Original Research Paper | Engineering | Volume : 10 | Issue : 06 | June 2025 | e-ISSN : 2456-5040

A COMPARATIVE STUDY AND ANALYSIS OF CONJOINED AND DUAL SHEAR SYSTEM

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ABSTRACT

This report presents a step by step and detailed analysis of various structural systems involving trial designs to discover an innovative structural design for enhanced structural stability and unique spatial configurations in tall building projects. Trials include models wherein the first model encompasses a truss configuration which fails for our requirements. By employing ETABS V.22.4.0 Software, various loading scenarios as per IS 875: 2015, standards are employed to know the story response plots, maximum story displacement, maximum drift, maximum story shear, time period and maximum overturning moment. ETABS stands for Extended Three Dimensional Analysis of Building System. ETABS is commonly used to analyze: Skyscrapers, concrete structures, low and high rise buildings, and portal frame structures.

This conjoined model is then compared with a dual shear wall system where in comparison is made for result parameters such as maximum story displacement, maximum story drift, maximum story shear and maximum overturning moment. The various parameters such as Height, Quality of Concrete, Plan Area and FSI being kept the same. This comparison shows us the key potential of conjoined systems compared to other structural systems.

KEYWORDS: Conjoined Tower, Three Dimensional Analysis of Building , ETAB, Skycrapers, Maximum Storey Displacement, Maximum Storey Drift, Maximum Storey Shear and Maximum Storey Overturning Moment

INTRODUCTION

The rapid vertical expansion of urban landscapes has led to an unprecedented evolution in tall building design, where structural efficiency, aesthetic appeal, and sustainability are paramount. As buildings reach new heights and occupy increasingly constrained footprints, the role of advanced lateral load-resisting systems becomes critically important. Over the past century, structural systems for high-rise buildings have undergone significant transformation—from early steel frame constructions to sophisticated braced tube, diagrid, and outrigger configurations.

Pioneering work by researchers such as Kyoung Sun Moon and Mir M. Ali has charted the historical development and modern resurgence of structural forms like braced tubes and diagrids. The braced tube system, exemplified by the John Hancock Center, marked a turning point in the 1960s, optimizing structural depth and lateral stiffness while contributing to the architectural language of structural expressionism. More recently, diagrid systems have gained prominence due to their structural efficiency and ability to accommodate complex geometries, including twisted, tilted, and freeform towers. Studies show that diagrids not only reduce lateral displacement significantly compared to conventional systems, but also enable more sustainable and architecturally flexible designs.

Outrigger systems, another widely adopted solution, enhance lateral stiffness and minimize building sway, particularly in slender towers exceeding 150 meters. Their integration with belt trusses helps mitigate differential column shortening, though they may introduce soft-story vulnerabilities and spatial constraints. Innovations like tube-in-tube systems and secondary bracing mechanisms further augment the performance of tall structures under wind and seismic loads.

With growing emphasis on sustainable vertical urbanism, recent explorations into conjoined super-framed towers and composite systems reflect a shift towards more livable and resilient megastructures. Additionally, research into masonry infill behavior and the inclusion of functional openings highlights the importance of realistic modeling in seismic design.

This paper synthesizes a broad range of structural innovations in tall building design, emphasizing their performance under lateral loads, material efficiency, and contribution to architectural and environmental goals. By comparing traditional systems with contemporary advancements, it aims to provide a comprehensive understanding of the strategies shaping the future of high-rise construction.

METHODOLOGY

Base Area	60 x 60 sqm
Built-up Area	2025 sqm
Support Condition	Fixed
Height	123 m
Floor to Floor Height	3 m

Table 1: Building Details

Grade of Concrete: For Beams, Columns, Slabs	M60
Grade of Longitudinal Steel	Fe500
Grade of Shear Reinforcement	Fe415

Table 2: Material properties

Load Case	Value
Dead Load	4 kN/m^2 for Slabs 4.5 kN/m^2 for Staircase 3 kN/m^2 for passage before Lift
Live Load	4 kN/m^2

Table 3: Gravity loading

Basic wind speed	44 m/s
Terrain category	3
Importance factor	1
Risk coefficient factor	1
Topography factor	1
Windward coefficient	0.84
Leeward coefficient	0.56

Table 4: Wind load parameters

Parameters	Value
Seismic Zone Factor, Z	0.16
Site Type	1
Importance Factor	1.2

Table 5: Earthquake parameters

Elements	Type	Depth (mm)	Width (mm)	Breadth(mm)
Beam	Frame	700	300	-
Column	Frame	-	900	900

Table 6: Member details

Elements	Type	Thickness(mm)
One Way Slab	Membrane	200
Two Way Slab	Membrane	225
Shear Wall	Shell- Thin	350

