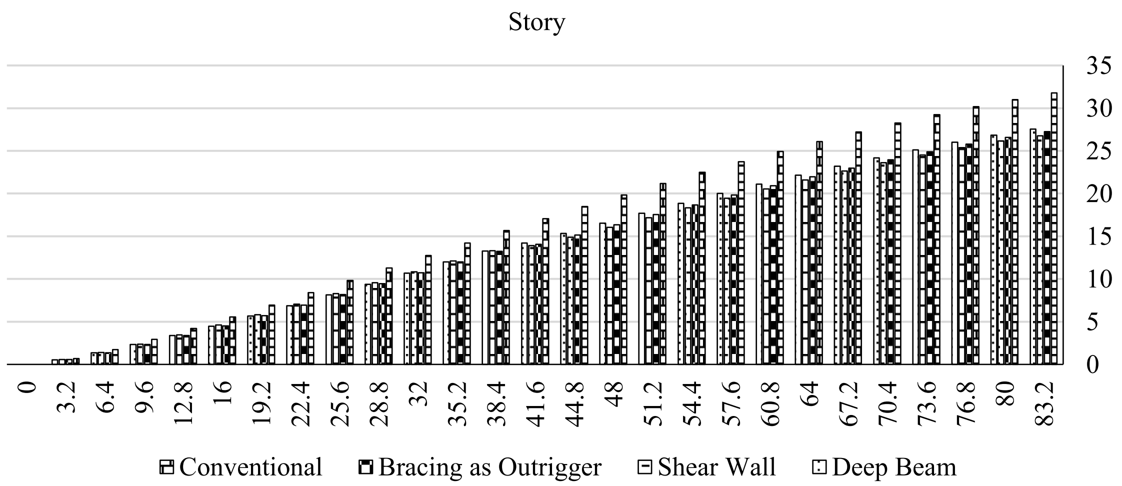

Figure 10. Maximum displacement of 13th & 26th story.

Story Drift Comparison Between Conventional and Outrigger Structures

Table 7 shows the comparison of story drift for outrigger at 13th & 26th story. Minimum drifts were observed at 13th & 26th floor in the structure of shear wall outrigger. Figure 11 shows graphical representation of story drift of 13th & 26th story.

Table 7. Comparison of story drift for outrigger at 13th and 26th story.

Story No.	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story 26	83.2	0.000254	0.000242	0.000227	0.000259
Story25	80	0.000283	0.000268	0.000261	0.000275
Story24	76.8	0.000308	0.000291	0.000289	0.000297
Story23	73.6	0.000333	0.00031	0.000306	0.000314
Story22	70.4	0.000356	0.000327	0.000325	0.000329
Story21	67.2	0.000378	0.000343	0.000341	0.000345
Story20	64	0.000396	0.000357	0.000355	0.000358
Story19	60.8	0.000413	0.000369	0.000367	0.00037
Story18	57.6	0.000427	0.000378	0.000375	0.000379
Story17	54.4	0.000438	0.000386	0.000381	0.000388
Story16	51.2	0.000448	0.000395	0.000387	0.000398
Story15	48	0.000455	0.000406	0.000399	0.000411
Story14	44.8	0.000461	0.000404	0.000386	0.000409
Story13	41.6	0.000466	0.000341	0.000295	0.000367
Story12	38.4	0.000468	0.000408	0.000401	0.000422
Story11	35.2	0.000469	0.000414	0.000412	0.000423
Story10	32	0.000468	0.000407	0.000403	0.00041
Story9	28.8	0.000466	0.000401	0.000402	0.000402
Story8	25.6	0.00046	0.000396	0.000399	0.000395
Story7	22.4	0.000452	0.000387	0.000391	0.000386
Story6	19.2	0.00044	0.000374	0.000379	0.000372
Story5	16	0.000424	0.000356	0.000362	0.000354
Story4	12.8	0.000402	0.000333	0.000339	0.00033
Story3	9.6	0.000372	0.000304	0.00031	0.000302
Story2	6.4	0.000329	0.000269	0.000275	0.000267
Story1	3.2	0.000215	0.000174	0.000179	0.000173
Base	0	0	0	0	0

