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Comparative Study of Steel, RCC and Composite frame Building

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Abstract – *Steel-concrete composite construction is a relatively a new concept for the construction industries. R.C.C is no longer economical because of their increased dead load and hazardous formwork; also Steel is not economical for high rise building frames due to less stiffness and more ductility, so steel concrete composite construction has got wide acceptance due to combine positive properties of both Steel and Concrete. This paper reviews that the composite frames are best suited for high rise buildings compared to that of steel and R.C.C. frame buildings. The paper includes comparative study of seismic performance of a Steel, R.C.C. and Composite (G+7) Storey frames. RCC, Steel and Composite Building frame situated in earthquake zone V. Equivalent Dynamic method is used for seismic analysis. ETAB 2015 software is used and results are compared.*

***Key Words*: Comparative Study, Steel frame, RCC frame Composite frame, Seismic analysis, Comparison Aspects, ETABS2015.**

1.0 INTRODUCTION

As compared to other developing countries the use of steel for construction purpose is very less in India. Steel structural members are prone to local and lateral buckling. Concrete structural members are generally thick and less likely to buckle but they are subjected to creep and shrinkage with time. Steel is more ductile material and so it can absorb more shocks and impact loadings. Thus, Composite structure is made to take the benefit of both steel and concrete materials. It is shown that the performance of building during an earthquake depends upon several factors like stiffness, ductility, lateral strength and simple and regular configuration. Earthquake has enforced the structural engineers to look for the alternate method of construction. Use of composite material is of particular interest, due to its significant prospective in improving the overall performance through rather modest alterations in manufacturing and constructional technologies.

The study includes comparative study of R.C.C. and Steel with Composite (G+7) multi-storey frames using dynamic method of analysis by ETABS2015 software. Comparative study includes deflections, bending moments in x & y direction, axial force & shear force in columns & beams in composite with respect to R.C.C. and Steel sections, Also the comparison of masses of R.C.C., Steel and composite frames is carried out.

2. ELEMENTS OF COMPOSITE STRUCTURE

2.1. Shear Connectors

Shear connections are crucial for steel concrete construction as they integrate the compression capacity of supported concrete slab with supporting steel beams to improve the load carrying capacity as well as overall rigidity.

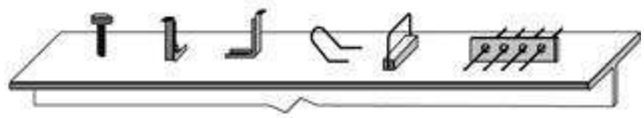

Fig. 2.1.a Types of Shear Connectors

2.2. Composite deck slab

Composite steel deck floors consist of a profiled steel deck with a concrete topping. Included in the concrete is some light welded mesh reinforcement which acts to control cracking, to resist longitudinal shear and, in the case of fire, to act as tensile reinforcement. Indentations in the profiled deck allow the concrete and steel to bond and share load. Composite action between the supporting beams and the concrete is created by welding shear studs through the deck onto the top flange of the beam.

Composite slabs with profiled decking are unsuitable when there is heavy concentrated loading or dynamic loading in structures such as bridges.

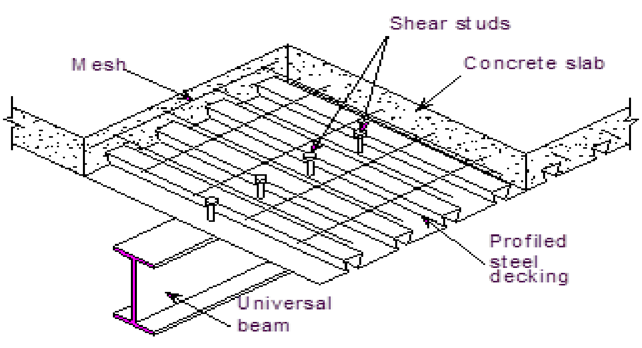

Fig. 2.2.a Composite Deck Slab

2.3 Composite beam

Steel - concrete composite beams have long been recognized as one the most economical structural systems for both multistory steel buildings and steel bridges. Buildings and bridges require a floor slab to provide a surface for occupant Concrete is the material of choice for the slab because its mass stiffness can be used to reduce deflections and vibrations of the floor system and to provide the required fire protection.

