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Comparative Study of R.C.C and Steel Concrete Composite Structures

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ABSTRACT
Steel concrete composite construction has gained wide acceptance world wide as an alternative to pure steel and pure concrete construction. The use of steel in construction industry is very low in India compared to many developing countries. There is a great potential for increasing the volume of steel in construction, especially in the current development needs India and not using steel as an alternative construction material and not using it where it is economical is a heavy loss for the country.
In this paper study of Four various multistoried commercial buildings i.e. G+12, G+16, G+20, G+24 are analysed by using STAAD-Pro software. Where design and cost estimation is carried out using MS-Excel programming and from obtained result comparison can be made between R.C.C and composite structure.
Keywords – Composite beam, Composite column, Composite slab, R.C.C structure, Shear connector

I. INTRODUCTION

Composite structures can be defined as the structures in which composite sections made up of two different types of materials such as steel and concrete are used for beams, and columns. This paper include comparative study of R.C.C. with Steel Concrete Composite (G+12, G+16, G+20, G+24) story buildings which situated in Nagpur earthquake zone II and wind speed 44m/s. Equivalent Static Method of Analysis is used. For modeling of Composite & R.C.C. structures, STAAD-Pro software is used and the results are compared. Comparative study includes deflection, axial force and shear force, bending moment in column and beam, cost. It is found that composite structure is more economical and speedy than R.C.C structure.

II. COPOSITE MULTISTORIED BUILDINGS

The primary structural components use in composite construction consists of the following elements.

1. Composite deck slab
2. Composite beam
3. Composite column
4. Shear connector

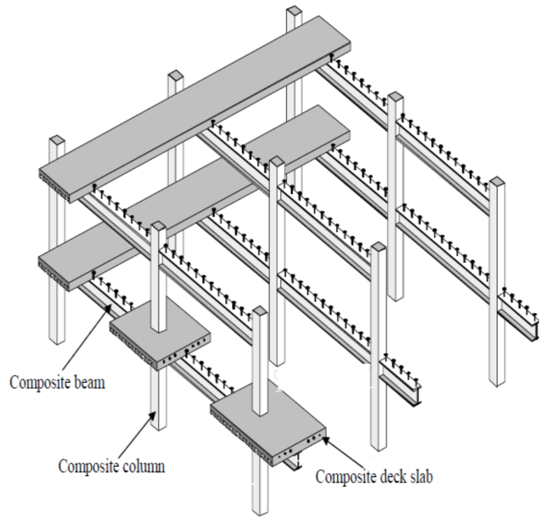


Fig.1: Steel-concrete composite frame

2.1. COMPOSITE DECK SLAB

Composite floor system consists of steel beams, metal decking and concrete. They are combined in a very efficient way so that the best properties of each material can be used to optimize construction techniques. The most common arrangement found in composite floor systems is a rolled or built-up steel beam connected to a formed steel deck and concrete slab. The metal deck typically spans unsupported between steel members, while also providing a working platform for concreting work. The composite floor system produces a rigid horizontal diaphragm, providing stability to the overall building system, while distributing wind and seismic shears to the lateral load-resisting systems.

Composite action increases the load carrying capacity and stiffness by factors of around 2 and 3.5 respectively. The concrete forms the compression flange – the steel provides the tension component and shear connectors ensure that the section behaves compositely. Beam spans of 6 to 12 m can be created giving 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 normally in the range 100 mm to 250 mm for shallow decking, and in the range 280 mm to 320 mm for deep decking. Composite slabs are usually designed as simply supported members in the normal condition, with no account taken of the continuity offered by any reinforcement at the supports.

