Comparative Study on Analysis and Cost of R.C.C. and Steel-Composite Structure

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Abstract: ***The project involves Analysis of a residential building with steel-concrete composite and R.C.C. construction. The proposed structure is a four multistoried buildings of G+9, G+12, G+15, G+18, with 3.0m as the height of each floor. The overall plan dimension of the building is 15m x 9m. The analysis and involves the load calculation, analyzing it by 2D modeling using software STAAD-Pro 2007. Analysis has been done for various load combinations as per the Indian Standard Code of Practice. The project also involves analysis of an equivalent R.C.C. structure so that a cost comparison can be made between a steel-concrete composite structure and an equivalent R.C.C. structure.***

Keywords: Composite construction, Steel Concrete composite section, RCC Slab, Steel, Comparative study.

1. Introduction

Structures in which composite sections made up of two different types of materials such as steel and concrete are used for beams, and columns is called as Composite structures. In this paper we compared the RCC with steel – concrete composite (G+9,G+12,G+15,G+18) story buildings which is situated in Pune earthquake zone III and wind speed is 43m/s.For analysis we used Equivalent Static Method. Results are compared with STAAD-Pro software. Comparative study includes Storey Stiffness, Displacement, Drifts, Axial Force in column, Shear force in column, Twisting Moment, Bending Moments in composite with respect to RCC Sections. Steel-concrete composite frame system can provide an effective and economic solution to most of these problems in medium to high-rise buildings.

2. Composite Construction

1. Definition

A composite member is defined as consisting of a rolled or a built up structural steel shape that is either filled with concrete encased by reinforced concrete or structurally connected to a reinforced concrete

slab.composite members are constructed such that the structural steel shape and the concrete act together to resist axial compression and bending.

2.Composite Buildings

The Composite construction consist of following elements ,
1. Composite deck slab
2. Composite beam
3. Composite column
4. Shear connector

2.1 Composite Deck Slab

Composite floor system is built up with steel beams, metal decking and concrete. They are combined in such a way that the best properties of each material can be used to optimize construction techniques. Majority used arrangement in composite floor systems are rolled or built-up steel beam joined to a formed steel deck and concrete slab. The metal deck generally spans unsupported between steel members provide a working platform for concreting work. The composite floor system provides stability to the overall building system by providing a rigid horizontal diaphragm, while distributing wind and seismic shears to the lateral load-resisting systems.

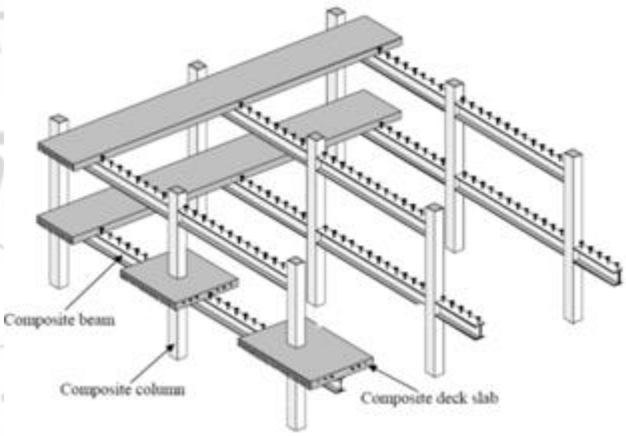

Figure 1: Steel-concrete composite frame

Load carrying capacity and stiffness increases by factors of around 2 and 3.5 respectively using composite action. The concrete generates the compression flange – the steel gives the tension factor and shear connectors ensure that the section act compositely. Beam spans of 6 to 12 m can be generated providing maximum flexibility and division of the internal space. Composite slabs use steel decking of 46 to 80 mm depth that can span 3 to 4.5 m without temporary propping. Slab thicknesses are generally in the range 100 mm to 250 mm for shallow decking, and in the range 280 mm to 320 mm for deep decking. In the normal condition Composite slabs are usually designed as simply supported members, with no account taken of the continuity given by any reinforcement for the supports.

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Composite Beam

A concrete beam is formed when a concrete slab which is casted in-situ conditions is placed over an I-section or steel beam. Under the influence of loading both these elements tend to behave in an independent way and there is a relative slippage between them. If there is a proper connection such that there is no relative slip between them, then an I-section steel beam with a concrete slab will behave like a monolithic beam.

In our present study, the beam is composite of concrete and steel and behaves like a monolithic beam. Concrete is very weak in tension and relatively stronger in tension whereas steel is prone to buckling under the influence of compression. Hence, both of them are provided in a composite such they use their attributes to their maximum advantage.

A composite beam can also be made by making connections between a steel I-section with a precast reinforced concrete slab. Keeping the load and the span of the beam constant, we get a more economic cross section for the composite beam than for the non-composite tradition beam. Composite beams have lesser values of deflectionthan the steel beams owing to its larger value of stiffness. Moreover, steel beam sections are also used in buildings prone to fire as they increase resistance to fire and corrosion.