Table 7: Modelling element

I) Design Load Patterns	
• Dead Load (DL) • Live Load (LL) • Wind Load in the x-axis (WX) • Wind Load in the y-axis (WY) • Earthquake Load in the x-axis (EQX) • Earthquake Load in the y-axis (EQY) • II) Wind Load Combinations • III) Earthquake Load Combinations	
II) Wind Load Combinations	**III) Earthquake Load Combinations**
• 1.2 (DL + LL + WX) • 1.2 (DL + LL – WX) • 1.2 (DL + LL + WY) • 1.2 (DL + LL – WY) • 1.5 (DL + WX) • 1.5 (DL – WX) • 1.5 (DL + WY) • 1.5 (DL – WY) • 0.9 DL + 1.5 WX • 0.9 DL – 1.5 WX • 0.9 DL + 1.5 WY • 0.9 DL – 1.5 WY	• 1.2 (DL + LL + EQX) • 1.2 (DL + LL – EQX) • 1.2 (DL + LL + EQY) • 1.2 (DL + LL – EQY) • 1.5 (DL + EQX) • 1.5 (DL – EQX) • 1.5 (DL + EQY) • 1.5 (DL – EQY) • 0.9 DL + 1.5 EQX • 0.9 DL – 1.5 EQX • 0.9 DL + 1.5 EQY • 0.9 DL – 1.5 EQY

Table 8: Load combination

MODELLING TRIALS

Results

Conjoined System		
Total Dead Weight	2491489	kN
Total Concrete Quality	99659	m^3
Total Constructable Area/Floor	2025	m2
Total Constructable Area	162000	m2
Vol of Concrete/ m2	0.615	m3/m2
Vol of Concrete/ Floor	1245.73	mm3/mm

Dual Shear Wall System		
Total Dead Weight	2488924	kN
Total Concrete Quality	99556	m3
Total Constructable Area/Floor	2025	m2
Total Constructable Area	162000	m2
Vol of Concrete/ m2	0.614	m3/m2
Vol of Concrete/ Floor	1244.45	mm3/mm

Comparative Study Between Conjoined and Dualshear Wall System

Load Consideration:
1) Gravity Loading
- Dead load and live load were considered according to the project requirements.
- By setting the self-weight multiplier value to one and self-weight of the structure was calculated automatically.

2) Wind Load (WL)
- Wind load was defined based on the project condition, exposure type, and probable maximum wind speed and project importance factor.

- Two load cases were considered. They are wind load in X direction (WX) and windload in Y direction (WY).
- It was conducted as shown in IS 875: Part 3

3) Seismic Load (EQ)
- Two load cases were considered for the direction X and Y, named EQX and EQY.
- It was conducted as shown in IS 1893: Part 1.

4.5.2. Modelling

4.5.2.1 Modelling of Conjoined system

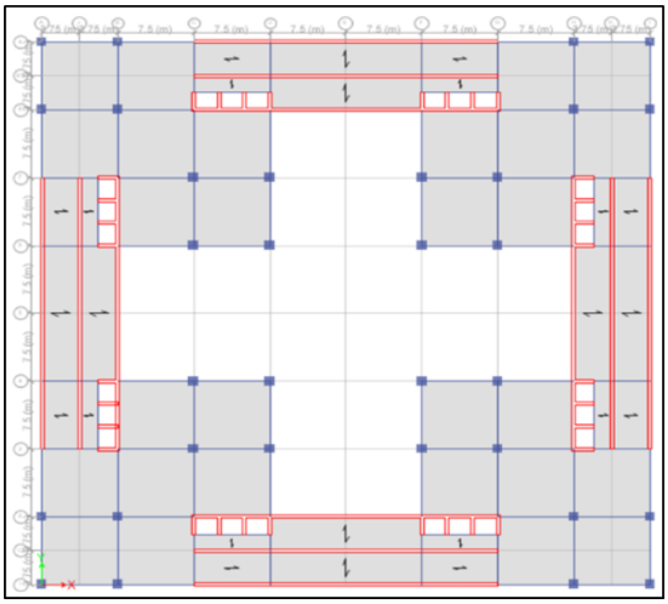

Figure: Plan for Conjoined System

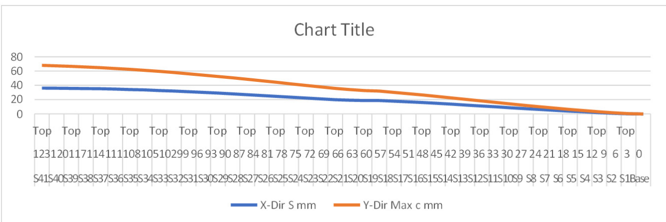

Figure: Comparison between Maximum Story Displacement of dual shear wall system and conjoined system