2.2. COMPOSITE BEAM

In conventional composite construction, concrete slabs rest over steel beams and are supported by them. Under load these two components act independently and a relative slip occurs at the interface if there is no connection between them. With the help of a deliberate and appropriate connection provided between them can be eliminated. In this case the steel beam and the slab act as a "composite beam" and their action is similar to that of a monolithic Tee beam. Though steel and concrete are the most commonly used materials for composite beams, other materials such as pre-stressed concrete and timber can also be used. Concrete is stronger in compression than in tension, and steel is susceptible to buckling in compression. By the composite action between the two, we can utilize their respective advantage to the fullest extent. Generally in steel-concrete composite beams, steel beams are integrally connected to prefabricated or cast in situ reinforced concrete slabs.

2.2.1 COMPOSITE ACTION IN BEAMS

Composite beams, subjected mainly to bending, consist of section action composite with flange of reinforced concrete. To act together, mechanical shear connectors are provided to transmit the horizontal shear between the steel beam and concrete slab, ignoring the effect of any bond between the two materials. These also resist uplift forces acting at the steel concrete interface. If there is no connection between steel beam and concrete slab interface, a relative slip occurs between them when the beam is loaded. Thus, each component will act independently. With the help of deliberate and appropriate connection between concrete slab and steel beam the slip can be minimized or even eliminated altogether. If slip at the interface is eliminated or drastically reduced, the slab and steel member will act together as a composite unit. Slip is zero at mid-span and maximum at the support of the simply supported beam subjected to uniformly distributed load. Hence, shear is less in connectors located near the centre and maximum in connectors located near the support.Composite beams are often designed under the assumption that the steel beam supports the weight of the structural steel or wet concrete plus construction loads.This approach results in considerably less number of connectors than they are required to enable the maximum bending resistance of the composite beam to be reached. However the use of such partial shear connection results in reduced resistance and stiffness.

2.2.2 ADVANTAGES OF COMPOSITE BEAMS

1. Keeping the span and loading unaltered, more economical steel section in terms of depth and weight) is adequate in composite construction compared with conventional non-composite construction.
2. Encased steel beam sections have improved fire resistance and corrosion.
3. It satisfied requirement of long span construction a modern trend in architectural design.
4. Composite construction is amenable to fast track construction because of use of rolled steel sections.
5. Composite sections have higher stiffness than the corresponding steel sections and thus the deflection is lesser.
6. Permits easy structural repairs/ modification.
7. Provides considerable flexibility in design and ease of fabrication.
8. Enables easy construction scheduling in congested sites.
9. Reduction in overall weight of the structure and there by reduction in foundation cost.
10. Suitable to resist repeated earthquake loading which requires high amount of resistance and ductility.

2.3. COMPOSITE COLUMN

A steel concrete composite column is a compression member, comprising either of a concrete encased hot rolled steel section or a concrete filled hollow section of hot rolled steel. It is generally used as a load bearing member in a composite framed structure. Composite members are mainly subjected to compression and bending. At present there is no Indian standard code covering the design of composite column. The method of design in this report largely follows EC4, which incorporates latest research on composite construction. Indian standard for composite construction IS 11384-1985 does not make any specific reference to composite columns. This method also adopts the European bucking curves for steel columns as a basic of column design.

2.3.1 THE ADVANTAGES OF COMPOSITE COLUMNS ARE

1) Increased strength for a given cross sectional dimension.
2) Increased stiffness, leading to reduced slenderness and increased bulking resistance.
3) Good fire resistance in the case of concrete encased columns.
4) Corrosion protection in encased columns.
5) Significant economic advantages over either pure structural steel or reinforced concrete alternatives.
6) Identical cross sections with different load and moment resistances can be produced by varying steel thickness, 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 simplifying the construction and architectural detailing.
7) Erection of high rise building in an extremely efficient manner.
8) Formwork is not required for concrete filled tubular sections.

2.4. SHEAR CONNECTOR

The total shear force at the interface between 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 (a) transmit longitudinal shear along the interface, and (b) Prevent separation of steel beam and concrete slab at the interface. Commonly used types of shear connectors as per IS: 11384-1985. There are three main types of shear connectors; rigid shear connectors, flexible shear connectors and anchorage shear connectors.