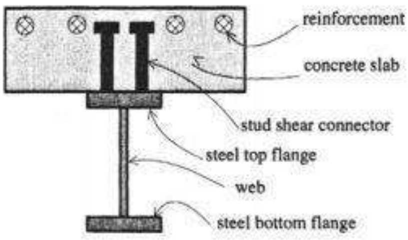

Fig. 2.3.a Composite Beam

2.4 Composite Column

Composite columns are constructed using various combinations of structural steel and concrete in an attempt to utilize the beneficial properties of each material. The interactive and integral behavior of concrete and the structural steel elements makes the composite column a very stiff, more ductile, cost effective and consequently a structurally efficient member in building and bridge constructions.

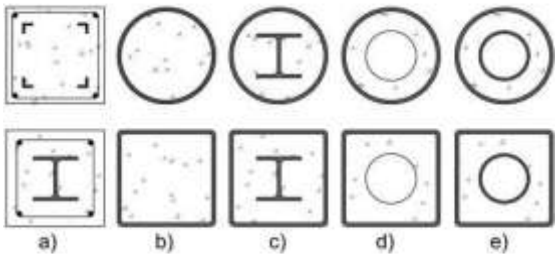

Fig. 2.4.a Various types of composite columns: concrete encased steel (CES) (a), CFST (b), combination of CES and CFST (c), hollow CFST sections (d) and double skin sections (e).

3.0 PROBLEM STATEMENT

- Eight storey (G+7) building frame with three bays in horizontal and three bays in lateral direction is analyzed by ETABS2015.
- The geometrical parameters of the building are as follows:
- Height of each storey = 3.5 m
- Center-to-center span between each column along X and Y direction = 5 m
- Fixed type support at the bottom. The loads on the building are as follows:
- Dead Load:-
  - Self weight of the frame
  - Dead floor load of the floors = 5.6 KN/m^2
  - Dead load of walls On beams = 8 KN/m^2
- Live load
- Live load on the floors = 4 KN/m^2
- Earthquake load in X-direction & Y-direction as specified in IS 1893: 2002.
- The seismic parameters of the building site are as follows:
- Seismic Zone: V
- Zone factor 'Z' = 0.36
- Soil type= Type II (Medium Soil)
- Building Frame System: Special Moment resisting RC frame.
- Response Reduction Factor = 5
- Importance factor = 1

4.0 METHODOLOGY

Analysis

The frames are analyzed for dead, live and earthquake forces for Steel, RCC and Composite framed building by ETABS 2015.The design forces in columns and beams are determined.

Design of slab, beam and column sections

The frames are designed for dead , live and earthquake forces for RCC sections for beams and columns in ETABS 2015 software. The maximum forces in columns and beams are determined from output file. The sections are designed for these three types of frame separately.

The codes IS 456-2000, IS 800-2007, IS 11384:1985 and AISC LRFD 2010 are used for RCC, Steel and Composite frame section design. The encased steel column is used for composite frame and thick concrete slab on top with shear connectors as a composite beam is considered in composite frame.

Comparison of results

The results obtained are compared in terms of deflections, base shear, story drifts, moments, reactions and weight effectiveness with respect to material quantities is presented.

5.0 ANALYSIS

In the present work Equivalent Dynamic method of analysis for (G+7) building frames which have been performed are as follows. ETABS Modeling for RCC, Steel and Composite frame Building

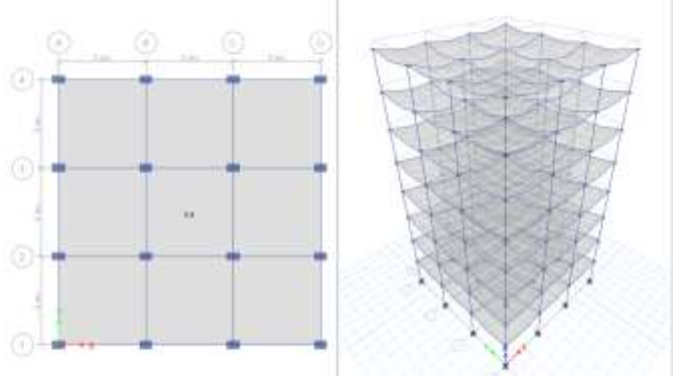

Fig. 5.1.a Modeling for RCC, Steel and Composite frame

- For Dynamic method analysis the following load combinations are used according to IS 1893

