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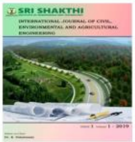

Study of the Behaviour of Concrete Filled Steel Tube Column and Fully Encased Composite Column on A G+10 Storey Special Moment Frame

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Abstract: One of the main problems with a G+10 Storey Special Moment Frame is its vulnerability to progressive collapse. In India fortified solid structures are generally utilized since this is the most advantageous and monetary framework for low-ascent structures. The RCC Structure is not, at this point reasonable due to the expanded dead burden, range dismissal and less solidness. There is extraordinary potential for expanding volume of steel in development. The level of steel can be expanded with the utilization of steel-solid composite segments. The undertaking presents the impact of Conventional RCC, CFST (Concrete filled Steel Tube) and Fully Encased Composite segment on a G+ 10 story extraordinary second casing. In this task three distinct structures are considered for the correlation under seismic examination. The direct static examination, for example "Identical seismic coefficient investigation" are accomplished for G+10 story structure. To correlate the behaviour of structure for seismic load, a simulation model is developed using ETAB software. Results are generated for the Self weight, Story Drift, Story Shear, Lateral burden appropriation, Base shear, Story dislodging and story float for all the three structures. As the composite is having more horizontal firmness, lesser decrease in self- weight, the base shear, and the sidelong burden appropriation along the story shows the huge variation such that Concrete-Filled Steel Tubular (CFST) and Encased Column models demonstrate a notable reduction in self-weight by 11.2% and 4.45%, respectively, compared to RCC columns.

Keywords: CFST, Fully encased column, Storey drift, ETABS

1. Introduction

Steel structural members are susceptible to local and lateral buckling. In contrast, concrete structural members, being generally thicker, are less prone to buckling but can experience creep and shrinkage over time [1]. Steel is a more ductile material, allowing it to absorb more shocks and impact loads. To take advantage of the beneficial properties of both materials, composite structures are designed [2]. The performance of buildings during an earthquake is influenced by various factors, including stiffness, ductility, lateral strength, and a simple and regular configuration [3].

A composite floor framework typically includes steel beams, metal decking, and concrete. These materials are combined effectively to optimize construction processes by leveraging the best properties of each [4]. The most common arrangement in composite floor systems involves a rolled or built-up steel beam connected to a profiled steel deck and concrete slab. The metal deck generally spans unsupported between steel members and also provides a working platform for concrete work [5].

This composite floor system creates a rigid horizontal diaphragm, providing stability to the overall structural system while distributing wind and seismic forces to the lateral load-resisting systems. Composite action increases load-carrying capacity and stiffness by factors of approximately 2 and 3.5, respectively [6].

In the composite system, concrete forms the compression flange, steel provides the tension component, and shear connectors ensure the section behaves compositely. Beam spans ranging from 6 to 12 meters can be achieved, offering maximum flexibility and internal space division [7].

Composite slabs typically use steel decking of 46 to 80 mm depth, capable of spanning 3 to 4.5 meters without temporary propping. Slab thicknesses usually range from 100 mm to 250 mm for shallow decking and from 280 mm to 320 mm for deep decking. Composite slabs are generally designed as simply supported members under normal conditions, without accounting for continuity provided by reinforcement at supports [8].

In traditional composite construction, concrete slabs rest on steel beams and are supported by them. Without a connection between them, these two components act independently under load, resulting in general slippage at the interface [9]. However, this slippage can be eliminated with a deliberate and appropriate connection between them. In this case, the steel beam and slab act as a "composite beam," similar to a reinforced concrete Tee beam [10].

Composite construction integrates the properties of concrete and steel. Shear studs at the interface are used in composite construction to connect the two different materials, which reduces the depth required and significantly saves material costs [11]. The thermal expansion coefficients of both concrete and steel are nearly the same, thus avoiding different thermal stresses in the component under temperature variations. A steel-concrete composite structure consists of a composite column, structural steel beam, and reinforced concrete slab, with shear connectors between the beam and slabs [12].

Composite action reduces the beam depth and rolled steel sections are often sufficient for building structures, making built-up girders generally unnecessary. The composite beam can also be constructed with profiled sheeting with a concrete topping or with cast-in-place or precast reinforced concrete slabs. A steel-concrete composite column is typically a compression. 2024 member where the steel element is a basic steel column. There are three types of composite columns commonly used in practice: Concrete Encased, Concrete-filled, and Battered Section [13].

2. Materials and Methods

The details of the building configuration, specification of the members and the material properties are as follows.

2.1 Building Data

Type of building = Residential

Number of storey = G + 10

Location of building = Coimbatore

Type of frame = SMRF (Special Moment Resisting Frame)

Zone = III

Zone factor = 0.16

Importance factor = 1

Live load = 2 KN/m^2

Thickness of slab = 0.15m

2.2 Dimensions of beam and column for all three cases

The structural dimensional detailing for RCC, CFST and Encased member is given in Table 1.