2.4.1 TYPES OF SHEAR CONNECTORS

1. RIGID TYPE

As the name implies, these connectors are very stiff and they sustain only 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. Also anchorage devices like hoped bars are attached with these connectors to prevent vertical separation.

2. FLEXIBLE TYPE

Headed studs, channels come under this category. These connectors are welded to the flange of the steel beam. They derive their stress resistance through bending and undergo large deformation before failure. The stud connectors are the types used extensively. The shank and the weld collar adjacent to steel beam resist the shear loads whereas the head resists the uplift.

3. BOND OR ANCHORAGE TYPE

It is used to resist horizontal shear and to prevent separation of girder from the concrete slab at the interface through bond. These connectors derived from the resistance through bond and anchorage action.

III. BUILDING DETAILS

The building considered here is a commercial building. The plan dimension is 63.20mx29.50m. The study is carried out on the same building plan for both R.C.C and Composite construction. The basic loading on both types of structures are kept same .

3.1 STRUCTURAL DATA FOR R.C.C BUILDING

Building Plan for R.C.C Structure:

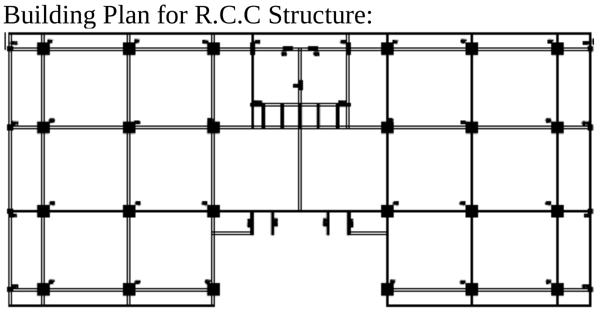


Fig.2: Plan showing typical floor of R.C.C

Table 1 : Structural data of R.C.C. Structure

Plan dimension	63.20mx29.50m
Total height of building	46.8, 61.2, 75.6, 90 m.
Height of each storey	3.6m
Height of parapet	1.0m
Type of Beam	Size of Beams
B_1	300mmx650mm
B_2	230mmx300mm
B_3	230mmx230mm
Type of columns	Size of columns
C_6, C_7	750mmx750mm
C_{11}	450mmx450mm
C_9	350mmx750mm
C_8	350mmx600mm
Thickness of slab	200mm
Thickness of walls	230mm
Seismic zone	II
Wind speed	44 m/s
Soil condition	Medium soil

Importance factor	1
Zone factor	0.1
Floor finish	1.0 kN/m2
Live load at all floors	4.0 kN/m2
Grade of concrete	M_{30}
Grade of reinforcing steel	Fe_{415}
Density of concrete	25 kN/m3
Density of brick	20 kN/m3
Damping ratio	5%

3.2 STRUCTURAL DATA FOR STEEL CONCRETE COMPOSITE BUILDING

Building Plan for Steel Concrete Composite Structure:

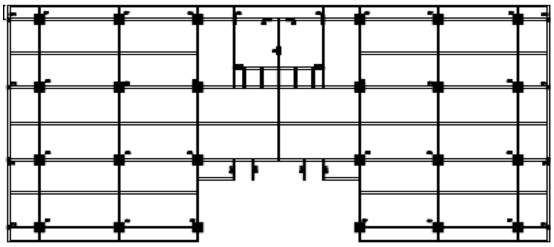


Fig.3: Plan showing typical floor of composite

Table 2: Data For Analysis Of Composite Structure

Plan dimension	63.20mx29.50m
Total height of building	46.8, 61.2, 75.6, 90 m.
Height of each storey	3.6m
Height of parapet	1.0m
Type of Beam	Size of Beams
B_1	ISMB450
B_2	ISMB300
B_3	ISMB200
Type of columns	Size of columns
C_6, C_7 (ISMB450)	500mmx500mm
C_9(ISMB300)	350mmx400mm
C_8(ISMB200)	300mmx300mm
Thickness of slab	200mm
Thickness of wall	230mm
Seismic zone	II
Wind speed	44 m/s
Soil condition	Medium soil
Importance factor	1.0
Zone factor	0.10
Floor finish	1.0 kn/m2
Live load at all floors	4.0 kn/m2
Grade of concrete	M_{30}
Grade of reinforcing steel	Fe_{415}
Density of concrete	25 kn/m3
Density of brick	20 kn/m3
Damping ratio	5%