1. 1.5(DL+LL)
2. 1.2(DL+LL+ELX)
3. 1.2(DL+LL-ELX)
4. 1.2(DL+LL+ELY)
5. 1.2(DL+LL-ELY)
6. 1.5(DL+ELX)
7. 1.5(DL-ELX)
8. 1.5(DL+ELY)
9. 1.5(DL-ELY)
10. 0.9DL+1.5ELX
11. 0.9DL-1.5ELX
12. 0.9DL+1.5ELY
13. 0.9DL-1.5ELY

Table. 5.1. a Structural data for RCC frame

Plan dimension	15m x 15m
Total height of building	28.0 m
Height of each storey	3.5m
Type of Beam B	Size of Beams 0.3m X 0.4m
Type of columns C	Size of columns 0.45m X 0.75m
Thickness of slab	125 mm
Seismic zone	V
Soil condition	Medium soil

Table. 5.1.b Structural data for Steel frame

Plan dimension	15m x 15m
Total height of building	28.0 m
Height of each storey	3.5m
Type of Beam B	Size of Beams ISMB350
Type of columns C	Size of columns ISHB350
Thickness of slab	125 mm
Seismic zone	V
Soil condition	Medium soil

Table. 5.1.c Structural data for Composite frame

Plan dimension	15m x 15m
Total height of building	28.0 m
Height of each storey	3.5m
Type of Beam B	Size of Beams ISWB350
Type of columns C	Size of columns 0.40m X0.35m with ISHB300
Thickness of slab	125 mm
Seismic zone	V
Soil condition	Medium soil

6.0 DESIGN

The sections adopted for Design are

Table. 6.a Design data for the frames

Section	RCC	Steel	Composite
Column	0.45m x 0.75m Cross section	ISHB 350	0.4m x 0.35 m with ISHB300 steel section
Beam Main and second ary	0.3m x 0.4m	ISMB 350 with 125 mm thick concrete slab on top with shear connectors.	ISWB 350 with 125 mm thick concrete slab on top with shear connectors.

7.0 RESULTS AND DISCUSSION

7.1 Deflections

The differences in storey deflection for different stories along X and Y direction are owing to orientation of column sections. Moment of inertia of column sections is differing in both directions. Deflection of steel frame is more than deflection of RCC and composite frame structure.

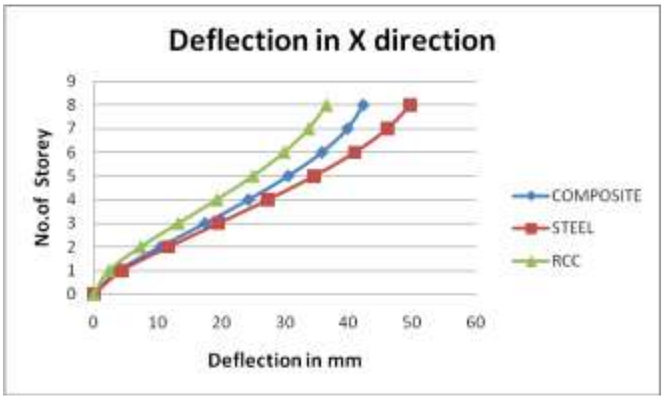

Fig. 7.1.a Deflection of frames in X direction

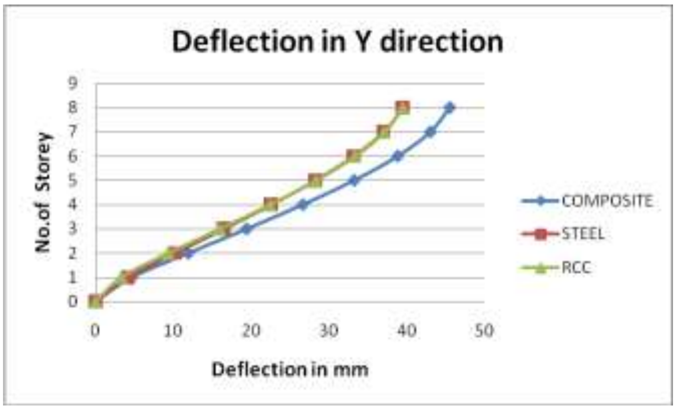

Fig . 7.1.b Deflection of frames in Y direction

7.2 Storey Drift

The differences in storey drift for different stories along X and Y direction are owing to orientation of column sections. Moments of inertia of column sections are differs in both directions, so storey drift are different in both direction.