Table 1.Comparison of dimensional specification of RCC,CFST and Encased Members

Member	Size of Beam	Size of Column
RCC	0.6m x 0.6m	0.68m x 0.68m
CFST	0.38 m x 0.38 m with tW and tf is 20mm	0.53 m x 0.53 m with tw and tf is 20mm
Encased	ISLB 600 encased with 0.68 m x 0.68 m	ISLB 450 encased with 0.6 m x 0.6 m

2.3 Material Properties

In seismic analysis, specific concrete grades, reinforcement grades, and brick infill are chosen to ensure structural resilience and ductility under dynamic loading. Higher-grade concrete and reinforcement provide greater strength and energy dissipation, reducing the risk of brittle failure. Properly selected brick infill enhances stiffness while preventing excessive weight that could amplify seismic forces.

2.3.1 RCC

Type of material = Isotrophic

Weight per volume = 25KN/m^2

Mass per volume = 2500 kg/m^3

Modulus of elasticity =5000√20

=22360.68N/mm^2

Poisson ratio = 0.2

Characteristic strength for Beam and slab= 20N/mm^2

2.3.2 Steel Reinforcement

Type of material = Isotrophic

Weight per volume = 75 KN/m^2

Mass per volume = 2500 kg/m^3

Yield strength = 415 N/mm^2

2.3.3 Brick Masonry Infill

Type of material = Isotrophic

Weight per volume = 20 KN/m^3

Mass per volume = 2000kg/m^3

2.3.4 Encased Column

Infill material = Concrete
Encased material= steel Tube

2.3.5 Concrete Filled Steel Tube

Encased material = Concrete

Embedded material = Structural steel section

2.3.6 Methods

The study examines the behavior of Concrete-Filled Steel Tube (CFST) columns and Fully Encased Composite Columns (FECC) in a G+10 storey Special Moment Resisting Frame (SMRF) using ETABS. A 3D structural model is developed, incorporating material properties and section assignments based on relevant design codes such as IS 456, IS 800, and IS 1893. Load cases, including dead, live, and seismic loads, are applied as per code provisions, and appropriate load combinations are considered. The analysis involves both linear static and response spectrum methods to evaluate key structural parameters such as storey displacement, drift, base shear, and axial forces. A comparative study is conducted to assess the seismic performance of CFST and FECC columns, focusing on their lateral stability, moment capacity, and overall deformation characteristics. The findings help determine the most effective column type for enhancing the seismic resilience of high-rise buildings.

3. Results and Discussion

Following tabulation shows the seismic weight and design base shear of the models.

Table 2 shows the reaction (FZ) for RCC, CFSR and Encased for Self Weight Load Case for all columns and the comparative analysis is reflected in Figure 1 and the force towards the footing is represented in Figure 2.

Table 2. Selfweight of RCC, CFST and Encased Structure

SELFWEIGHT		RCC	CFST	ENCASED
Columns	**Load case**	**FZ**	**FZ**	**FZ**
		kN	**kN**	**kN**
C1	SELFWT	1127.301	850.4104	956.9981
C2	SELFWT	1568.885	1305.623	1482.349
C3	SELFWT	1568.885	1452.158	1478.465
C4	SELFWT	1127.301	840.2553	1046.946
C5	SELFWT	1512.671	1236.614	1395.521
C6	SELFWT	2010.817	2016.606	2047.72
C7	SELFWT	2010.817	2008.382	2047.424
C8	SELFWT	1512.671	1235.782	1392.999
C9	SELFWT	1376.708	1090.725	1255.66
C10	SELFWT	1819.414	1788.508	1824.697
C11	SELFWT	1819.414	1788.276	1824.417

C12	SELFWT	1376.708	1090.457	1254.978
C13	SELFWT	1507.384	1235.396	1392.406
C14	SELFWT	2001.95	2016.14	2049.044
C15	SELFWT	2001.95	2016.003	2046.052
C16	SELFWT	1507.384	1235.081	1391.803
C17	SELFWT	1049.394	775.9098	978.9269
C18	SELFWT	1453.998	1202.01	1274.794
C19	SELFWT	1453.998	1201.891	1367.198
C20	SELFWT	1049.394	775.6033	975.141