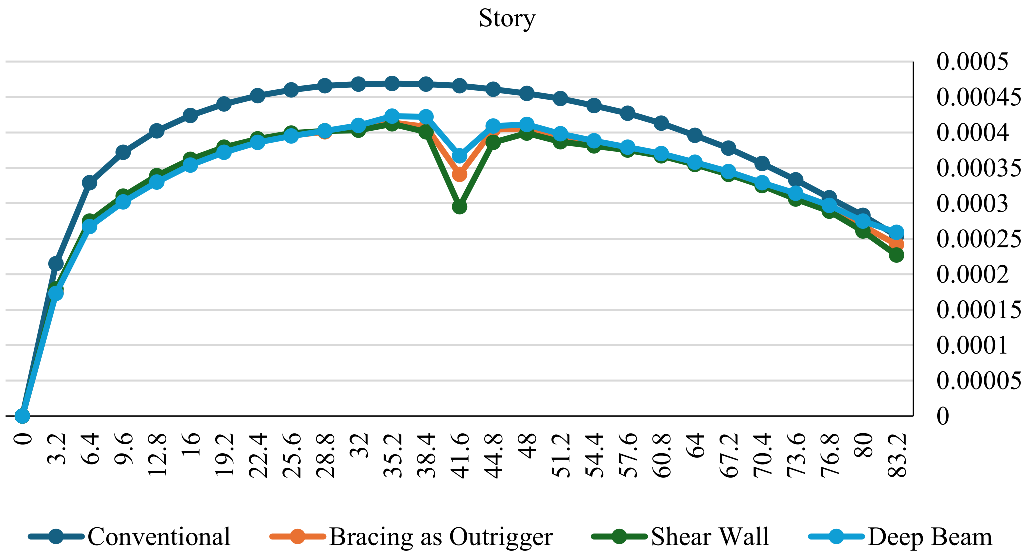

Figure 11. Story drift at 13th and 26th story.

17th & 26th (H & 2H/3)

Story Displacement Comparison Between Conventional and Outrigger Structure

As stiffness increases displacement decreases. In Table 8, the comparison of story displacement for the outrigger at 17th and 26th floor of the building shown, in which it is observed that shear wall as outrigger shows minimum displacement as compared to others. Figure 12 shows the graphical representation of maximum story displacement for outrigger at 17th and 26th story.

Table 8. Comparison of story displacement for outrigger 17th and 26th story.

Story No	Story Height	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story26	83.2	31.793	27.207	26.764	27.516
Story25	80	31.015	26.555	26.184	26.82
Story24	76.8	30.16	25.776	25.435	26.002
Story23	73.6	29.24	24.924	24.604	25.126
Story22	70.4	28.256	24.023	23.726	24.207
Story21	67.2	27.209	23.079	22.804	23.247
Story20	64	26.103	22.091	21.839	22.245
Story19	60.8	24.943	21.059	20.838	21.2
Story18	57.6	23.732	20.004	19.818	20.133
Story17	54.4	22.476	19.007	18.921	19.103
Story16	51.2	21.177	18.2	18.316	18.218
Story15	48	19.842	17.041	17.177	16.995
Story14	44.8	18.473	15.805	15.961	15.735
Story13	41.6	17.076	14.56	14.73	14.481
Story12	38.4	15.655	13.302	13.474	13.221
Story11	35.2	14.216	12.027	12.195	11.948
Story10	32	12.762	10.744	10.901	10.668
Story9	28.8	11.302	9.459	9.603	9.39
Story8	25.6	9.842	8.182	8.31	8.12
Story7	22.4	8.391	6.923	7.033	6.87
Story6	19.2	6.959	5.694	5.786	5.65
Story5	16	5.561	4.508	4.581	4.472
Story4	12.8	4.21	3.381	3.436	3.354
Story3	9.6	2.928	2.327	2.365	2.308
Story2	6.4	1.74	1.36	1.382	1.349
Story1	3.2	0.689	0.554	0.563	0.549
Base	0	0	0	0	0