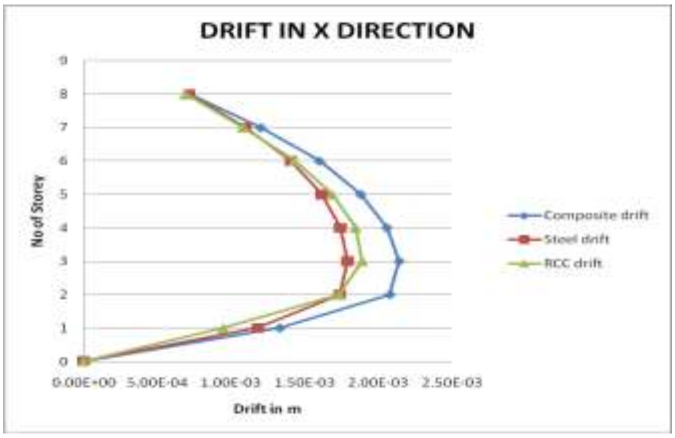

Fig. 7.2.a Storey Drift in X direction

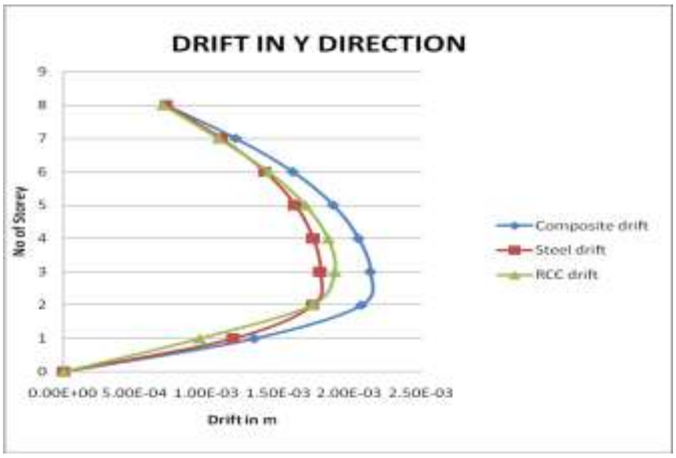

Fig. 7.2.b Storey Drift in Y direction

7.3 Base Shear

Base Shear for RCC frame is maximum because the weight of the RCC frame is more than the steel and the composite frame.

Fig. 7.3.a Base Shear for RCC Frame

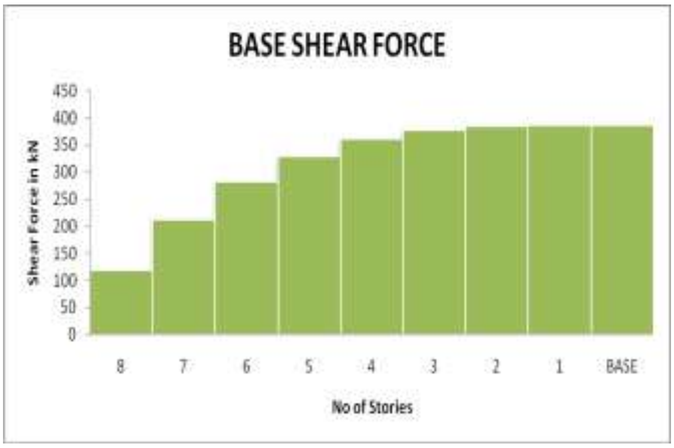

Fig. 7.3.b Base Shear for Steel Frame

Fig. 7.3.c Base Shear for Composite Frame

7.4 Resultant Forces and Moments

Here the results of steel and Composite are compared with respect to the results of RCC.

7.4.1 Shear Forces in Beams

Shear forces in the beams are reduced in composite frame structure as well as RCC frame structure as compared to Steel frame.