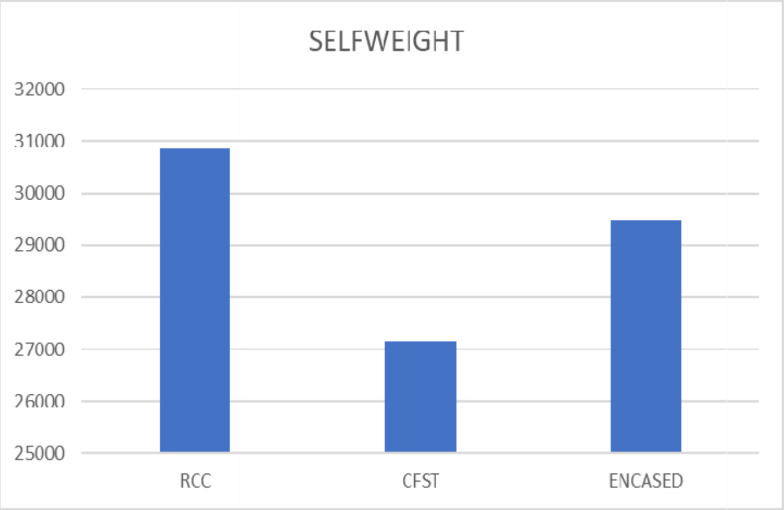


Figure 1. Selfweight of RCC, CFST, ENCASED STRUCTURE

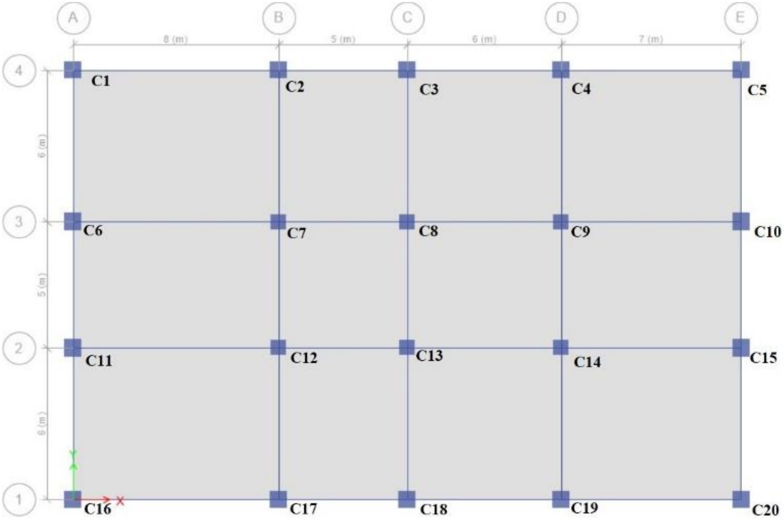


Figure 2. Plan with Column

Table 3 shows the reactions for RCC, CFSR and Encased for Drift Case for all columns and the comparative analysis is reflected in Fig 3 and the force towards the footing is represented in Figure 4.

Table 3. DRIFT OF RCC , CFST AND ENCASED STRUCTURE

Story	RCC		CFST		ENCASED		Permissible Limit
	X-Dir(Mm) SLX	Y-Dir(Mm) SLY	X-Dir(Mm) SLX	Y-Dir(Mm) SLY	X-Dir(Mm) SLX	Y-Dir(Mm) SLY	0.04 X H
10F	0.001121	0.001126	0.00153	0.001512	0.003459	0.003239	12
9F	0.001622	0.001618	0.002219	0.002182	0.004169	0.003989	12
8F	0.002135	0.002122	0.002921	0.002855	0.00501	0.004853	12
7F	0.002578	0.002554	0.003526	0.003435	0.005834	0.005686	12
6F	0.00293	0.002895	0.004006	0.003894	0.006562	0.006412	12
5F	0.003193	0.003149	0.004367	0.004235	0.007167	0.007007	12
4F	0.003381	0.003327	0.004625	0.004478	0.007649	0.007475	12
3F	0.003516	0.003453	0.004813	0.004651	0.008028	0.007841	12
2F	0.003635	0.003564	0.004978	0.004799	0.008337	0.00814	12
1F	0.003826	0.003743	0.005266	0.005006	0.008632	0.008437	12
GF	0.004179	0.004057	0.005773	0.005505	0.008927	0.008771	12