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

V. RESULTS AND DISCUSSION

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

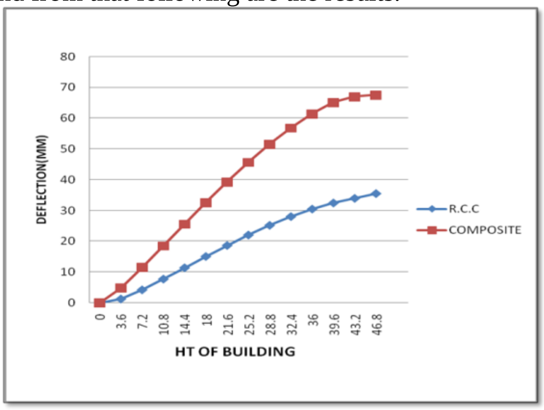


Fig.4: Comparison of deflection (column no. 35)

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

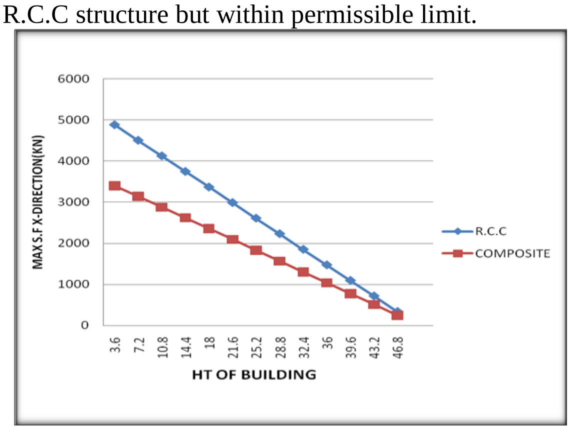


Fig.5: Comparison of S.F X-dir.(column no. 35)

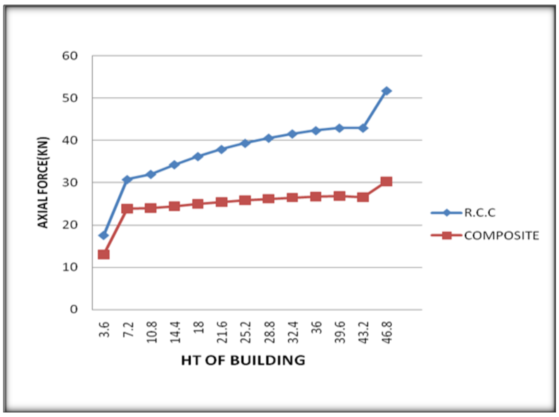


Fig.6: Comparison of axial force (column no. 35)

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.

