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COMPARATIVE STUDY ON ANALYSIS, DESIGN AND COST OF R.C.C. AND STEEL-COMPOSITE STRUCTURE

YOGESH R. SURYAVANSHI[1], PRASHANT S. PATIL[2], DESHMUKH SIDDHESHWAR SHRIKANT[3], GAIKWAD AMOL RAMRAO[4], INAMDAR FIROJ NAJMODDIN[5], PURI SUJAY UTTAM[6]

[1, 2]Assistant Professor, JSPM'S Imperial College of Engineering and Research, Wagholi, Pune, India
[3, 4,5&6]Graduate student, JSPM'S Imperial College of Engineering and Research, Wagholi, Pune, India

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ABSTRACT

The project involves Analysis, design and cost of a residential building with steel-composite and R.C.C. construction. The proposed structure is a G+9 building, with 3.2m as the height of each floor. The overall plan dimension of the building is 19.94m x 11.86m. The analysis involves the load calculation, analyzing it by 2D modeling using software STAAD-Pro 2007. Design of R.C.C. and steel-composite elements done by hand calculation. Analysis has been done for various load combinations as per the Indian Standard Code of Practice. The project also involves analysis and design of an equivalent R.C.C. structure so that a cost comparison can be made between a steel-composite structure and an equivalent R.C.C. structure.

KEYWORDS: Steel-composite construction, STAAD-Pro 2007, cost comparison, Analysis

1. INTRODUCTION TO STEEL-COMPOSITE CONSTRUCTION

1.1 Definition

A composite member is defined as consisting of a rolled or a built-up structural steel shape that is filled with concrete, encased by reinforced concrete or structurally connected to a reinforced concrete slab. Composite members are constructed such that the structural steel shapes and the concrete act together to resist axial compression and /or bending. 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 bridge or a floor slab, then a composite member is formed. In such a composite T-beam the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. Here it is very important to note that both the materials are used to fullest of their capabilities and give an efficient and economical construction which is an added advantage. However, the real attraction of such construction is based on having an efficient connection of the Steel to the Concrete, and it is this connection that allows a transfer of forces and gives composite members their unique behavior.

1.2 Advantages of Steel-Composite Construction:

1. Faster construction for maximum utilization of rolled and/or fabricated components (structural steel members) and hence quick return of the invested capital

2. More use of a material i.e. steel, which is durable, fully recyclable on replacement and environment friendly.
3. Reductions in overall weight of structure and thereby reduction in foundation cost.
4. Cost of formwork is lower compared to RCC construction.
5. Cost of handling and transportation is minimized for using major part of the structure fabricated in the workshop.
6. Easy structural repair/modification/maintenance.
7. Structural steel component has considerable scrap value at the end of useful life.
8. Better seismic resistance i.e. best suited to resist repeated earthquake loadings, which require a high amount of ductility and hysteretic energy of the material/structural frame.
9. Composite sections have higher stiffness than the corresponding steel sections (in a steel structure) and thus bending stresses as well as deflection are lesser.

1.3 Need of steel in construction

In building construction, role of steel is same as that of bones in a living being. Steel is very advantageous because it:

1. Offers considerable flexibility in design and is easy for fabrication
2. Facilities faster construction scheduling of projects
3. Enables easy construction scheduling even in congested sites
4. Permits large span construction repair/modification
5. It an ideal material in earthquake prone locations due to high strength, stiffness, ductility
6. It is environment friendly and fully recyclable on replacement

2. BACKGROUND

In India most of the building structures fall under the category of low rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical in nature. But since the population in cities is growing exponentially and the land is limited, there is a need of vertical growth of buildings in these cities. So, for the fulfillment of this purpose a large number of medium to high rise buildings are coming up these days. For these high rise buildings it has been found out that use of composite members in construction is more effective and economic than using reinforced concrete members. The popularity of steel-concrete composite construction in cities can be owed to its advantage over the conventional reinforced concrete construction. Reinforced concretes frames are used in low rise buildings because loading is nominal. But in medium and high rise buildings, the conventional reinforced concrete construction cannot be adopted as there is increased dead load along with span restrictions, less stiffness and framework which is quite vulnerable to composite construction essentially different materials are completely compatible and complementary to each other; they have almost the same thermal expansion; they have an ideal combination of strengths with the concrete efficient in compression and the steel in tension; concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-tensional buckling. This paper includes comparative study of RCC with Composite Story building 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.

3. SCOPE OF STUDY

The aim of present study is to compare analytical parameters such as deflections, axial forces and bending moment of G+ 9 storey's R.C.C and steel-composite building frame. Both R.C.C. and steel-composite frames are designed for same loadings. The R.C.C. slab is used in both cases. Also Cost comparisons of steel-composite elements with convectional R.C.C elements are done to prove steel-composite structures are more economical as compared to R.C.C. structure.