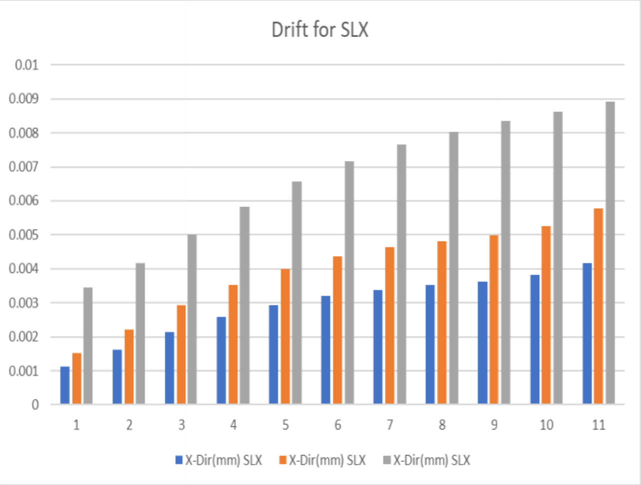


Figure 3. Drift of RCC, CFST and ENCASED in X-Direction

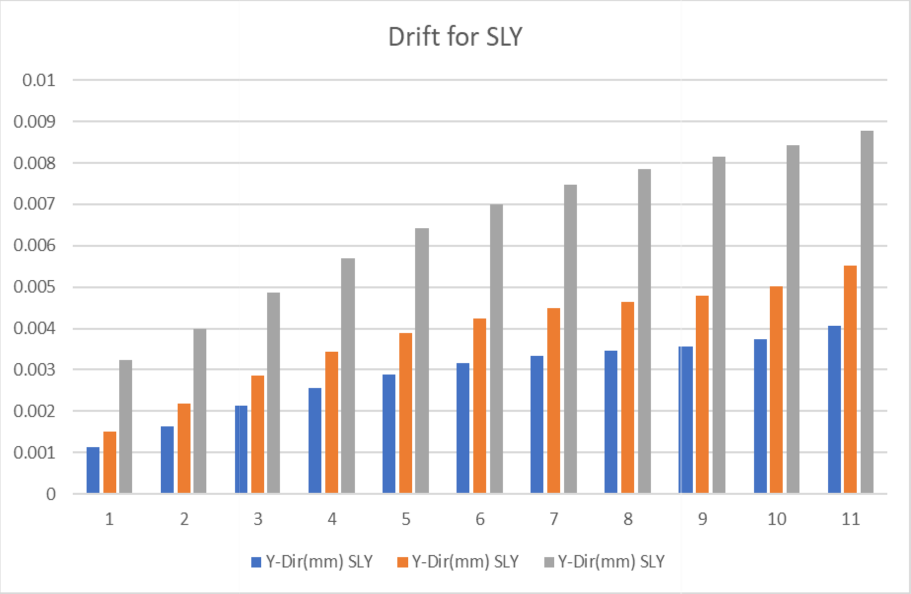


Figure 4. Drift of RCC, CFST and ENCASED in Y-Direction

Table 4. Storey Shear Of RCC , CFST and Encased Structure

Story	RCC		CFST		ENCASED	
	X-Dir(KN) SLX	Y-Dir(KN) SLY	X-Dir(KN) SLX	Y-Dir(KN) SLY	X-Dir(KN) SLX	Y-Dir(KN) SLY
10F	-601.316	-601.316	-561.25	-561.25	-574.208	-574.208
9F	-1141.15	-1141.15	-1048.26	-1048.26	-1096.66	-1096.66
8F	-1575.06	-1575.06	-1439.71	-1439.71	-1516.61	-1516.61
7F	-1914.62	-1914.62	-1746.05	-1746.05	-1845.24	-1845.24
6F	-2171.38	-2171.38	-1977.68	-1977.68	-2093.73	-2093.73
5F	-2356.88	-2356.88	-2145.03	-2145.03	-2273.27	-2273.27
4F	-2482.69	-2482.69	-2258.53	-2258.53	-2395.03	-2395.03
3F	-2560.36	-2560.36	-2328.6	-2328.6	-2470.2	-2470.2
2F	-2601.44	-2601.44	-2365.66	-2365.66	-2509.96	-2509.96
1F	-2617.49	-2617.49	-2380.14	-2380.14	-2525.5	-2525.5
GF	-2618.87	-2618.87	-2381.31	-2381.31	-2526.79	-2526.79

Table 4 shows the Storey Shear for RCC, CFST and Encased for Drift Case for all columns and the comparative analysis is reflected in Fig 5 and Fig 6 in X and Y direction respectively.

Table 5 shows the Lateral Load Distribution of RCC, CFST and Encased for Drift Case for all columns and the individual is reflected in fig 7, fig 8 and fig 9 respectively.

