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Comparative Behaviour Of RCC And Composite Frame Building

Khetal Jeevan Oswal*[1], Dr. M. R. Shiyekar*[2].

*[1]PG Student, Applied Mechanics Department, Government College of Engineering, Karad, Maharashtra, India.

*[2] Adjunct Professor, Applied Mechanics Department, Government College of Engineering, Karad, Maharashtra, India.

Abstract

The rapid urbanization and demand for high-rise buildings have emphasized the need for efficient structural systems. Reinforced Cement Concrete (RCC) structures, although widely used, pose limitations in terms of self-weight and construction speed. Composite structures, integrating steel and concrete, offer significant benefits in strength-to-weight ratio, construction efficiency, and seismic performance. This study presents a comparative analysis of RCC and steel-concrete composite frame systems for a G+10 story building. Key performance parameters such as structural weight, time period, base shear, maximum story displacement and story drift are evaluated. Material consumption for both steel and concrete is estimated, followed by a cost comparison to highlight economic feasibility. The analysis is carried out using ETABS with Response Spectrum method under seismic zone III.

Keywords: RCC, Composite, structural weight, time period, base shear, story displacement, story drift, cost comparison, Response Spectrum

1. INTRODUCTION

Modern construction trends demand faster execution, higher load-bearing capacity, and better performance under dynamic loads. Conventional RCC structures are robust and time-tested but often lead to larger member sizes and heavier sections, impacting architectural flexibility and increasing seismic forces. To address these limitations, composite construction emerges as an innovative solution, leveraging the combined advantages of steel and concrete. Composite construction integrates steel and concrete elements to form unified structural members. The steel provides high tensile strength, while concrete resists compressive forces. This synergy results in reduced member sizes, faster construction timelines, and improved load-carrying capacity.

Composite Columns: Composite columns typically consist of a steel section encased in reinforced concrete or concrete-filled steel tubes. This configuration enhances axial load capacity and stiffness, contributing to better seismic performance and fire resistance.

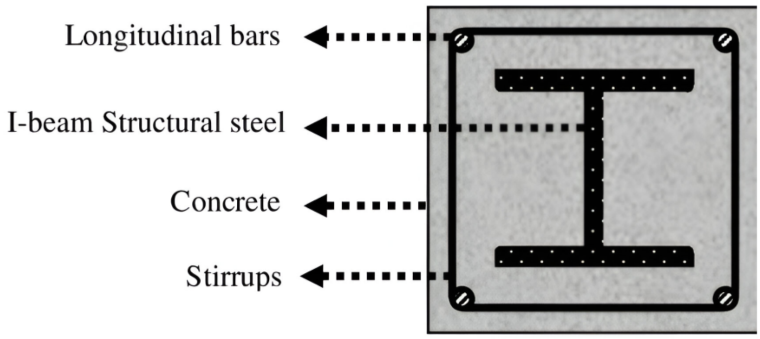


Figure 1.1: Composite Column

Composite Deck Slab : The composite floor system comprises a rolled or built-up steel beam connected to a cold formed steel deck with concrete topping. Decking with deformed ribs known as embossed decking is commonly used. The deformations on the ribs allow for a stronger bond between the concrete and the decking. Concrete slab thickness must be more than or equal to 2.5 inches above steel deck. Shear connectors ensure effective interaction between the steel and concrete components.