2.2 Advantages of Composite Beams

1) The most effective utilization of steel and concrete is achieved.
2) Keeping the span and loading unaltered, a more economical steel section (in terms ofdepth and weight) is adequate in composite construction compared with conventionalnon-composite construction.
3) As the depth of beam reduces, the construction depth reduces, resulting in enhancedheadroom.
4) Because of its larger stiffness, composite beams have less deflection than steel beams.
5) Composite construction is amenable to "fast-track" construction because of usingrolled steel and pre-fabricated components, rather than cast-in-situ concrete.
6) Encased steel beam sections have improved fire resistance and corrosion.

3. Composite Column

Comprising either of a concrete encased hot rolled steel section or a concrete filled hollow section of hot rolled steel having a steel concrete composite column is a compression member. It is normally used for composite framed structure as a load bearing member. Composite members are majorly subjected to compression and bending. At current point there is no Indian standard code covering the design of composite column.

Both concrete and the steel interact together by friction and bond In a composite column. Hence, they resist external loading. Typically, in the composite construction, the primary construction loads are beared and supported by bare steel columns. Concrete is filled inside the tubular steel sections or is later casted around the I section. The combination of both steel and concrete use their attributes in the most effective way. Smaller and lighter foundations can be used Due to the lighter weight and higher strength of steel. The concrete casted around the steel sections at later stages in construction helps in restricting away the lateral deflections, sway and bucking of the column. It is very useful and efficient to erect very high rise buildings if we use steel-concrete composite frames with composite decks and beams. The time taken for erection is also less hence speedy construction is achieved.

3.1 The Advantages of Composite Columns are

1) Strength is increased for a given cross sectional dimension.
2) Increased stiffness, leading to reduced slenderness and increased bulking resistance.
3) In the case of concrete encased columns good fire resistance.
4) Corrosion protection in encased columns.
5) Significant economic advantages over reinforced concrete alternatives or either pure structural steel.
6) By varying steel thickness identical cross sections with different load and moment resistances can be produced, the concrete strength and reinforcement. This allows the outer dimensions of a column to be held constant over a number of floors in a building, thus solving the construction and architectural detailing.
7) Erection of high rise building in an extremely efficient manner.
8) For concrete filled tubular sections Formwork is not required.

4. Shear Connector

Shear connections are essential for steel concrete construction as they integrate the compression capacity of supported concrete slab with supporting steel beams / girders to improve the load carrying capacity as well as overall rigidity. Though steel to concrete bond may help shear transfer between the two to certain extent, yet it is neglected as per the codes because of its uncertainty. All codes therefore, specify positive connectors at the interface of steel and concrete.

4.1 Types of Shear Connectors

The total shear force at the interface between a concrete slab and steel beam is approximately eight times the total load carried by the beam. Therefore, mechanical shear connectors are required at the steel-concrete interface.

These connectors are designed to
1) Transmit longitudinal shear along the interface
2) Prevent separation of steel beam and concrete slab at the interface.

Thus, mechanical shear connectors are provided to transmit the horizontal shear between the steel beam and the concrete slab, ignoring the effect of any bond between the two. It also resists uplift force acting at thesteel interface. Commonly

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used types of shear connectors as per IS: 11384 – 1985: Code of practice for composite construction in structural steel and concrete. There are three main types of shear connectors; rigid shear connectors, flexible shear connectors and anchorage shear connectors. These are explained below:

4.1.1. Rigid Shear Connectors

As the name implies, these connectors are very stiff and they sustain nonly a small deformation while resisting the shear force. They derive their resistance from bearing pressure on the concrete, and fail due to crushing of concrete. Short bars, angles T-sections are common examples of this type of connectors. In addition, anchorage devices like hopped bars are attached with these connectors to prevent vertical separation.

4.1.2. Flexible Shear Connectors

Flexible shear connectors consist of headed studs, channels or tees welded to the top flange of the steel beams come under this category. They derive their stress resistance through bending and undergo large deformation before failure. The stud connectors are the types used extensively.

4.1.3. Anchorage Shear Connectors

Anchorage type shear connector is used to resist longitudinal shear and to prevent separation if the beam/ girder from the concrete slab at the interface through bond.