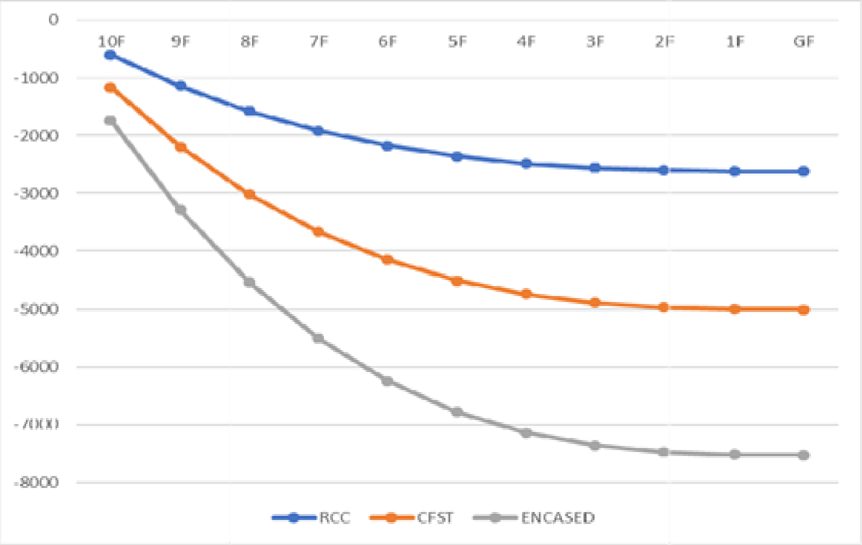


Figure 5. Storey Shear of RCC, CFST and ENCASED in X-Direction

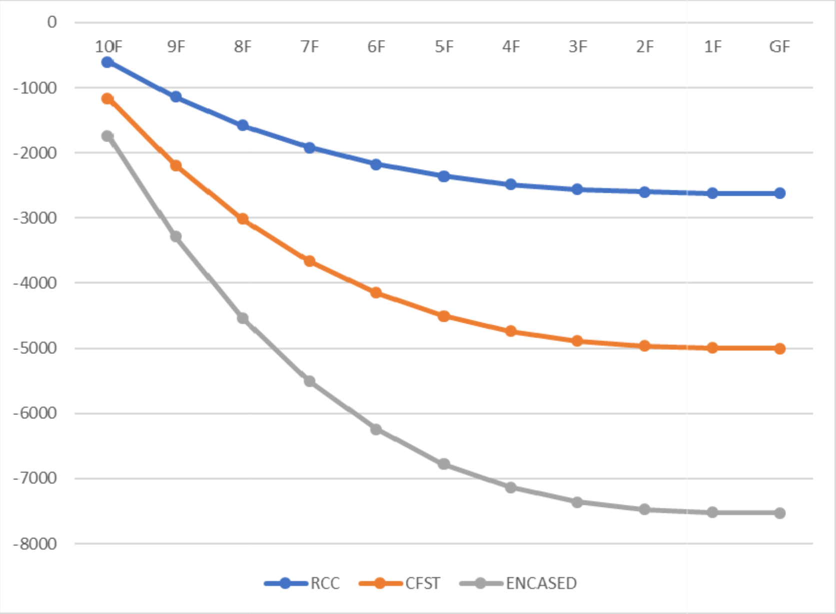


Figure 6. Storey Shear of RCC, CFST and ENCASED in Y-Direction

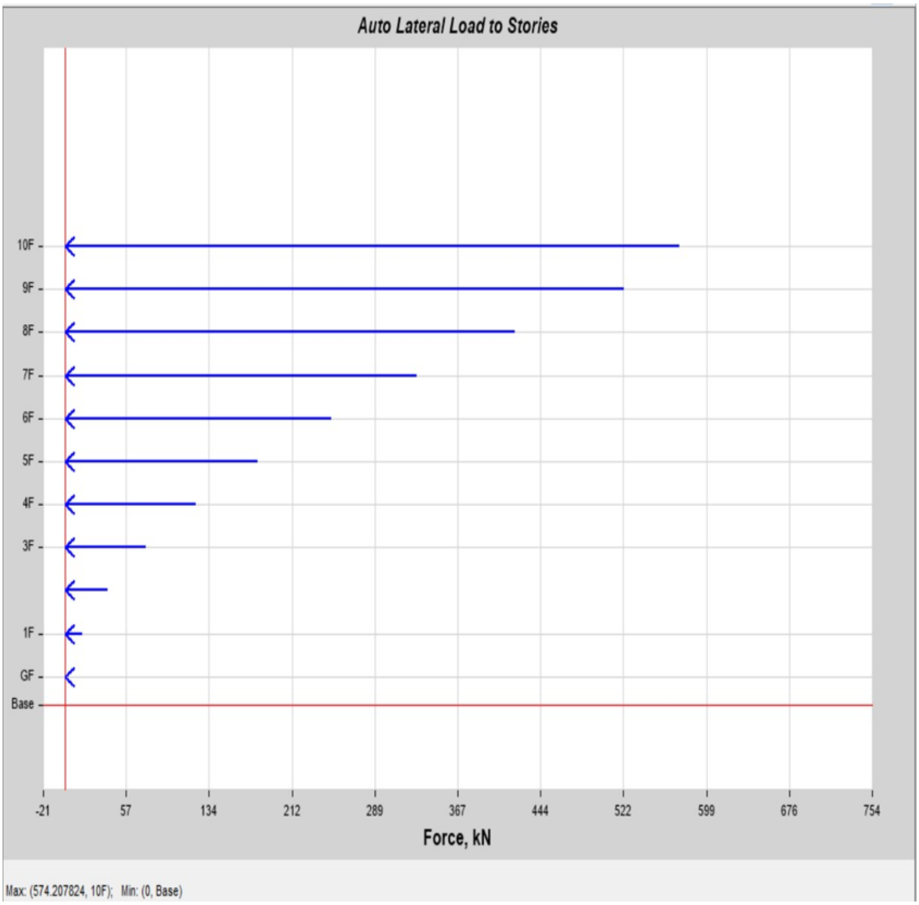
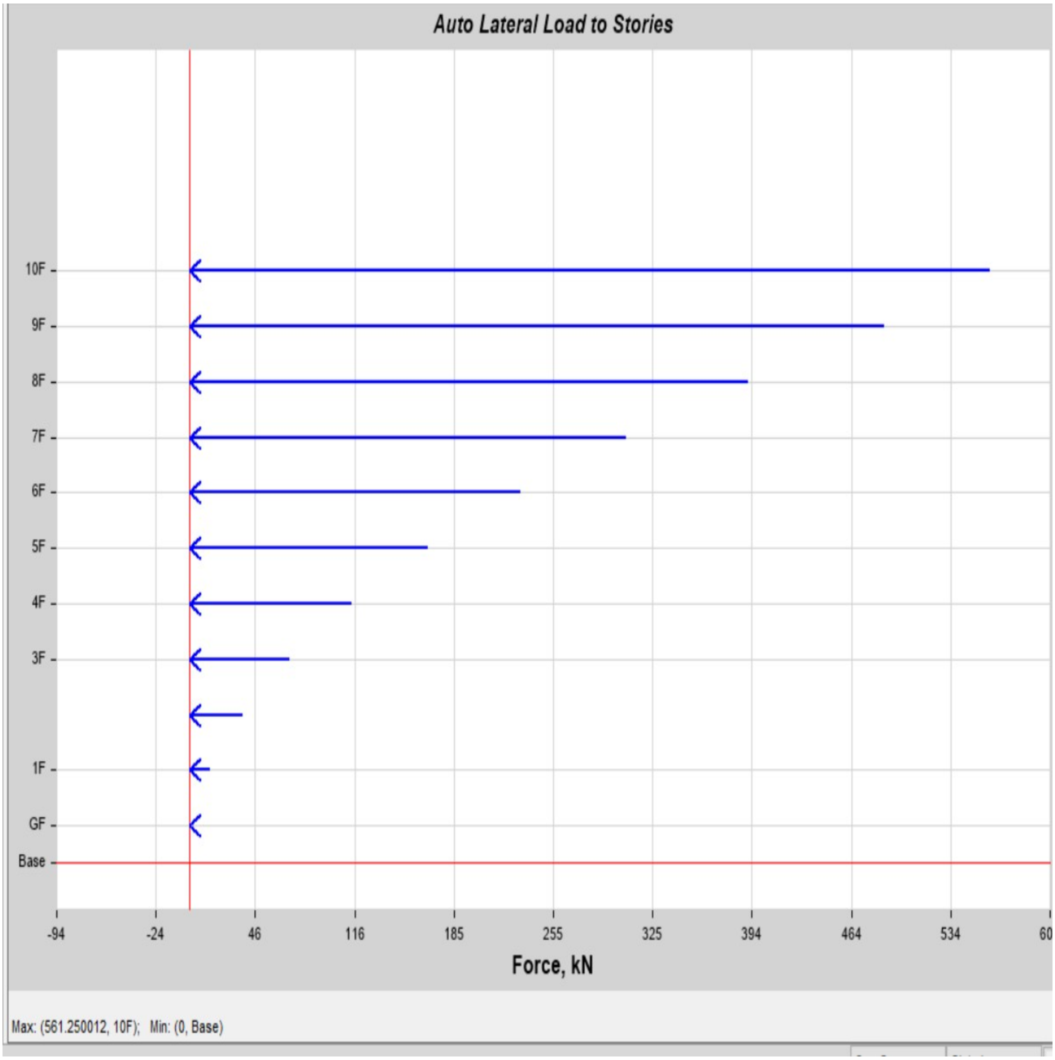