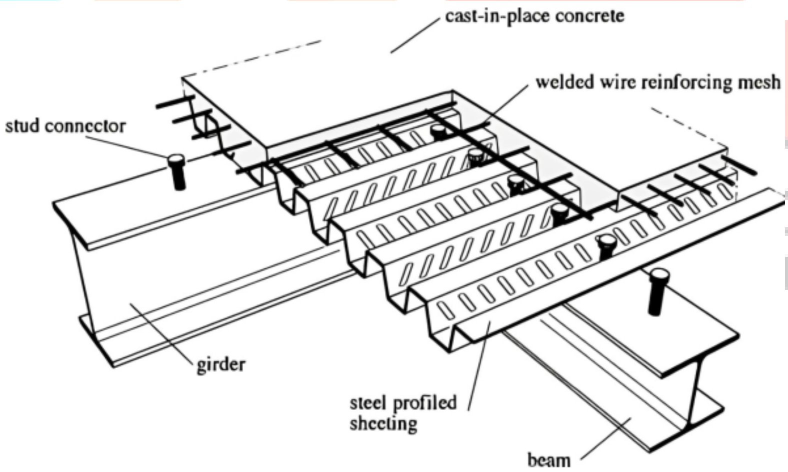


Figure 1.2: Composite Deck Slab

2. METHODOLOGY

The study involves a comparative analysis of a multi-storey building designed using two structural systems: Reinforced Cement Concrete (RCC) and Steel-Concrete Composite. The building model was developed in ETABS software as per IS 1893:2016 guidelines. Both RCC and composite frames were designed for the same plan, geometry, and loading conditions to ensure consistency. Response Spectrum Method was adopted to perform seismic analysis, accounting for dynamic behaviour under lateral loads. Structural parameters such as self-weight, time period, base shear, storey displacement, and storey drift were extracted and compared. Composite sections used composite columns, composite deck slab with steel beams, while RCC used conventional beam-column elements. The primary objective was to evaluate seismic performance, structural efficiency, and material optimization between the two systems

3. STRUCTURAL MODELING AND ANALYSIS :

3.1 General

Response Spectrum Analysis in ETABS is a dynamic analysis method used to evaluate a structure's behavior under seismic loading. It considers the structure's natural frequencies and mode shapes to estimate peak responses due to ground motion. ETABS automates this process by generating and applying response spectra as per relevant codes making it efficient for seismic design of buildings.

3.2 General Description of Building:

The building used for analysis is a G+10 story commercial building situated in seismic zone III. The plan area of building is 33.36 meters long and 24.06 meters wide. Typical story height is 4 meters and total height of building is 47 meters.