5. Building Details

The Building assumed is a commercial building .The plan dimension is 19.94M x 11.86m.The study is carried out on both R.C.C. and composite construction. The basic loading is same for both types of structure

5.1 Structural Data for R.C.C. Building

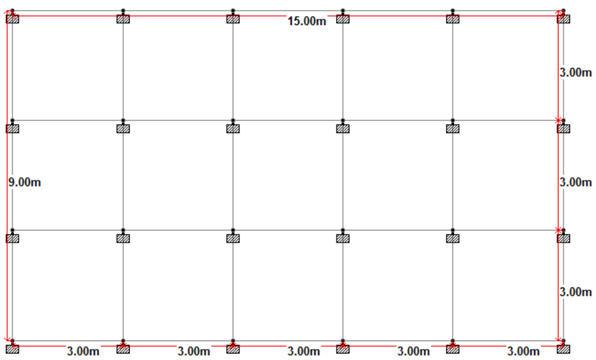

Figure 2: Plan showing typical floor of R.C.C.

Table 1: Structural Data for R.C.C. Structure

Plan dimension	15m x 9m
Total height of building	30.0 m
Height of each storey	3.0m
Height of parapet	1.0m
Type of Beam	Size of Beams
B1	0.3m X 0.6m
B2	0.3m X 0.45m
B3	0.3m X 0.3m
Type of columns	Size of columns
C6	0.3m X 0.75m,0.3m X 0.6m, 0.3m X 0.45
Thickness of slab	120 mm
Thickness of walls	230mm
Seismic zone	III
Wind speed	44 m/s
Soil condition	Medium soil

3.2 Structural Data for Composite Building

Building Plan for Composite Structure

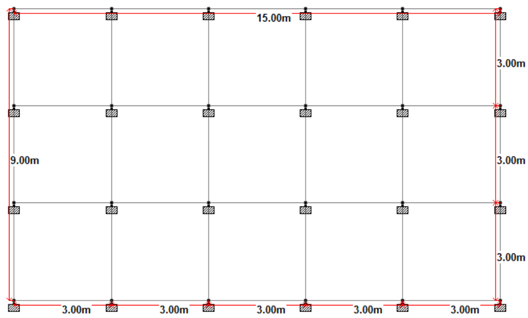

Figure 3: Plan Showing typical floor of composite

Table 2: Data For Analysis Of Composite Structure

Plan dimension	15m x 9m
Total height of building	30.0 m
Height of each storey	3.0m
Height of parapet	1.0m
Type of Beam	Size of Beams
B1	ISMB 450 @ 54.4 kg
Type of columns	Size of columns
C6, C7 (ISMB450)	ISMB400 @49.4kg
Thickness of slab	120mm
Thickness of wall	230mm
Seismic zone	III
Wind speed	39 m/s
Soil condition	Medium soil
Importance factor	1
Zone factor	0.16
Floor finish	1.5 kn/m2
Live load at all floors	5.0 kn/m2

6. Analysis

The explained 3D building model is analysed using Equivalent Static Method. The building models are then analysed by the software Staad Pro. Different parameters such as deflection, shear force & bending moment are studied for the models. Seismic codes are unique to a particular region of country. In India, Indian standard criteria for earthquake resistant design of structures IS 1893 (PART-1): 2002 is the main code that provides outline for

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calculating seismic design force. Wind forces are calculated using code IS-875 (PART-3) & SP64.

7. Results and Discussion

Analysis of four various building is done and from that following are the results.

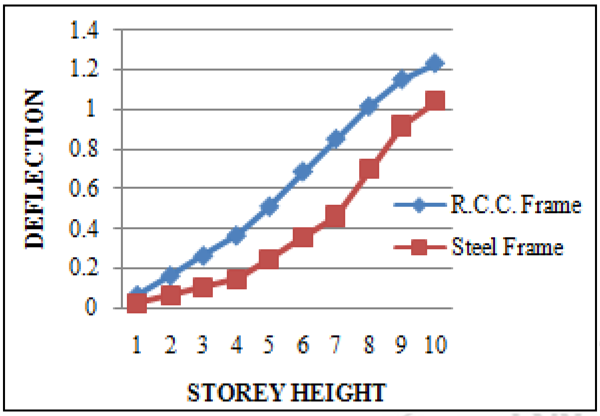


Figure 4: Comparison of deflection

The Fig.4 shows that the deflection in composite structure is nearly double than that of R.C.C structure but within permissible limit.