Figure 7. Lateral Load Distribution Of RCC

Table 5. Lateral Load Distribution Of RCC , CFST And Encased Structure

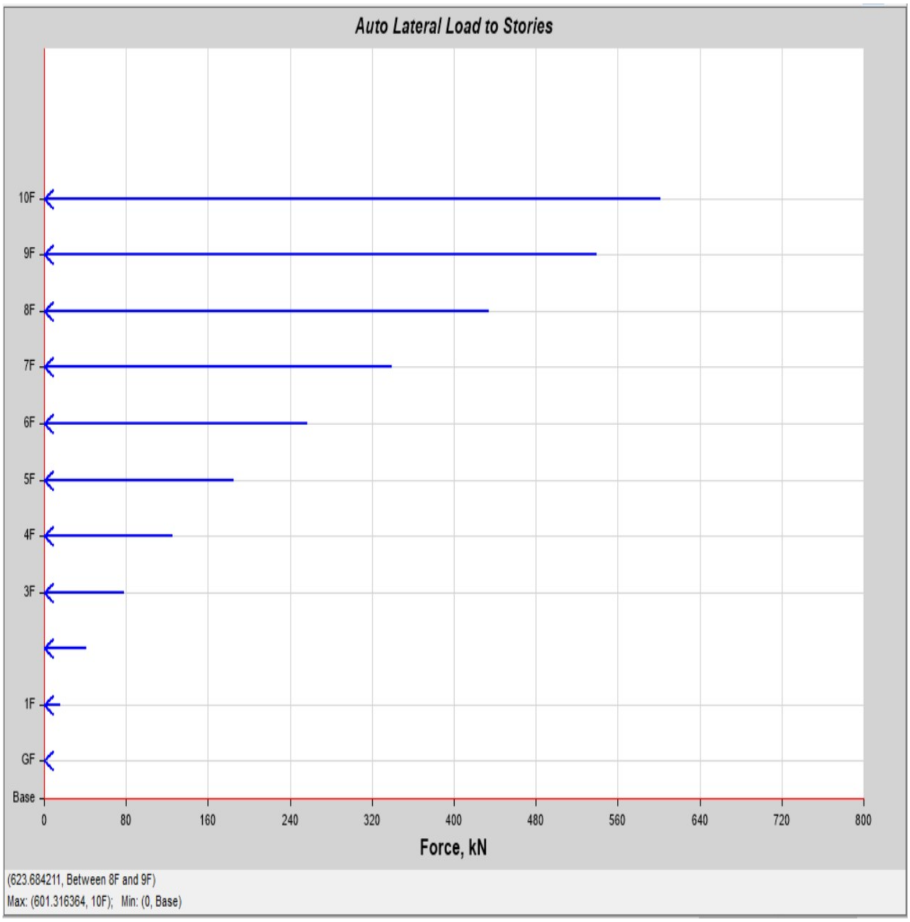
Story	RCC		CFST		ENCASED	
	X- Dir(KN) SLX	**Y- Dir(KN) SLY**	**X- Dir(KN) SLX**	**Y- Dir(KN) SLY**	**X- Dir(KN) SLX**	**Y- Dir(KN) SLY**
10F	601.3164	601.3164	561.25	561.25	574.2078	574.2078
9F	539.8291	539.8291	487.0065	487.0065	522.4534	522.4534
8F	433.9173	433.9173	391.4582	391.4582	419.9507	419.9507
7F	339.5596	339.5596	306.3334	306.3334	328.63	328.63
6F	256.7558	256.7558	231.6321	231.6321	248.4915	248.4915
5F	185.5061	185.5061	167.3542	167.3542	179.5351	179.5351