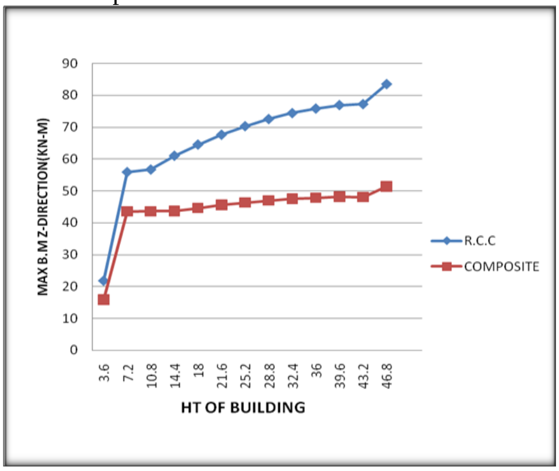
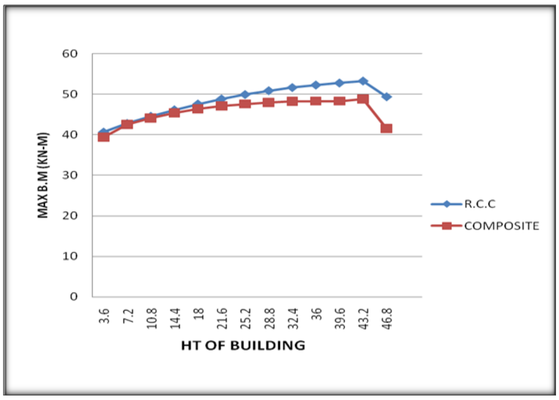


Fig.7:Comparison of B.M Z-Dir. (column no. 35)

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



<u>Fig. 8: Comparison of B.M (beam no. 35)</u>

Table 3: Comparisons of Composite and R.C.C Building w.r.t their various property are tabulated are as follows:-

Story	G+12		G+16		G+20		G+24	
Comparison Property	Composite	R.C.C	Composite	R.C.C	Composite	R.C.C	Composite	R.C.C
Max. Axial Force In Y-DIR (kN)	17892.89	17532	22631.05	2838	26976.86	976	33431.81	31338
Max. Shear Force In X-DIR (kN)		253.01	218	401	246	6	274.7	558.17
Max. Shear Force In Z-DIR (kN)	8	151.5	265	193	306	4.54	360.63	297.54
Max. B.Moment (kNm)		555.25	707	736.3	838.23	8.18	969.38	1201.05

VI. COMPARISON OF COST BETWEEN COMPOSITE & 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 4: Comparison Of Cost For G+12 Building

	R.C.C STRUCTURE	COMPOSITE STRUCTURE	DIFFERENCE	In %
SLAB	30515095.46 Rs	22001265.2 Rs	-8513830.26 Rs	-27.9004
BEAM	7023461.66 Rs	18657333.23 Rs	11633871.34 Rs	62.35549
COLUMN	9236275.38 Rs	10488763.64 Rs	1252488.26 Rs	13.56053
FOOTING	9945576.59 Rs	5510013.64 Rs	-4435562.95 Rs	-44.5983
TOTAL	56720409.09 Rs	56657375.48 Rs	-63033.61 Rs	-0.11125

Extra cost of R.C.C structure = 63,034 Rs

Table 5: Comparison Of Cost For G+16 Building

	R.C.C STRUCTURE	COMPOSITE STRUCTURE	DIFFERENCE	In %
SLAB	39990551.1 Rs	28772039.3 Rs	-11218511.8 Rs	-28.0529
BEAM	8207075.16 Rs	20863500 Rs	12656424.84 Rs	60.663
COLUMN	13701333.92 Rs	13060635.76 Rs	-640698.16 Rs	-4.67617
FOOTING	11130922.5 Rs	6701718.52 Rs	-4429203.98 Rs	-39.7919
TOTAL	73029882.68 Rs	69397893.58 Rs	-3631989.1 Rs	-5.23357

Extra cost of R.C.C structure = 36,31,990 Rs

Table 6: Comparison Of Cost For G+20 Building

	R.C.C STRUCTURE	COMPOSITE STRUCTURE	DIFFERENCE	In %
SLAB	44760579.6 Rs	38172664.5 Rs	-6587915.1 Rs	-14.7181
BEAM	11348412.16 Rs	24248155.8 Rs	12899743.64 Rs	53.19886
COLUMN	27217564.9 Rs	16089150.08 Rs	-11128414.8 Rs	-40.8869
FOOTING	12449462.5 Rs	8210217.11 Rs	-4239245.39 Rs	-34.0516
TOTAL	95776019.16 Rs	86720187.49 Rs	-9055831.67 Rs	-10.4426