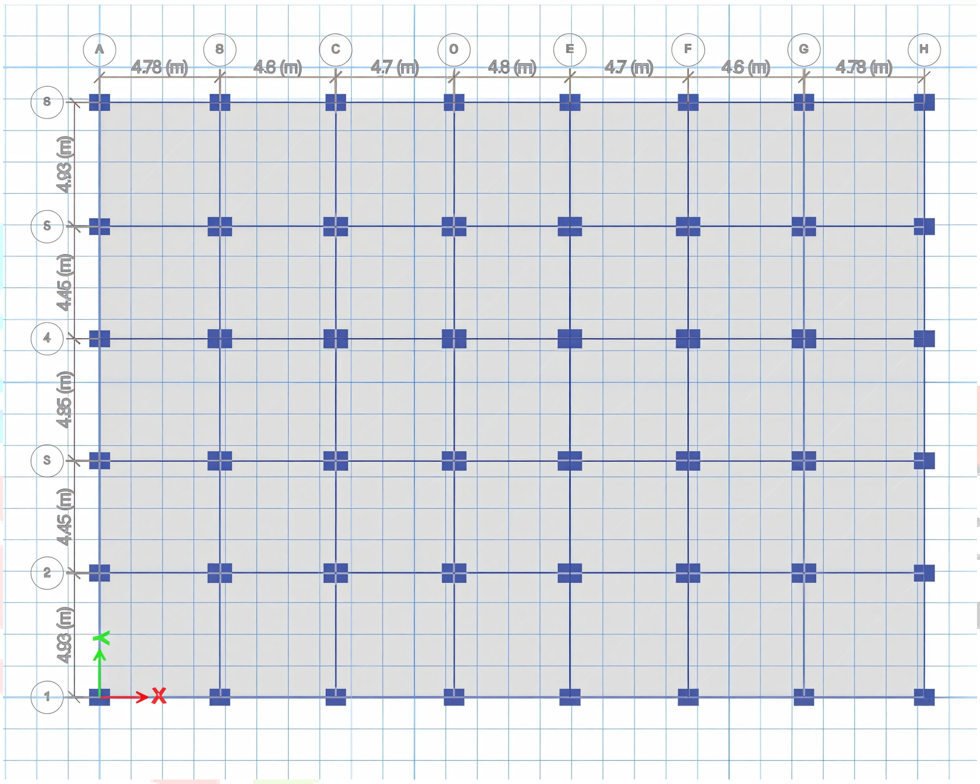


Figure 3.2.1: Plan view

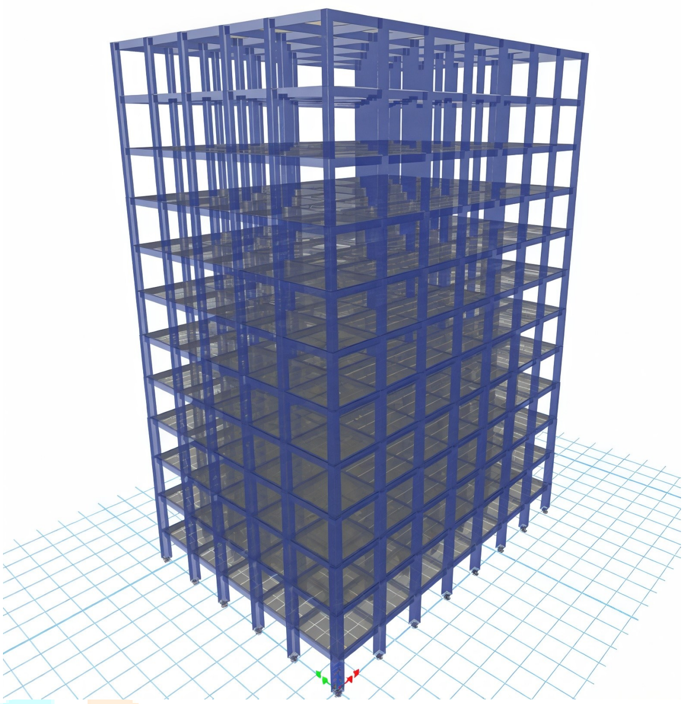


Figure 3.2.2: Three Dimensional view

3.3 Basic Data:

1. Building Configuration = G+10
2. Plan dimensions of building = 33.36 x 24.06
3. Number of bays in X-direction = 07
4. Number of bays in Y-direction = 05 Base Story height = 3 m
5. Typical Story height = 4 m
6. Height of building = 47 m

3.4 Applied Loads:

1. Dead Load : Program calculated
2. External wall load (230 mm) : 18.4 KN/m
3. Internal wall load (150 mm) : 12 KN/m
4. Super dead load : 1.5 KN/m^2
5. Live Load : 3 KN/m^2
6. Wind Load Data :

- Basic wind speed : 44 m/s
- Terrain category : 3
- Building Height : 47 m
- Design Wind Pressure: Pz = 0.6 x Vb^2 = 0.6 x 44^2 = 1161.6 N/m2 = 1.1616 KN/m2

1. Seismic Load Data :

- Seismic Zone III (Z = 0.16)
- Importance Factor (I) = 1.0
- Response Reduction Factor (R) = 5.0
- Soil Type : Medium (Type 2)

3.5 Material properties:

1. Grade of concrete : M30
2. Grade of steel : Fe500
3. Grade of Steel section : Fe250
4. Grade of steel deck : Fe250

3.6 Section properties:

3.6.1 Column section properties:

Designation	RCC		Composite		
	Dimensions (mm)	Steel reinforcement	Dimensions (mm)	Steel section	confinement reinforcement
C1	950 x 750	2.06	650 x 550	ISHB 450	0.67
C2	800 x 650	2.07	650 x 500	ISHB 450	0.73
C3	750 x 600	1.95	550 x 500	ISHB 400	0.53
C4	650 x 500	2.12	500 x 450	ISHB 350	0.52
C5	550 x 500	2.05	450 x 400	ISHB 300	0.62
C6	500 x 450	1.95	400 x 380	ISHB 225	0.53

Table 3.6.1.1 : Column section properties

3.6.2 Beam section properties:

1. For RCC : 300 x 450 mm
2. For Composite : ISHB 300

3.6.3 Slab section properties:

1. For RCC slab thickness : 150 mm
2. For Composite deck slab :

- Slab dept, tc: 100 mm
- Rib depth, hr: 50 mm
- Rib width top, wrt: 117 mm
- Rib width bottom, wrb: 135 mm
- Rib spacing, Sr: 317 mm
- Deck shear thickness: 1 mm
- Deck Unit Weight: 0.11 KN/m^2
- Shear stud Diameter: 19 mm
- Shear stud height, hs: 150 mm
- Shear stud Tensile strength, Fu: 400 N/mm^2

