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Comparative Study on Multi-storey Structure of R.C.C and Composite Material

A. Sattainathan Sharma*, R. Anjughap Priya, R. Thirugnanam and P. Rathna Priya

Department of Civil Engineering, Valliammai Engineering College, Kattankulathur - 603 203, Tamil Nadu, India; livic.nathan@gmail.com, anjughappriya@gmail.com, yoursthirugnanam@gmail.com, rathna4396@gmail.com

Abstract

Background/Objectives: Steel-concrete composite system of construction has widely accepted all over the world as a novel, alternate and additional method of construction over the existing conventional pure steel and concrete construction. In India, this new concept is under the verge of popularity and also most of the building structures were built as low rise buildings. Composite construction combines dynamic properties of steel and concrete at its maximum extent to provide appreciably a greater strength and stability for the framed structures. The major objective of this paper is to compare a framed structure made by Reinforced cement concrete and Composite material located in earthquake zone of IV (G+20 storey) with the plan dimension is 30m x 24m. Various aspects like story displacement, story drift, deflection and stiffness were studied and compared. **Methods/Statistical analysis**: The method of Equivalent Static analysis has been preferred in the current scenario of analysis. For the seismic analysis (IS-1893-2002), SAP2000 software has been used. By using Extended-three dimensional Analysis of Building Structure (E-TABS) software. **Findings:** The wind force effect and seismic response of steel-concrete composite frames are in the desired limit in comparison with R.C.C structures. On comparison of the framed structures, the R.C.C structure imposes more dead load and carry higher bending moment. From the analysis results, its clearly shows that the inter storey drift for composite structure is comparatively more than RCC structure in both transverse and longitudinal direction but are accepted to be in desired (permissible) limits. It has been found from the study that use of composite members in construction is more effective and economic than using reinforced concrete members. The overall performance of manufacturing and construction techniques is improved to higher extent by the usage of composite materials in construction. **Applications/Improvements**: Composite structures are found to be the best mode of construction for high-rise building while comparing with the conventional R.C.C structures as they serve well for various parameters like deflection, stiffness, story drift and lesser dead weight.

Keywords: Composite, High-rise Structures, R.C.C, Shear Connectors, Seismic Response

1. Introduction

Reinforced concrete structures have been satisfying greater demands in civil & structural engineering sector for more than 3-4 decades. The applications and usages of R.C.C in large numbers in structural as well as architectural view, stands as a witness and demonstrated its versatility very well. Composite construction is formed when two heterogious materials are binded together effectively so that they act together as a single element from a structural point of view[1]. When this occurs, it is called composite action. In developing countries like India, most of the building structures fall under the category of low rise buildings[2]. So, these conventional Reinforced cement concrete and pure sectional Steel constructions proves to be convenient and economical in nature hence widely used all around. But when it comes to the need for vertical growth of buildings due to lack of land-space area and rapid growth of population, medium to high-rise buildings emerges as a solution to full-fill this need.

In recent trend, the composite mode of construction has gained several advantages in comparison with the conventional system construction[3]. Composite construction marries both steel and concrete (i.e.) it clubs the dynamic

**Author for correspondence*

properties of both the material (concrete in compression and steel in tension) and also have same thermal expansion which ends up in fast-track construction. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material[4]. Increasing the volume of Steel in construction of building structures is what developing countries like India need at this decade. Engineers are familiar with the problems involved in constructing either steel or concrete building, as each of these materials has its own peculiarity[5]. Steel structural members are generally fabricated as component consisting of thin plate and shell elements, so on loading, they are subjected to local and lateral buckling. Therefore, there is need for check against the failure due to buckling and instability, while concrete structural elements are generally thick enough and less prone to buckle; but they are subjected to creep and shrinkage with time. Hence, a novel technique called steel-concrete composite construction emerged so as to bind up the dynamic properties of both the materials. For framed structural systems, steel-concrete composite system of construction proved to be the most economical solution to necessarily meet the engineering design requirements of stiffness and strength.

