Analytical Investigation of Composite Structure in Comparison of RCC Structure

Vrunda R Laddha¹, Sharda P Siddh², Prashant D Hiwas³

¹Structural Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur.
Email: vrundaladdha100@gmail.com
²,³Assistant Professor, Department of Civil-Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur.

ABSTRACT. High rise structures becoming very common everywhere due to scarcity of land and increasing population. Though we have RCC structure system as high-rise buildings, but in RCC buildings due to bulky size of the components of the structure self-weight will be more due to the heavy density of materials. By observing the difficulties and challenges in the field of high-rise structures engineers are using efficient structural system that is Steel Concrete Composite Structure. Composite structure consists composite deck slab, composite beam and composite column. Composite Structure complies of Concrete which is good in compression and structural steel which good in tension and composition of these material makes structure better in ductility which comparatively on higher side than RCC structure. Here G+7 high rise structure is considered for analysis by ETABS software. This paper involves Analysis of Commercial building by Equivalent static method on Composite structure and RCC structure with same plan of building and same design data. The structure is in earthquake zone III and wind speed 44m/s. Analytical comparisons of both Composite and RCC frame based on structural parameters are made with help of graphs and tables. By comparing the results, we found that Steel-Concrete Composite Structures are more desirable than RCC structures.

Keywords: Composite structure, Composite slab, Composite beam, Composite column, Shear connectors, ETABS.

1. Introduction

Worldwide different types of RCC, Steel and Composite steel concrete structures with various floor systems are used for multistorey buildings. There is a great prospective for increasing the volume of steel in construction industry, especially in India. Since the population in cities is increasing rapidly and the land is limited, there is a need of vertical growth of buildings in cities. So, for the fulfillment of this purpose a large number of mediums to high rise buildings are being constructed on a large scale. For medium to high rise buildings, the conventional RCC structures is not excellent choice as there is increased dead load along with the span restrictions and consuming more time to construct. This study gives a brief description of various components of steel-concrete composite structure. Comparative analysis of composite frame and RCC frame was carried out by using ETABS software.

The cost comparison of composite design structure is more economical in case of high-rise buildings and construction is speedy [1]. In composite structure due to high ductile nature of steel it leads to increased seismic resistance of the composite section [2]. “Literature study summarise that the composite sections using steel encased and concrete infilled are economical option if design well and time effective solution in major civil structures such as bridges, warehouses and high-rise buildings”.

1.1 Composite structures

Composite structures are those which is made up of two different materials are bound together strongly that they act together as a single unit from a structural point of view. When a steel component like an I-section beam is attached to a concrete component such that there is a transfer of forces and moments between them, such as a deck slab, then a composite member is formed. Composite structures are
gaining popularity due to its fast construction time, comparatively less weight, provide large column to
column distance and unique design.
Advantages associated with steel-concrete composite construction:
• The most effective use of steel and concrete is achieved.
• Because of larger stiffness of composite beams, it has lesser deflection than steel beams.
• Composite construction done with fast-track construction because of using rolled steel.
• Saving in steel weight about 30% to 50% over non-composite structure.
• It offers considerable flexibility in design, pre-fabrication and construction scheduling in congested
areas.

2. Elements of composite structure

2.1 Composite slab: Composite floor is the general term used to denote the composite action of steel
beams and concrete or composite slab that form a structural floor. When concrete hardens it will
combine structurally with profiled steel sheet to form a composite element. Behaviour of composite slab
depends on deck profile, thickness of steel sheet, material properties, span length, construction details,
etc.

![Figure 1: Components of Profiled Composite Slab](image1)

Advantages of Composite Slab:
• Supports loads during construction and acts as a working platform.
• Concreting can be done in more than one floor which leads less time consumption.
• No need of formwork and scaffoldings.
• Acts as transverse reinforcement to the composite beams.
• Distributes shrinkage strains, thus preventing serious cracking of concrete.

2.2 Shear Connector: It is a headed stud like element which is projected on top flange of steel beam to
transfer shear between composite slab and steel girder. The main purpose of the head of the stud is to
prevent uplift. The modern method of attaching shear studs in composite buildings is by through-deck
welding.

2.3 Composite beam: Composite beam is a series of parallel T-beams with thin wide flanges. The
concrete flange is in compression and steel beam is largely in tension. Composite beam is subjected
mainly to bending, under load each component of structure acts independently with relative movement
or slip occurring at the interface. Composite beams have less depth than non-composite beams and often
are used in structures having long spans.
Advantages of Composite beam:
3. Composite beams have higher stiffness; thus, it has less deflection.
4. It can cover for large space without the need of any intermediate columns.
5. No need of formwork and scaffolding so that more economical steel section is achieved.

2.4 Composite column: It is a compression type member which comprise steel sections with a concrete encasement or core. It has mainly two types:

a) Concrete encased in steel section, and  
b) Concrete filled steel tube section (CFST Column)

Encased columns usually consist of standard I-section or H-section with a rectangular or square concrete section encasement to form a solid composite section.

Concrete filled columns consist of circular, square and rectangular, hollow sections which is filled with concrete. It uses the advantages of both steel and concrete. It is used in many structural applications, especially for columns in high-rise buildings and bridge piers. Infill concrete in steel tube delays local buckling and improves compression stress and durability. The size of this column is smaller, so that increases the usable floor area.