4F	125.8103	125.8103	113.4997	113.4997	121.7608	121.7608
3F	77.6686	77.6686	70.0687	70.0687	75.1687	75.1687
2F	41.0809	41.0809	37.0611	37.0611	39.7586	39.7586
1F	16.0472	16.0472	14.477	14.477	15.5466	15.5466
GF	1.3752	1.3752	1.1645	1.1645	1.2872	1.2872
BASE SHEAR	**2618.9**	**2618.9**	**2381.3**	**2381.3**	**2526.8**	**2526.8**



Max: (561.250012, 10F); Min: (0, Base)

Figure 8. Lateral Load Distribution of CFST



(623.684211, Between 8F and 9F)
Max: (601.316364, 10F); Min: (0, Base)

Figure 9. Lateral Load Distribution of Encased

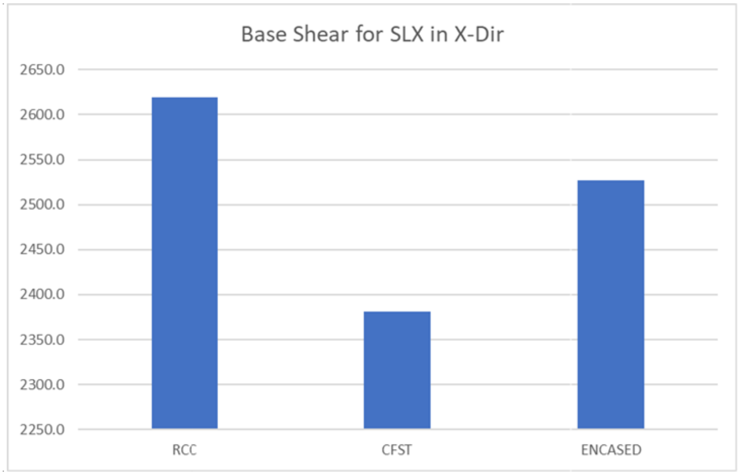


Figure 10. Base Shear for SLX in X-Direction

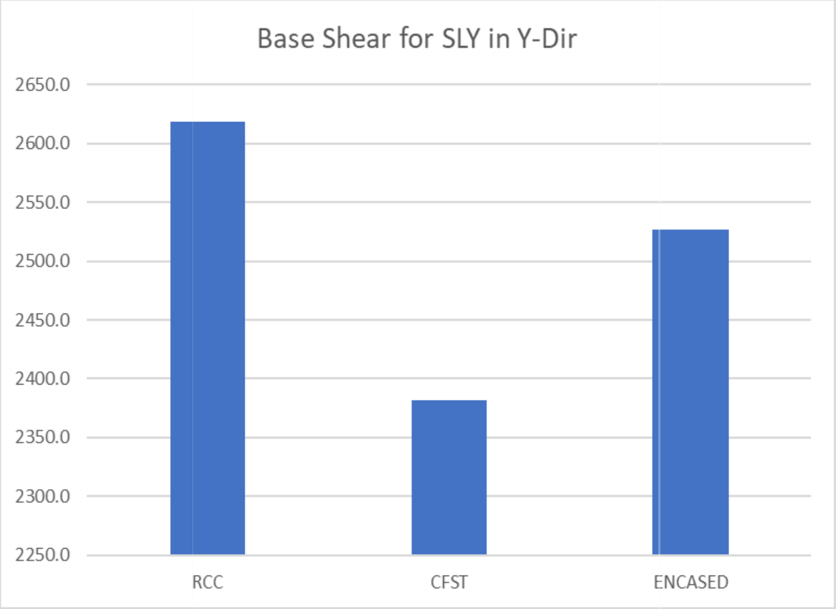


Figure 11. Base Shear For Sly In Y-Direction

The beam force comparison and column force comparison is reflected in Table 6 and Table 7 respectively.