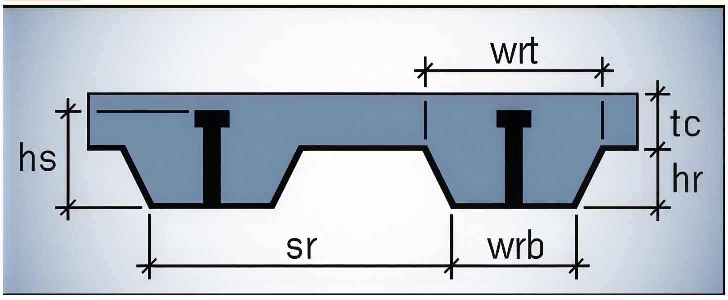


Figure 3.6.3.1 Composite deck slab parameters

4. ANALYSIS AND RESULTS:

4.1. Base shear:

- Base shear is the total horizontal force at the base of a structure caused by ground motion during an earthquake. It represents the overall seismic load the building must resist and is critical in structural design.

- **For RCC frame building :**

Direction	Z	I	R	Time period (seconds)	Coefficient used	W (KN)	Base shear (KN)
X	0.16	1	5	1.548	0.0145053	76996.5724	1082.362
Y	0.16	1	5	1.683	0.012926	76996.5724	995.2225

Table 4.1.1 Base shear data for RCC building

- **For Composite frame building:**

Direction	Z	I	R	Time period (seconds)	Coefficient used	W(KN)	Base shear(KN)
X	0.16	1	5	2.25	0.011	52624.498	578.8695
Y	0.16	1	5	2.435	0.011	52624.498	534.7625

Table 4.1.2 Base shear data for Composite building

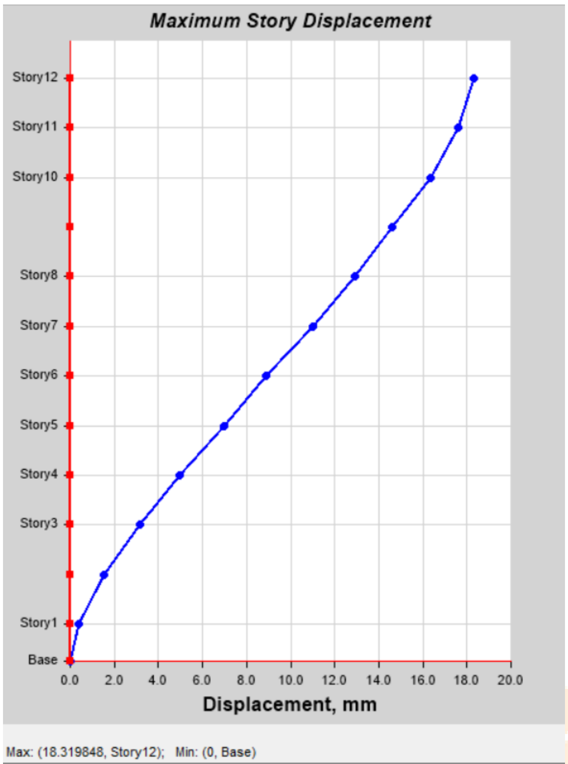
4.2. Story Displacement and story drift :

1. Maximum story displacement (Top story displacement with respect to base story) :

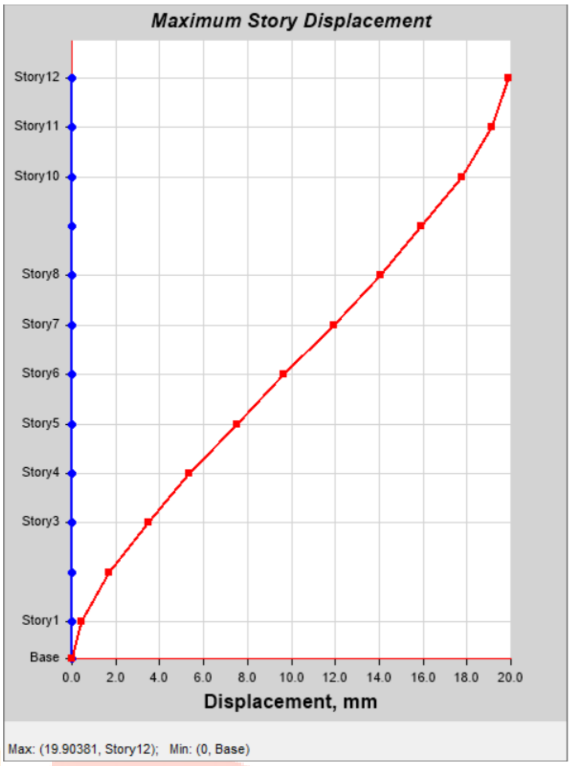
- RCC building : X-direction - 18.319 mm, Y-direction - 19.90 mm
- Composite building : X-direction - 28.927 mm, Y-direction - 33.42 mm