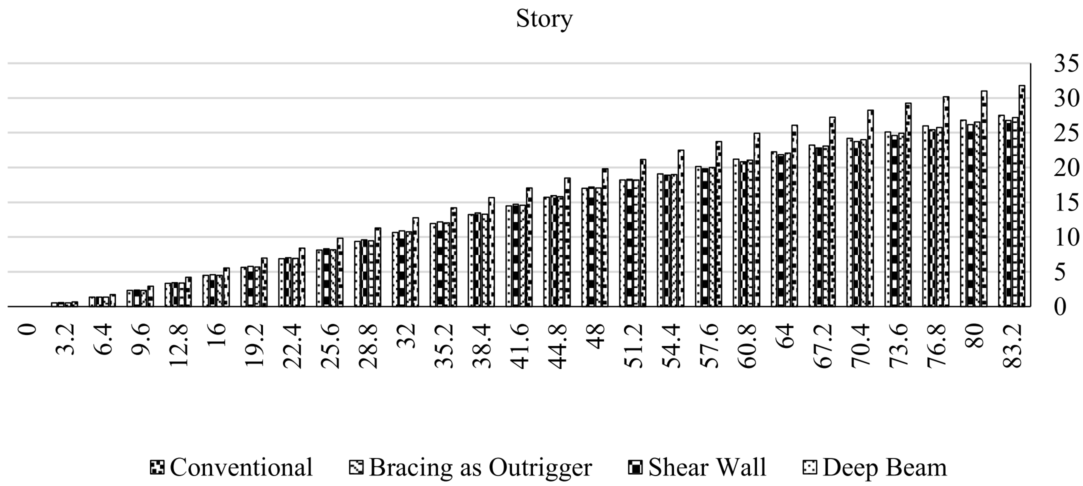

Figure 12. Maximum displacement at 17th & 26th story.

Story Drift Comparison Between Conventional and Outrigger Structure

As the drift is minimum it opposes to lateral forces. Figure 13 shows graphical representation of story drift at 17th & 26th story. Table 9 shows the comparison of story drift for outrigger at 17th &26th story. Minimum drift is at 17th & 26th story in the structure of shear wall as outrigger.

Table 9. Comparison of story drift for outrigger at 17th and 26th story.

Story No.	Story Ht	Conventional	Bracing as Outrigger	Shear Wall	Deep Beam
Story 26	83.2	0.000254	0.000237	0.00022	0.000255
Story25	80	0.000283	0.000262	0.000251	0.00027
Story24	76.8	0.000308	0.000284	0.000278	0.000292
Story23	73.6	0.000333	0.000302	0.000294	0.000308
Story22	70.4	0.000356	0.000318	0.00031	0.000323
Story21	67.2	0.000378	0.000333	0.000325	0.000338
Story20	64	0.000396	0.00035	0.000339	0.000355
Story19	60.8	0.000413	0.000368	0.000359	0.000375
Story18	57.6	0.000427	0.000373	0.000357	0.00038
Story17	54.4	0.000438	0.000325	0.000285	0.00035
Story16	51.2	0.000448	0.000391	0.000383	0.000406
Story15	48	0.000455	0.000405	0.0004	0.000414
Story14	44.8	0.000461	0.000406	0.0004	0.000409
Story13	41.6	0.000466	0.000407	0.000406	0.000409
Story12	38.4	0.000468	0.000411	0.000412	0.000411
Story11	35.2	0.000469	0.000412	0.000415	0.000411
Story10	32	0.000468	0.000411	0.000414	0.000409
Story9	28.8	0.000466	0.000407	0.000411	0.000404
Story8	25.6	0.00046	0.0004	0.000405	0.000397
Story7	22.4	0.000452	0.000389	0.000395	0.000386
Story6	19.2	0.00044	0.000375	0.000381	0.000372
Story5	16	0.000424	0.000356	0.000362	0.000354
Story4	12.8	0.000402	0.000332	0.000337	0.000329
Story3	9.6	0.000372	0.000303	0.000308	0.0003
Story2	6.4	0.000329	0.000267	0.000272	0.000265
Story1	3.2	0.000215	0.000173	0.000176	0.000172
Base	0	0	0	0	0