1.1 Objective of the Study

Steel-concrete composite construction is familiar at present owing to their advantages to the traditional and conventional construction. Composite construction binds the dynamic properties of concrete, which was strong in compression and steel, which was strong in tension, and also the thermal expansion and its co-efficient factor seems to be same in most cases and hence results in fast track construction. The objectives of the study are to investigate major parameters like story drift, storey displacement, wind effect and seismic response of steel-concrete composite frames over traditional reinforced concrete frames.

2. Materials and Methods

2.1 Composite Construction

Steel-concrete composite construction defines structural steel sectional element encased in concrete (or) concrete filled steel tublars in case of columns and the Reinforced cement concrete deck slab (or) profiled deck slab is made connected to the steel sectional beam by means of shear connectors(mechanical) so that the two components will act together as a single component. Many structural engineers in indian scenario are not welcoming the use of steel-concrete composite buildings because of its unfamiliarity, lack of awareness and its analysis and design seems to be little complex[6]. But literature quotes that if proper configuration is adopted, then steel-concrete composite structures can provide effective and economical systems of structural frame with greater stability & durability, rapid erection and effective seismic performance characteristics[7]. The real attraction of composite construction is based on having an effective connection between structural steel and reinforced concrete, and it is this connection that allows a transfer of forces and gives composite members their unique behaviour.

2.2 Elements of Composite Construction

2.2.1 Composite Beam, Slab and Shear Connectors

A steel-concrete sectional composite beam is fabricated with the help of a steel beam sandwiched over a reinforced concrete slab is cast by using an element called shear connectors. The overall depth of the beam is decreased by the effective composite action between steel beam and concrete slab. The overall depth of the beam is decreased by the effective composite action between steel beam and concrete slab [4]. Profiled sheeting along with concrete topping either cast in site or else precast reinforced cement concrete slab can also be casted as a composite beam.

2.2.2 Composite Column

Generally, column is considered as a compression member. In this case of composite action, mostly the steel section will act as a structural member. Concrete encased, concrete filled(CFST), battered section are widely used types of composite columns in many countries.

2.2.3 Shear Connectors

Shear connections (Figure 1) are prominent and very essential component for composite construction. Shear connectors improve the load carrying capacity of the element/member and overall rigidity in steel-concrete composite beam[9]. Figure 2 shows the required mechanical shear connectors at the interface. The two primary functions of shear connectors are (a) at the interface of beam and slab, this transmits the shear acting along longitudinal, and (b) helps in avoiding the steel beam and concrete slab splitting at the interface/junction.

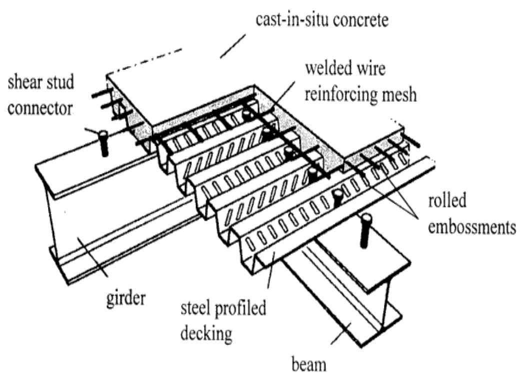

Figure 1: Typical composite beam slab details with shear connectors.

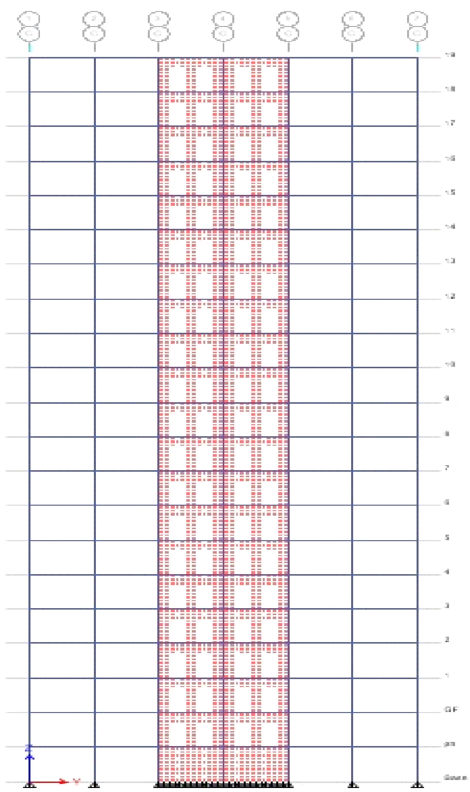

Figure 2: Elevation showing the shear wall.