Table 5. Beam Force Comparison

LOAD COMBINATION				**1.2DL+1.2LL+1.2SLX**				
ACTION	STOREY LEVEL	MAX VALUE FOR RCC		MAX VALUE FOR CFST		MAX VALUE FOR ENCASED		REMARK
		END 1	END 2	END 1	END 2	END 1	END 2	
AF	TOP	9.07	9.07	5.95	5.95	7.7	7.7	**AF in beam is not considered**
	MIDDLE	-1.63	-1.63	-0.99	-0.99	-0.072	-0.072	
	BOTTOM	2.15	2.15	0.67	0.67	1.32	1.32	
SF	TOP	A	125.2	-63.75	114.82	-73.83	123.6	**SF decreases from top to bottom**
	MIDDLE	-64.39	142.83	-59.75	129.75	-62.32	134.72	
	BOTTOM	-39.86	167.26	-31.23	149.27	-41.69	155.04	
BM	TOP	-198.2	92.35	-189.3	84.9	- 196.23	90.18	**BM is higher in bottom and lesser in top**
	MIDDLE	-261.23	110.28	- 254.23	106.089	- 246.61	101.46	
	BOTTOM	-349.25	116.56	- 337.37	135.43	- 321.68	- 131.62	
TM	TOP	0.029	0.029	0.055	0.055	0.0257	0.0257	**M is negligible**
	MIDDLE	0.016	0.016	-0.036	-0.36	- 0.0062	- 0.0062	
	BOTTOM	0.0041	0.0041	-0.016	-0.016	- 0.0035	- 0.0035	

All Action are lesser for CFST and Encased when compared to conventional RCC

Table 6. Column Force Comparison

Load Combination				1.2dl+1.2ll+1.2slx				
ACTION	**STOREY LEVEL**	**MAX VALUE FOR RCC**		**MAX VALUE FOR CFST**		**MAX VALUE FOR ENCASED**		**REMARK**
		END 1	**END 2**	**END 1**	**END 2**	**END 1**	**END 2**	
AF	TOP	213.97	179.79	178.64	164.78	200.74	161.25	AF increase from top to bottom
	MIDDLE	997.62	962.83	836.22	822.36	953.23	953.27	
	BOTTOM	1848.23	1848.23	1563.66	1549.54	1798.32	1798.23	
SF	TOP	-76.23	-76.23	-56.75	-56.75	93.21	93.21	SF decreases from top to bottom
	MIDDLE	19.117	19.117	10.71	10.71	18.34	18.34	
	BOTTOM	36.78	36.78	23.67	23.67	36.51	36.54	
BM	TOP	-139.23	49.08	-87.4	56.67	-136.34	27.35	BM increase from top to bottom
	MIDDLE	-18.31	-65.23	-2.23	-29.49	-9.24	-24.31	
	BOTTOM	23.12	-68.73	24.58	-35.46	-19.49	-59.32	
TM	TOP	0.2542	0.2542	0.023	0.023	1.48	1.48	TM is negligible
	MIDDLE	0.0043	0.0043	0.0021	0.0021	-0.087	-0.087	
	BOTTOM	0.132	0.132	0.558	0.558	0.048	0.048	

All Action are lesser for CFST and Encased when compared to conventional RCC

4. Conclusion

The study reveals several key advantages of steel-concrete composite columns over traditional reinforced concrete (RCC) columns. Both Concrete-Filled Steel Tubular (CFST) and Encased Column models demonstrate a notable reduction in self-weight by 11.2% and 4.45%, respectively, compared to RCC columns. Additionally, the axial force distribution indicates that internal columns experience greater forces than external ones across both traditional RCC and composite columns. However, the CFST and Encased Column models show a significant reduction in axial force, by 16.03% and 4.5% respectively, relative to RCC columns. The CFST model also shows a 9% reduction in base shear, while the Encased Column model shows a 3.5% reduction. Storey drift, although higher in the Encased model compared to both CFST and RCC models, remains within the specified code limits.

Furthermore, lateral loads on stories due to seismic forces are reduced by 6.67% in the CFST model and 5% in the Encased Column model compared to RCC. The inherent ductility of steel-concrete composite structures enhances their performance under earthquake conditions, making them a more resilient option than RCC structures. The construction of composite structures is also more time-efficient, owing to the rapid erection of the steel frame and reduced formwork requirements for concrete. Overall, the findings suggest that steel-concrete composite construction is not only more economical for high-rise buildings but also enables faster construction processes, making it a preferable alternative to traditional RCC construction.

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