Extra cost of R.C.C structure = 90,55,832 Rs

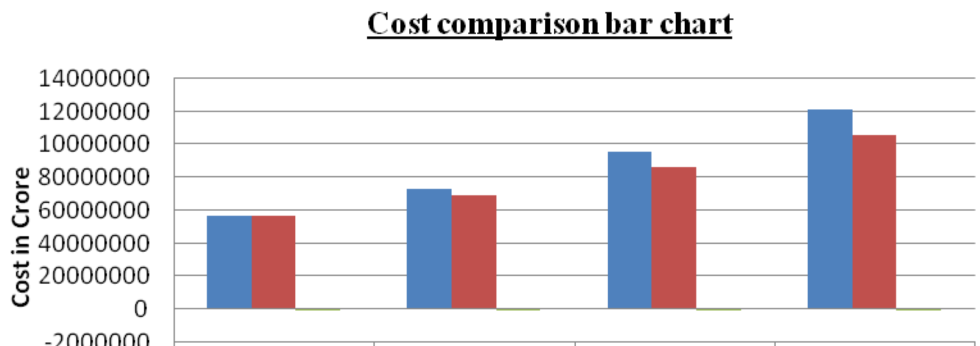
Table 7: Comparison Of Cost For G+12 Building

	R.C.C STRUCTURE	COMPOSITE STRUCTURE	DIFFERENCE	In %
SLAB	61256708.1 Rs	45509281.5 Rs	-15747426.6 Rs	-25.7072688
BEAM	13520592.3 Rs	31648141.2 Rs	18127548.9 Rs	57.27839997
COLUMN	33361527.3 Rs	18684650.94 Rs	-14676876.36 Rs	-43.9934186
FOOTING	13213824.35 Rs	9897935.24 Rs	-3315889.11 Rs	-25.094091
TOTAL	121352652.1 Rs	105740008.9 Rs	-15612643.17 Rs	-14.7651238

Extra cost of R.C.C structure = 1,56,12,644 Rs

Table 8:Comparison of total cost between R.C.C Structure and Composite Structure

Story	Cost of R.C.C Structure (Cr)	Cost of Composite Structure (Cr)	% Difference
G+12	5,67,20,409	5,66,57,375	-0.111
G+16	7,30,29,883	6,93,97,893	-5.23
G+20	9,57,76,019	8,67,20,187	-10.44
G+24	12,13,52,652	10,57,40,009	-14.77



	G+12	G+16	G+20	G+24
R.C.C STRUCTURE	56720409	73029883	95776019	121352652
COMPOSITE STRUCTURE	56657375	69397893	86720187	105740009
% Difference	-0.112	-5.23	-10.44	-14.77

Fig.9: Cost comparison bar chart

From Fig.9 it is obvious that increase in the number of story results in increased cost for RCC construction as compared to composite construction.

VII. CONCLUSION

Analysis and design of four various building can be done and comparison can be made between them and from that result conclusions can be drawn-out are as follows:-

1. In case of a composite structural system because of the lesser magnitude of the beam end forces and moments compared to an R.C.C system, one can use lighter section in a composite structure. Thus, it is reduces the self-weight and cost of the structural components.
2. From Fig.3 & Fig.4 it is seen that the downward reaction (F_y) and bending mome'nt in other two direction for composite structural system is less. Thus one can use smaller size foundation in case of composite construction compared to an R.C.C construction.
3. Under earthquake consideration because of inherent ductility characteristics, steel-concrete composite structure perform better than a R.C.C structure.
4. In the cost estimation for building structure no savings in the construction time for the erection of the composite structure is included. As compared to RCC structures, composite structures require less construction time due to the quick erection of the steel frame and ease of formwork for concrete. Including the construction period as a function of total cost in the cost estimation will certainly result in increased economy for the composite structure.
5. The cost comparison reveals that steel-concrete composite design structure is more economical in case of high rise buildings and construction is speedy.

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