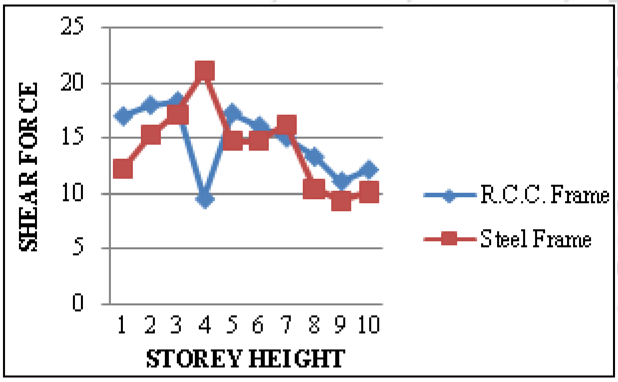


Figure 5: Comparison of Shear Force

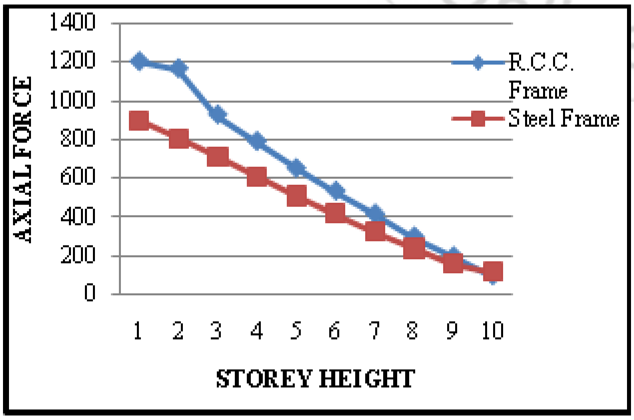


Figure 6: Comparison of axial force

The Fig.5,6 shows that the Shear force and Axial force in R.C.C structure is on higher side than that of composite structure.

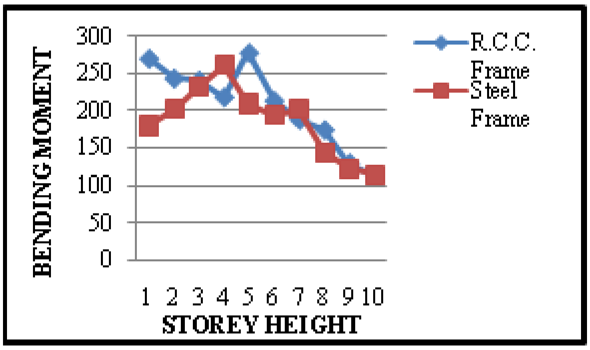


Figure 7: Comparison of B.M Z-Dir.

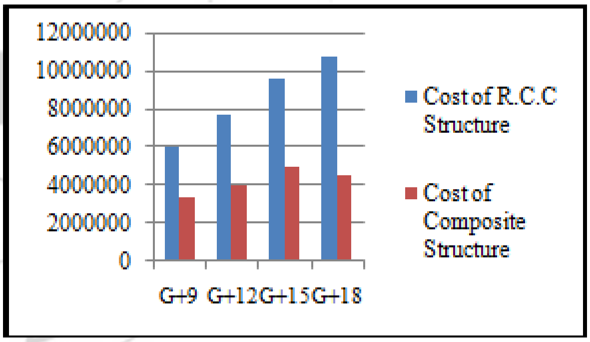
The Fig.7 shows that there is significant reduction in B.M of column (Z-DIR) in composite structure.

8. Comparison of Cost Between Composite and R.C.C. Structure

From analysis we get Axial force and B.M. This value is used in MS-Excel programming for design and then cost estimation is done in excel. From that results are obtained and tabulated are as follows:-

Table 3: Comparison of cost

Story	*Cost of R.C.C Structure*	*Cost of Composite Structure*	*Difference*
G+9	6007325	3418120	2589205
G+12	7730830	4042635	3688195
G+15	9695255	4970475	4724780
G+18	10876325	4591360	6294965



9. Conclusion

1) A G+9 structure of plan dimensions 15 M x 9M has been analysed, and cost per unit quantities are worked out.
2) Though the cost comparison reveals that steel-concrete composite design structure is more costly, reduction in direct cost of steel-composite structure resulting from speedy erection will make steel-composite structure economically viable. Further, under earthquake consideration because of the inherent ductility characteristics, steel-concrete structure will perform than conventional R.C.C. structure.
3) The axial forces, bending moment and deflections in R.C.C. are somewhat more as compared to the Steel composite structure.
4) The seismic forces are also not very harmful to the Steel composite structure as compared to the R.C.C. structure, due to low dead weight.

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5) There is the reduction in cost of steel structure as compared to R.C.C. structure due to reduction in dimensions of elements.
6) As the result shows steel composite option is better than R.C.C. Because composite option for high rise building is best suited. Weight of composite structure is low as compared to R.C.C. structure which helps in reducing the foundation cost.
7) As the dead weight of the steel composite structure is less as compared to R.C.C. structure, it is subjected to fewer amounts of forces induced due to the earthquake.
8) It is clear that the nodal displacements in steel composite structure, by both the method of seismic analysis, compared to R.C.C. structure in all the three global directions are less which is due to the higher stiffness of member in a steel composite structure to R.C.C. structure.
9) Composite structure is more economical than that of R.C.C. structure. Composite structures are the best solution for high rise structure as compared to R.C.C. structure. Speedy construction facilitates quicker return on the invested capital and benefits in terms of rent.

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