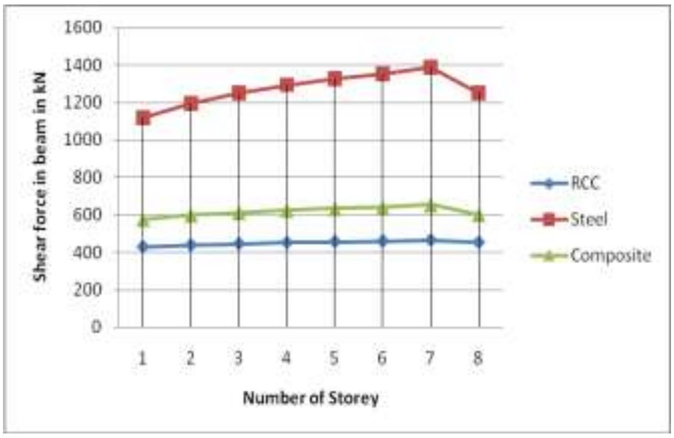

Fig. 7.4.1.a Shear Forces in Beams

7.4.2 Bending Moments in Beams

Bending moments in beams are reduced in Composite frame structure also reduced in RCC frame structure as compared to Steel frame structures.

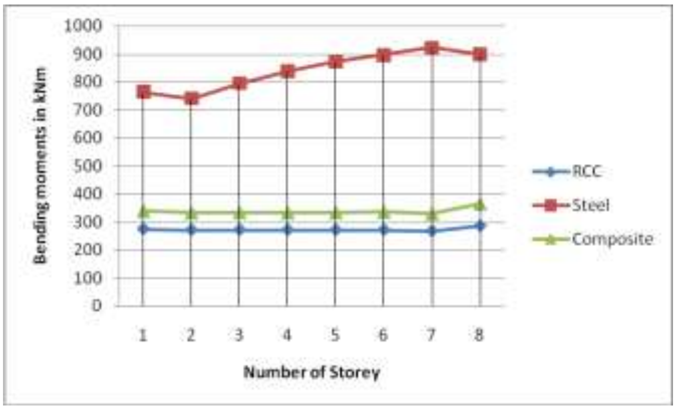

Fig. 7.4.2.a Bending Moments in Beams

7.4.3 Axial Forces in Columns

Axial forces in column have been reduced in steel as well as composite structure as compared to RCC structure

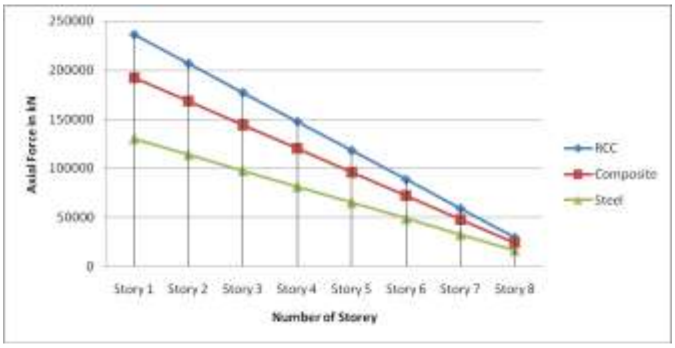

Fig. 7.4.3.a Axial Forces in Columns

7.4.4 Bending Moments in Columns

Bending moments in column have been much reduced in steel as well as composite structure as compared to RCC structure

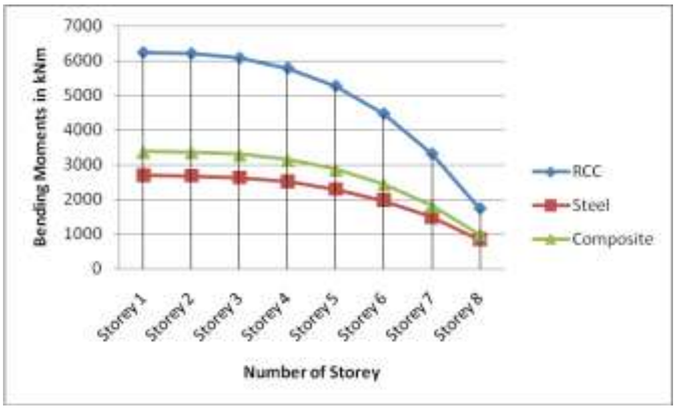

Fig. 7.4.4.a Bending moments in Columns

7.5 Weight Effectiveness

For comparison of weights have prepared three ETABS models (G+7), (G+11) and (G+15), so we get minimum three points as shown in fig 7.5.a. Weight of the composite structure is quite low as compared to RCC structure, which helps in reducing foundation cost and weight of steel is less as compared to composite .