Advantages of Concrete filled composite column:

- Composite column increases strength for a given cross-sectional area.
- It eliminates the need of formwork.
- Increased column and beam capacity.
- Increased stiffness and ductility.

3. Details of Composite frame and RCC frame:

The structure considered here is a Commercial 8 storey (G+7) building with plan dimension 28m x 20m and height of structure is 28m. Study is carried out for the same building plan of both Composite frame and RCC frame with all loadings on structure are kept same.
Table 1: Design data for both the structures

| Type of building | Commercial Building (G+7) | Density of concrete | 25 kN/m³ |
|------------------|---------------------------|---------------------|----------|
| Plan Dimensions  | 28 x 20 m                 | Density of AAC block wall | 700 kg/m³ |
| Total height of the structure | 28 m | Live load at floors | 4 kN/m³ |
| Height of each storey | 3.5 m | Floor finish | 1 kN/m² |
| Height of parapet | 1 m | Seismic zone | III |
| Thickness of the slab | 125 mm | Wind speed | 44 m/s |
| Thickness of external walls | 200 mm | Importance factor | 1 |
| Thickness of internal walls | 150 mm | Zone factor | 0.16 |
| Grade of Concrete | M30 | Soil condition | Medium soil |
| Grade of reinforcing steel | Fe500 | Damping ratio | 5% |
| Grade of Structural steel | Fe345 | - | - |

Table 2. Structural Member Sizes of the Structures

| Member       | RCC                  | COMPOSITE                      |
|--------------|----------------------|--------------------------------|
| Column       | 400mm x 1000mm       | HSS (300 x 400 x 16) mm        |
|              | 400mm x 900mm        | HSS (300 x 400 x 12) mm        |
|              | 350mm x 850mm        | HSS (300 X 350 X 12) mm        |
| Beam         | 300mm x 500mm        | ISMB 450                       |
|              | 300mm x 450mm        | ISMB 400                       |
|              | 300mm x 400mm        | ISMB 350                       |
| Slab         | RCC Slab with 125 mm thickness | Composite deck slab with 125mm thickness |

Note: HSS - Hollow Structural Section (HSS sizes taken from AISC steel construction manual)
4. Analysis of Structure:

The 3D model of structure is analysed using “Equivalent Static Method” on ETABS 16 software. In composite structure, composite slab is designed as per BS 5950: Part 4 [5] and composite beam as per BS 5950: Part 3 [6] while column is modelled as concrete filled steel tube as per AISC 360-16 code [7]. RCC structure analysed as per IS 456:2000 [9]. The dead, live and wind load are considered as per IS:875 (Part 1), IS:875 (Part 2) and IS - 875 (part 3): 2015 [10] and for earthquake loading IS:1893 (Part 1) - 2002 [11] is used.

5. Results and Discussion:

a) **Axial Forces on Column Base of the Structure:** Maximum Axial Force on Column base due to DL + LL is given below. The lateral forces acting on a composite structure are about 18% to 33% lesser than RCC structure shown in fig.6.

b) **Storey Stiffness:** The graph shows that composite frame gives significantly less value about 45% to 70% of stiffness as compared to RCC frame because of lesser dimensions of column cross sections used in the Composite structure as compared to RCC shown in fig.7.

![Figure 4: Plan of the Structure](image)

![Figure 5: 3-D Model of Structure](image)

![Figure 6: Comparison of Axial Forces on Column Base of the Structure](image)

![Figure 7: Storey Stiffness Comparison](image)
c) **Storey Displacement:** Story displacement is on higher side for the Composite Structure due to its lower stiffness is about 3% to 20% more than the RCC structure shown in fig.8.

d) **Storey Drift:** The storey drift value obtained by equivalent static method in X-direction is about 14% to 35% more for composite structure shown in fig. 9. RCC structure has lower values of storey drift because of its higher stiffness.

e) **Storey Shear:** Storey shear is about 54% to 60% lesser for composite structure as compared to RCC structure it is because of its lower self-weight of RCC structure, shown in fig. 15.

f) **Bending Moment and Shear force of Column:** Form the software results composite column has significantly less value of shear force and bending moment for same column as compared to RCC column, shown in fig. 10 and fig. 11.
Figure 11: Column (C24) of RCC frame

g) **Bending Moment, Shear force and Deflection of Beam:** From the results it is clear that the composite column has significantly less value of shear force, maximum bending moment and deflection for same column as compared to RCC column, shown in fig. 12 and fig. 13.

Figure 12: Beam (B70) of Composite frame
**h) Total weight of Structure:** Weight of the Composite frame is much lesser than the RCC frame because of smaller cross section of structural elements used in composite frame. Total weight of structure of composite frame is 47% lesser than RCC frame shown in fig. 14.

![Diagram](image-url)  
**Figure 14: Comparison of Total Weight of Structure**

![Diagram](image-url)  
**Figure 15: Comparison of Storey Shear**
5. Conclusions
From analytical results of Composite structure and RCC structure, it is concluded that:
1. Bending moment, shear force and deflection values of Composite structure are quite less for the same loadings compared with RCC structure, which ultimately results in reduced dimensions of beams and columns in Composite structure.
2. Due to inherent ductility characteristics of steel, Composite structure performs better than RCC structure under earthquake consideration.
3. Weight of Composite structure is quite lower for Composite structure hence it will reduce foundation cost.
4. Composite structure is best suited where there is need of faster construction, having more usable space with longer span and for site situated in earthquake prone region.

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