2.3 Building Details

Figure 3 shows totally five by six bays with a centre-centre distance between two grids as 6m by 4m. For the respective floor plan, the building details are presented in Table.1. and for analysis purpose a commercial building is modeled and analyzed. The dimension of the building as shown in plan is 30mx24m. for the same building plan, a comparative study is carried between Reinforced Cement Concrete and composite system of construction as shown in Figure 4. Loading cases for both the type of structure is assumed to be same.

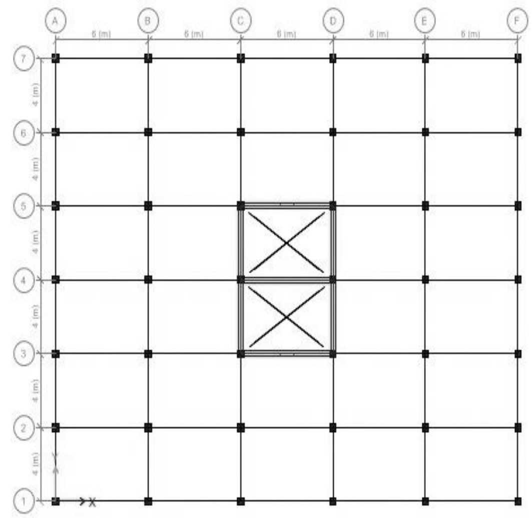

Figure 3. Plan showing typical floor.

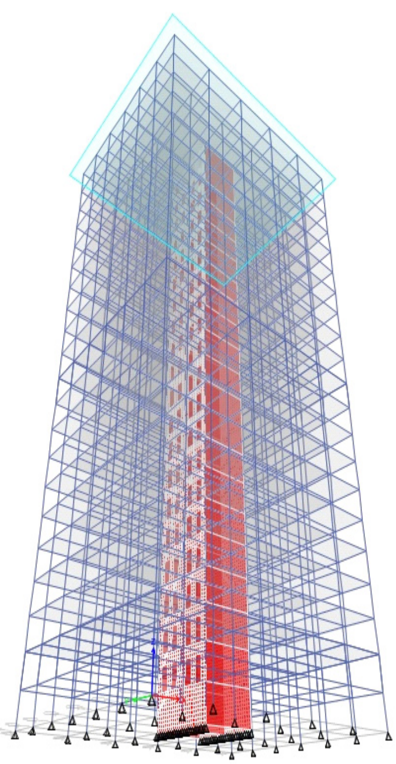

Figure 4. 3-D ground level view from E-TABS.

Table 1. Data for Analysis of RCC and Composite Structure

Particulars	Dimension/ Value for RCC Structure	Dimension/Value for Composite Structure
Plan Dimension	30x24 m	30x24 m
Total height of the building	60 m	60 m
Height of each storey	3 m	3 m
Height of parapet	1 m	1m
Depth of foundation	3 m	3 m
Size of beams L.S beam Size of beams S.S beam	300x650mm 300x450mm	ISMB 450 ISMB 300
Size of outer columns Size of internal columns	450x1000 450x850	CFST element CFST element
Thickness of slab Thickness of walls	140mm 230mm	140 mm with 75-100 mm profiled deck sheeting
Seismic zone Wind speed Importance factor Zone factor Damping ratio	III 50 m/s 1.0 0.16 5%	III 50 m/s 1.0 0.16 5%
Floor finish Live load at all floors Density of concrete Density of brick Density of steel	1.0kN/m^2 4.0 kN/m^2 25 kN/m^3 20 kN/m^3 7850 kg/m^3	1.0kN/m^2 4.0 kN/m^2 25 kN/m^3 20 kN/m^3 7850 kg/m^3
Grade of concrete Grade of reinforcing steel Soil condition	M20 Fe415 hard soil	M20 Fe415 hard soil