Table. 7.5.a Mass of frames

NO of Storey	RCC (Mass in Kg)	Steel (Mass in Kg)	Composite (Mass in Kg)
G+7	1217120.47	787453.36	905483.95
G+11	1825680.71	1181180.04	1572084.01
G+15	2434240.95	1528546.06	2096112.01

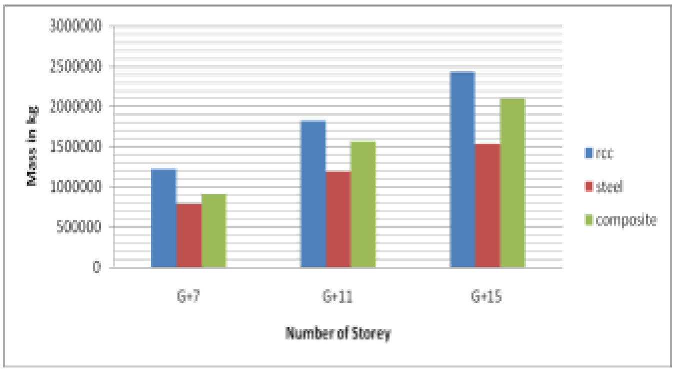

Fig. 7.5.a Mass of Frames

7.6 Economy of Frames

For comparison of economy have did approximate calculations and compared the (G+7) RCC, Steel, Composite frame building by considering material quantities only .table 7.6.a shows approximate relation in economy.

Table. 7.6.a Cost of Frames

Economy in building frames	
Type of Frame (G+7)	Material cost in Rs.
RCC	8390171.52
Steel	14687008.2
Composite	7315525

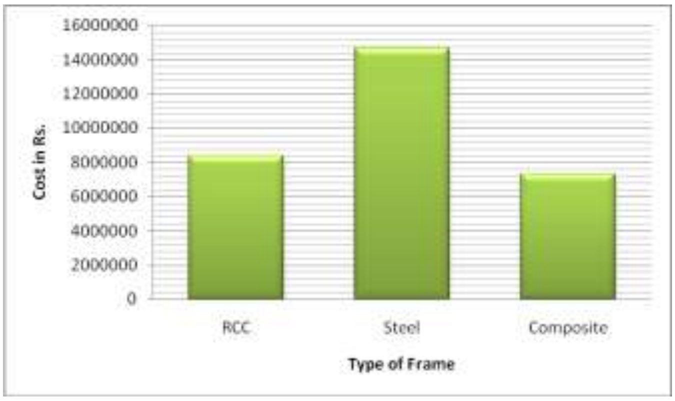

Fig. 7.6.a Cost of Frames

8.0 CONCLUSIONS

Following are few conclusions from Model Analysis with Results using ETABS2015. Following factors be considered to decide structural suitability. Seismic performance of the structure, Deflections, Storey drift, Base shear, Resultant Forces, Moments, Weight and Cost effectiveness of framed structures.

- Overall response of composite structure is better than RCC and Steel structure.
  i.e. composite structure produces less displacement and resists more design actions.
- Composite structures are best suitable for high rise buildings and they are resulted in speedy construction.
- Steel frame option is better than RCC but the composite frames option for high rise building is best.
- Lateral displacement of top story of Composite frame is 17% lesser than steel frame and 15 % more than RCC frame in X direction
- Lateral displacement of top story of Composite frame is more than steel frame and RCC frame which is equal to 15% in Y direction
- Lateral displacement of top story of Composite frame is 17% lesser than steel frame and 15 % more than RCC frame in X direction
- Maximum story drift of third story of Composite frame is 11.17% lesser than steel frame and 55 % more than RCC frame in X direction
- Maximum story drift of third story of Composite frame is more than both Steel and RCC frame which is equal to 13% and 19.50% respectively in X direction
- Base shear for Composite frame is 84% less than RCC frame and 16% more than steel frame.
- Maximum shear force in seventh story beam in Composite frame is nearly 40.45% greater than RCC frame and 112.29% less than Steel frame.
- Maximum bending moments in seventh storey beam for composite frame is 23.42% greater than RCC frame and 178.83% less than Steel frame.

- Axial forces in columns are higher for RCC frame than composite frame and steel frame which equals to 24% and 81% respectively.
- Bending moments in columns are higher for RCC frame than composite and steel frame which equals to 84% and 130% respectively.
- Weight of composite frame is 15% more than Steel frame and 34% lesser than RCC frame for (G+7) building frame.
- Cost of composite frame is nearly half than Steel frame and 15% higher than RCC frame for (G+7) building frame.

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