Story	Elevation	Location	X-Dir S	Y-Dir Max c
	m		mm	mm
S41	123	Top	36.267	31.965
S40	120	Top	36.055	31.402
S39	117	Top	35.914	30.854
S38	114	Top	35.654	30.264
S37	111	Top	35.315	29.645
S36	108	Top	34.873	28.989
S35	105	Top	34.329	28.295
S34	102	Top	33.688	27.565
S33	99	Top	32.955	26.798
S32	96	Top	32.139	25.999
S31	93	Top	31.245	25.168
S30	90	Top	30.282	24.308
S29	87	Top	29.256	23.421
S28	84	Top	28.176	22.511
S27	81	Top	27.05	21.581
S26	78	Top	25.887	20.633
S25	75	Top	24.699	19.671
S24	72	Top	23.498	18.699
S23	69	Top	22.303	17.725
S22	66	Top	21.145	16.783
S21	63	Top	20.091	15.843
S20	60	Top	19.311	14.921
S19	57	Top	18.911	14.034
S18	54	Top	18.849	13.214
S17	51	Top	17.908	12.281
S16	48	Top	17.055	11.371
S15	45	Top	16.034	10.467
S14	42	Top	14.904	9.568
S13	39	Top	13.681	8.676
S12	36	Top	12.442	7.794
S11	33	Top	11.214	6.926
S10	30	Top	9.978	6.075
S9	27	Top	8.743	5.248
S8	24	Top	7.518	4.447
S7	21	Top	6.314	3.678
S6	18	Top	5.141	2.949
S5	15	Top	4.009	2.266
S4	12	Top	2.934	1.639
S3	9	Top	1.937	1.08
S2	6	Top	1.05	0.602
S1	3	Top	0.357	0.239
Base	0	Top	0	0

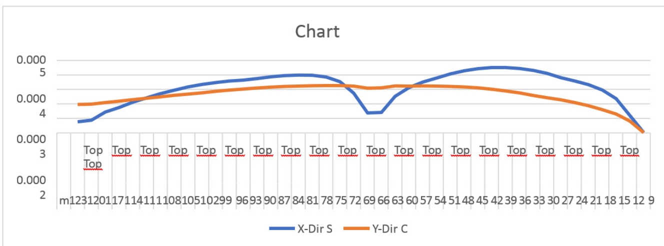

Figure: Comparison between Maximum Story Drift of dual shear wall and Conjoined System

Story	Elevation	Location	X-Dir S	Y-Dir C
	m			
S41	123	Top	0.000075	0.000196
S40	120	Top	0.000086	0.000198
S39	117	Top	0.000142	0.000209
S38	114	Top	0.000174	0.000219
S37	111	Top	0.000211	0.000229
S36	108	Top	0.000242	0.000239

Volume : 10 | Issue : 06 | June 2025 | e-ISSN : 2456-5040

S35	105	Top	0.000271	0.000249
S34	102	Top	0.000295	0.000259
S33	99	Top	0.000317	0.000268
S32	96	Top	0.000334	0.000277
S31	93	Top	0.000348	0.000287
S30	90	Top	0.000358	0.000296
S29	87	Top	0.000364	0.000303
S28	84	Top	0.000375	0.00031
S27	81	Top	0.000388	0.000316
S26	78	Top	0.000396	0.000321
S25	75	Top	0.0004	0.000324
S24	72	Top	0.000398	0.000326
S23	69	Top	0.000386	0.000327
S22	66	Top	0.000354	0.000327
S21	63	Top	0.000274	0.000323
S20	60	Top	0.000137	0.000309
S19	57	Top	0.00014	0.000311
S18	54	Top	0.000252	0.000325
S17	51	Top	0.000313	0.000324
S16	48	Top	0.000351	0.000325
S15	45	Top	0.000379	0.000324
S14	42	Top	0.000408	0.000321
S13	39	Top	0.00043	0.000317
S12	36	Top	0.000444	0.000311
S11	33	Top	0.000452	0.000302
S10	30	Top	0.000452	0.00029
S9	27	Top	0.000445	0.000276
S8	24	Top	0.000432	0.000258
S7	21	Top	0.000411	0.000243
S6	18	Top	0.000382	0.000228
S5	15	Top	0.000358	0.000209
S4	12	Top	0.000333	0.000187
S3	9	Top	0.000296	0.000159
S2	6	Top	0.000236	0.000129
S1	3	Top	0.000119	0.00008
Base	0	Top	0	0