2.4 Analysis

The analysis is carried out using equivalent static method for both the type of building. By using Extended-three dimensional Analysis of Building Structure (E-TABS) software, the models of both structures were analyzed. The study parameters were deflection, shear force, bending moment, story drift, stiffness and displacement. Since the design is related to India, for calculation of seismic loads and parameters, Indian standard of code for earthquake resistant design of structures IS 1893 (PART-1): 2002 and IS-875 (PART-3) were referred for values.

3. Results and Discussion

For both R.C.C and steel-concrete composite structures the Equivalent static analysis was done. Also to code, the loads were calculated and distributed as per the code IS1893:2002[11] and the results obtained are compared with various parameters.

3.1 Storey Stiffness

From the analysis it is noted that the transverse and longitudinally storey stiffness for composite structure was large. It was about 10%-12% more in transverse direction and 7%-9% more in longitudinal direction than R.C.C structure

3.2 Lateral Displacement

Displacement in composite structure is slightly higher than that of in RCC structure but it is within the permissible limit by 4% to 5% in longitudinal direction and transverse direction than that in RCC structure.

3.3 Storey Drift

The result shows that the inter storey drift for composite structure is comparatively more than RCC structure in both transverse and longitudinal direction. The storey drift is reduced by 2% to 4% and 3% to 5% in transverse and longitudinal directions respectively.

3.4 Axial Force, Shear Force, Twisting Moment and Bending Moment in Columns

Table 2 depicts that axial force in the composite columns is reduced to 20% - 30% when compared to RCC columns. From Table 2 it was observed that the shear force of composite column is reduced from 28% to 32% in transverse direction and 18% to 23% in longitudinal directions. The bending moment in the columns were found to be

Table 2. Comparison of various parameters RCC and Composite Structure

Comparision Property	RCC	Composite	Reduction, %
Max.Axial Force (kN)	9874.87	7587.08	23.16
Max.Shear Force (kN) x-axis y-axis	166.9 kN 131.1 kN	113.45 100.25	2.05 23.56
Max.B.M (kN.m) (x-axis) (z-axis)	510.4 581.2	434.7 441	14.76 24.12
Weight (kN)	309387.5	239813.8	22.48

reduced to 12% to 24 %. And it is also observed that twisting moments are considered to be negligible and are also reduced by 48% to 63% in transverse direction and 49% to 65% in longitudinal directions for composite structure when compared to that of R.C.C structures. The results show that the axial force in composite column is reduced to 20%-30% than the R.C.C columns. Thus, the axial and shear force is higher in R.C.C columns than the composite columns.

Table 2, clearly shows that by practicing composite materials and composite system of construction has several advantages. Table 2, depicts that the dead load of composite structure varies from 20% - 25%, which is found to be less than the dead load taken by R.C.C structure. This results clearly states that reduction of seismic forces was observed to be 15% to 20% less.

4. Conclusion

This Analysis and design results of G+20 storied Composite, and R.C.C Structure has been studied and represented here. The comparison results of these building models are as follows.

a. The displacement(deflection) and storey drift in R.C.C. Structure is merely less than composite structure but are in permissible limit as precerbied by the codal provisons. It is due to the flexibility of composite structure when compared to RCC structures.
b. The dead weight of composite structure varies from 20% to 25% which is less than RCC structure thus resulting in reduction of seismic forces from 15% to 20%.
c. It was found also that Bending moment in columns of Composite structure is reduced from 12% to 24 %.
d. The Stiffness of the composite structure is found greater when compared with RCC structure.
e. Presents work shows that by using Concrete Filled Steel Tublar (CFST) column in design of tall buildings provides good results when compared to R.C.C and conventional steel building and also economically serve as a better solution for tall buildings.
f. Weight of composite structure is low when compared to R.C.C. structure resulting in reduction of foundation cost.
g. For high rise structures, composite structures are found to be the best mode of construction.

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