2. Maximum Story Drift : (Relative lateral displacement between two story) :

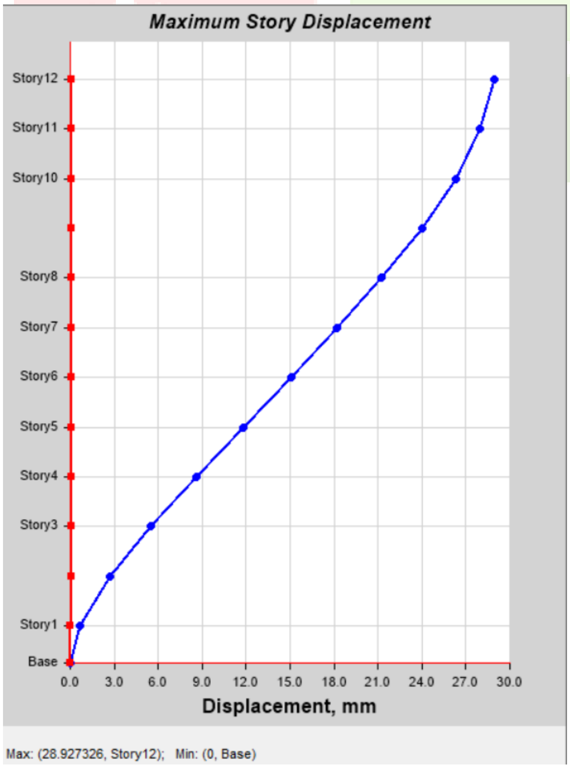
- RCC building : X-direction - 2.1 mm (story 7), Y-direction - 2.307 mm (story 7)
- Composite building : X-direction - 3.284 mm (story 6), Y-direction - 3.691 mm (story 6)
- Allowable story drift (relative lateral displacement between two story) : H/250 = 4000/250 = 16 mm
- All values of story drift are within allowable limit.



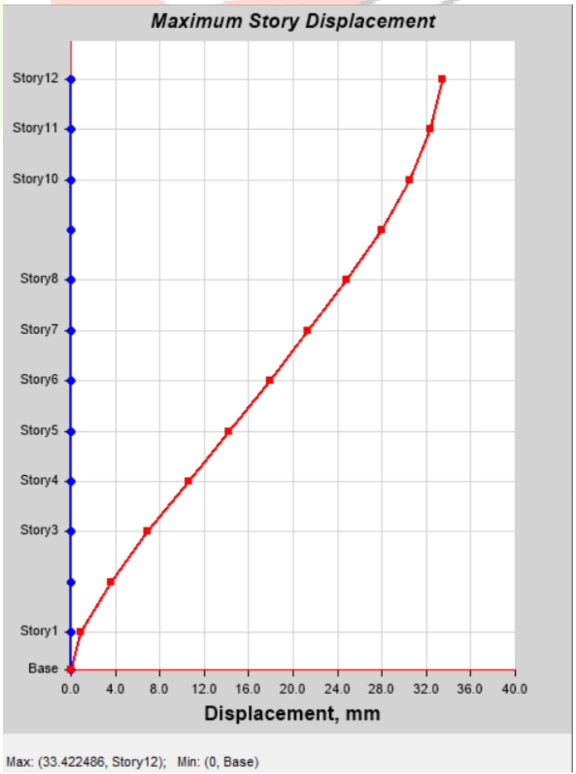
Graph 4.2.1. Maximum story displacement in X-direction for RCC building