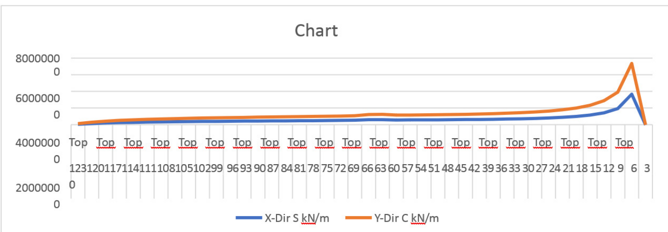

Figure: Comparision between Maximum Story Stiffness of dual shear wall system and conjoined system

Story	Elevation	Location	X-Dir S	Y-Dir C
	m		kN/m	kN/m
S41	123	Top	737417.56	737417.56
S40	120	Top	1573032.68	1573032.68
S39	117	Top	2210012.66	2210012.66
S38	114	Top	2632346.23	2632346.23
S37	111	Top	2985362.96	2985362.96
S36	108	Top	3276562.8	3276562.8
S35	105	Top	3520240.98	3520240.98
S34	102	Top	3727499.23	3727499.23
S33	99	Top	3906678.3	3906678.3
S32	96	Top	4069104.94	4069104.94
S31	93	Top	4210247.34	4210247.34
S30	90	Top	4338514.57	4338514.57
S29	87	Top	4457510.14	4457510.14
S28	84	Top	4570501.75	4570501.75
S27	81	Top	4680591.48	4680591.48
S26	78	Top	4790605.05	4790605.05
S25	75	Top	4904267.4	4904267.4
S24	72	Top	5022469.42	5022469.42
S23	69	Top	5146385.9	5146385.9
S22	66	Top	5280358.71	5280358.71
S21	63	Top	5483687.85	5483687.85
S20	60	Top	6183395.5	6183395.5
S19	57	Top	6269881.99	6269881.99
S18	54	Top	5870882.46	5870882.46
S17	51	Top	5891069.43	5891069.43
S16	48	Top	5968192.35	5968192.35
S15	45	Top	6048823.59	6048823.59
S14	42	Top	6148694.62	6148694.62
S13	39	Top	6282543.8	6282543.8
S12	36	Top	6456414.31	6456414.31
S11	33	Top	6664932.19	6664932.19
S10	30	Top	6927268.1	6927268.1
S9	27	Top	7259424.03	7259424.03
S8	24	Top	7686167.4	7686167.4
S7	21	Top	8213655.2	8213655.2
S6	18	Top	8969394.71	8969394.71
S5	15	Top	10047404.1	10047404.1
S4	12	Top	11683631.8	11683631.8
S3	9	Top	14399213.9	14399213.9
S2	6	Top	19496207.4	19496207.4
S1	3	Top	36617405.8	36617405.8
Base	0	Top	0	0

RESULTS

4.5.3.1. Comparative analysis result:

Type of parameters	Conjoined system (Envelope I)	Dual shear wall system (Envelope I)	Limitations

Maximum displacement (mm)	294.922	357.288	486
Maximum story drift (mm)	0.00176	0.00183	0.012
Maximum time period (sec)	6.631	8.115	-
Maximum overturning moments (kN-m)	118802229	89116345	-
Maximum shear force (kN)	50292.397	37719.295	-

Table: Comparative Analysis of Conjoined and Dual shear wall system

Comparative analysis result:

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Table: Comparative Analysis of Conjoined and Dual shear wall system

CONCLUSION AND REMARK

The study considers comparative analysis of an innovative conjoined structural system involving three spandrel beam configurations against a dual shear wall structure. These structures are theoretically analyzed using ETABS 21 software for different types of loads including Dead load, Live load, wind load and Earthquake loads and the required sections as per the relevant IS Codes are obtained. The following inferences and conclusions ae obtained from the analysis results and design:

1. Under identical loading conditions and with the same structural weight and constructable area, there's a noticeable reduction in both story displacement and time period within the conjoined system compared to the dual shear wall system.
2. The conjoined system offers supplementary usable area along the spandrel beams, creating space for expanded utility and recreational purposes. These aspects underscorethe superiority of the conjoined system over the conventional dual shear wall approach.
3. The conjoined system demonstrates its potential for taller structures, with a maximum probable height exceeding 300m. In contrast, the dual shear wall system shows signs of potential failure at a height of 240m. This significant disparity in maximum achievable height further emphasizes the advantages and structural robustness of the conjoined system in high-rise construction scenarios.
4. The conjoined system exhibits a notable reduction in time period compared to the dual shear wall configuration, signifying enhanced performance against seismic and wind loading.
5. An incremental rise in overturning moment in the conjoined system stems from the elongation of the lever arm due to the utilization of conjoined beams connecting the cores of four towers.
6. Substantial decrease in the values of story drift is observed at levels featuring conjoint beams, underscoring the pivotal role of these beams in stabilizing position and minimizing deflections, even at elevated heights.

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