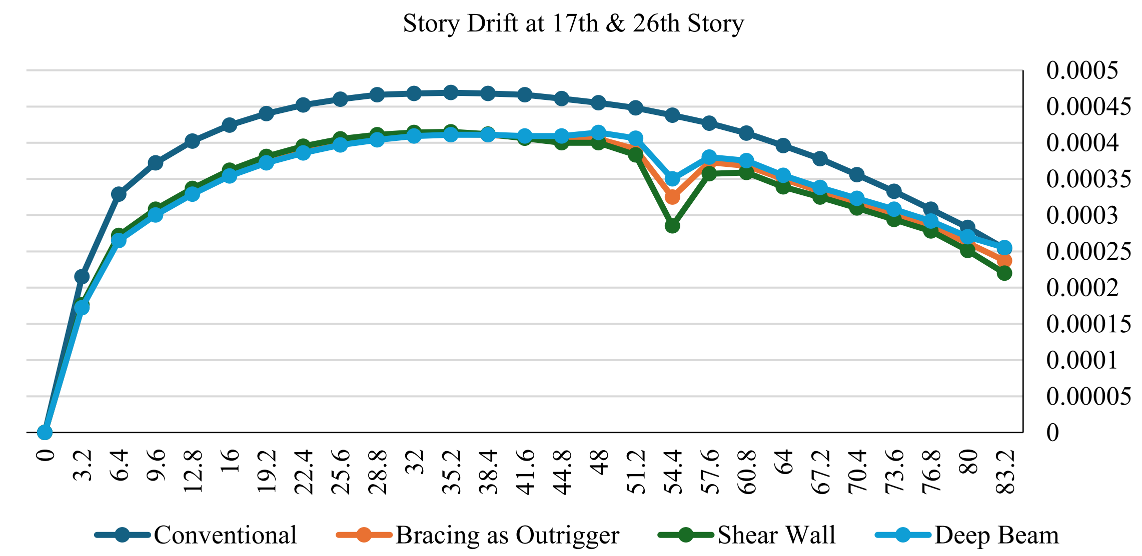

Figure 13. Story drift at 17th & 26th story.

CONCLUSIONS

According to above results, it is observed that as stiffness of story increases, the displacement decreases. The analysis of a G+26 story high-rise structure using the response spectrum method with an integrated outrigger system demonstrates the significant role outriggers play in enhancing the structural performance of tall buildings under seismic loading. The inclusion of outrigger systems significantly reduces lateral displacements and inter-story drifts, thereby improving the overall stability of the building. Outriggers effectively redistribute moments and shear forces from the central core to peripheral columns, optimizing the load path and improving stiffness. The placement of outriggers at intermediate heights covering 1/2–2/3 of the building height creates substantial results for displacement control while delivering maximum efficiency.

The following conclusions are made. The following conclusions are made. The following conclusions are made.

- Placing outriggers on the 13th and 26th floors proved to be effective in mitigating overall structural responses, as these levels correspond to zones of significant dynamic activity.
- The difference in story drift values between conventional, outrigger at 13^{th} & 26^{th} story systems is more significant in taller buildings than in other ones. From study, it can also conclude that where the outriggers are provided in story that gives minimum story drift.
- The difference in story displacement values between conventional, outrigger at 13^{th} & 26^{th} story systems is greater than other systems.
- The study assessed the effectiveness of this configuration by analyzing selected dynamic parameters, including base shear, lateral displacement, and inter-story drift
- According to the above results, it is observed as the stiffness of the floor increases and reduces displacement.
- It is seen that a structure with shear walls as an outrigger gives less displacement compared to other types of outriggers used in analysis.
- As story drift reduces, it means there is a strong opposition for the lateral forces.
- The maximum story shear values obtained from response spectrum analysis are higher.
- Future research can expand on this study by incorporating nonlinear analysis of the outrigger system, considering soil-structure interaction and the influence of higher vibration modes on deformation behavior.
- As stiffness of shear wall is more than bracing and deep beam it gives less displacement.

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