Graph 4.2.2. Maximum story displacement in Y-direction for RCC building



Graph 4.2.1. Maximum story displacement in X-direction for Composite building



Graph 4.2.2. Maximum story displacement in Y-direction for Composite building

5. Comparison of results for RCC and Composite frame building:

5.1. Comparison of seismic parameters:

Parameters	Direction	RCC	Composite
Self weight (KN)	X	76996.5724	52624.498
	Y		
Time period (seconds)	X	1.548	1.683
	Y	2.25	2.435
Base shear (KN)	X	1082.362	578.8695
	Y	995.2225	534.7625
Maximum story displacement (mm)	X	18.319	28.927
	Y	19.90	33.42
Maximum story Drift (mm)	X	2.1 (story 7)	3.284 (story 6)
	Y	2.307 (story 7)	3.691 (story 6)

Table 5.1. Comparison of seismic parameters for RCC and Composite frame building

5.2. Comparison of Material quantities:

Material	RCC	Composite
Concrete	65392.63 KN	31565.18 KN
HYSD 500 Bars	4641.83 KN	952.196 KN
Steel section	0	4134.332 KN
Steel deck	0	903.72 KN

Table 5.2.1 : Comparison of material quantities for RCC and Composite frame building

5.3. Cost Comparison:

Material	RCC	Composite
Concrete	1,74,38,034 Rs	86,84,048 Rs
HYSD 500 Bars	3,41,03,240 Rs	69,88,594 Rs
Steel Section	0 Rs	2,52,86,434 Rs
Steel Deck	0 Rs	62,60,604 Rs
Total	5,15,41,274 Rs	4,72,19,680

Table 5.3.1 : Cost comparison of RCC and Composite frame building

6. CONCLUSION

1. **Enhanced space efficiency through smaller sections :** With present structural design, composite columns were reduced in size by 25-30 % in comparison to RCC columns. This allows for more usable floor space, improved aesthetics, and grater design flexibility, especially beneficial in modern multi story buildings.
2. **Significant Weight Reduction:** In comparison wit RCC structure, the composite structure exhibited a 31.65% reduction in self-weight (from 76996.57 kN in RCC to 52624.50 kN in Composite), which directly contributes to lower seismic forces and improved structural efficiency.
3. **Base Shear Reduction:** In comparison with RCC structure, the composite structure showed a substantial decrease in base shear (X-direction: from 1082.36 kN to 578.87 kN and Y-direction : from 995.225 KN to 534.7625 KN), resulting in lower lateral seismic forces.
4. **Time period :** In comparison with RCC structure, Composite structure showed slightly higher time periods in both X and Y directions, indicating increased flexibility under seismic loads.
5. **Comparable Lateral Performance:** Although the composite structure showed slightly higher story displacement and drift values as compared to RCC structure, the difference remains minor and well within acceptable limits, indicating the composite structure maintains comparable lateral performance to RCC, while still benefiting from reduced seismic forces and structural weight.

6. **Reduction in concrete quantity and weight :** As compared to RCC structure, Concrete weight in the composite structure was cut by more than 50% (from 65392.63 KN in RCC to 31565.18 KN). This not only lightens the structure but also contributes to cost savings and smaller environmental footprint.
7. **Cost Efficiency with comparable total cost :** Despite incorporating steel sections and decking, the composite structure had a slightly lower cost (Rs 4.72 Cr) compared to RCC (Rs 5.15 Cr). Efficient use of steel and reduced concrete quantity contribute to this economic advantage

7. Concluding Remarks:

In conclusion, the comparative analysis between RCC and composite structure reveals clear advantages in adopting composite systems for modern multi-storey buildings. The most notable benefit is the substantial reduction in overall structural weight, leading to lower seismic forces and improved performance during earthquakes. Additionally, the composite design proves to be cost-effective despite involving steel sections, primarily due to the reduced use of concrete. The increased flexibility, indicated by higher time periods, makes the structure more resilient under dynamic loading. Moreover, the drastic reduction in concrete volume contributes to sustainability by lowering material consumption. Smaller column sizes in composite design further enhance the usable floor space and offer greater architectural freedom. These factors collectively highlight the practicality and efficiency of composite construction. While initial design and detailing may be more complex, the long-term structural and economic benefits are significant. Thus, composite systems offer a balanced solution of strength, flexibility, and efficiency. They are well-suited for the demands of contemporary high-rise construction.

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