4. METHODOLOGY

4.1 Problem Statement

To analysis the G+9 R.C.C. framed structure and steel composite framed structure under various loading condition using software STAADPro2007 and also to design various elements of both frames manually and elemental analysis of connections using ansys software.

4.2 Project details

Composite floors are designed based on limit state design philosophy. Since IS 456:2000 is also based on limit state methods, the same has been followed wherever it is applicable.The design should ensure an adequate degree of safety and serviceability of structure. The structure should therefore be checked for ultimate and serviceability limit states.

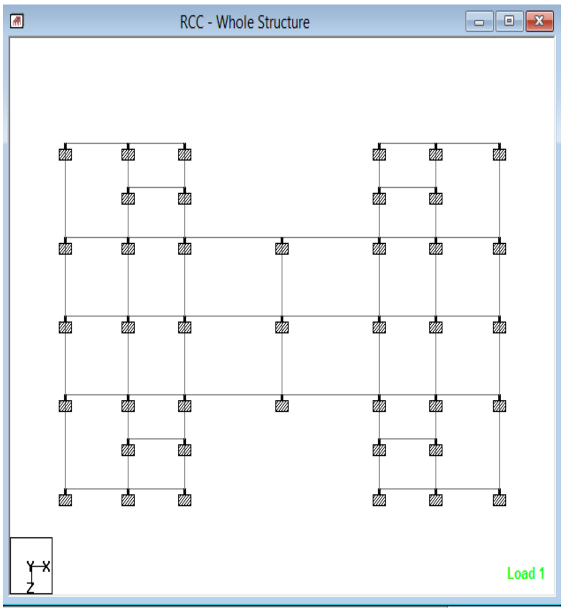


Fig.1 Plan

4.3 Design data:

Model: G+9
Seismic zone: III
Zone factor: 0.16
Importance factor: 1
Height of building: 30.1 m
Floor height: 3.20m
Depth of foundation: 1.5 m
Plan size: 19.94 m X 11.86 m
Type of soil: Medium
Slab depth: 120 mm thick for R.C.C.
Wall thickness: 230 mm

Material Properties

Unit weight of masonry: 20kN/m3
Unit weight of R.C.C.: 25kN/m3
Unit weight of steel: 79kN/m3
Grade of concrete: M20 for R.C.C and Steel
Grade of steel: HYSD bars for reinforcement Fe 415
Modulus of Elasticity for R.C.C.: 5000 X $\sqrt{F_{CK}}$ N/mm2
Modulus of Elasticity for Steel: 2.1 x 105N/mm2

Load Consideration

Dead load: Self Weight
Live load in office area: 4kN/m2
Live load in passage area: 4kN/m2
Live load in urinal: 2kN/m2
Floor finish load: 1.2kN/m2
Stair case loading: 12kN/m2

Load Combination Consideration:

Load combinations as per IS 1893-2002:

1. 1.7 (D.L.+ L.L)
2. 1.7 (D.L.+ E.Q)
3. 1.7 (D.L. - E.Q)
4. 1.3 (D.L. + L.L + E.Q.)
5. 1.3 (D.L. + L.L – E.Q.)

Load calculation:

1) Dead Load:
D.L. was taken as per IS (Part-I) 875:1987
At any floor level
Thickness of slab = 125mm
Load from slab = 0.125 X 25 = 3.125kN/m^2
Partitions = 1.91kN/m^2 =195Kg
Floor finish (F.F) = 1.2kN/m^2
Wt. of metal deck = 0.15kN/m^2
Wt. of duct and plastering = 0.8kN/m^2
Total D.L. = 7.185kN/m^2
D.L. of walls:
Outer beam = 12kN/m^2
Inner beam = 6kN/m^2
2) Live Load (L.L) = 3kN/m^2
3) Seismic load (S.L):
Building from system: moment resisting R.C.C. frame
Response reduction factor for R.C.C.: 3
Response reduction factor for steel: 5
Approximate fundamental period (T)
= $0.09(H/D^{1/2})$
= $0.09 \text{ X } (30.1/19.94^{1/2})$
= 0.6067 sec

4.4 Dimensions consideration for design:

For R.C.C. frame

Beam sizes:
Internal beam: 0.15m X 0.45m
External beam: 0.15m X 0.6m
Column size: 0.2m X 0.6m

For steel frame

Beam size: ISMB 350 @ 54.4 kg

Column size: ISMC400 @49.4kg

5. ANALYSIS

Analysis was done using STAAD-Pro 2007.

Footing was idealized as fixed support.

The load cases adopted are dead load and live load, wind load and the seismic load.

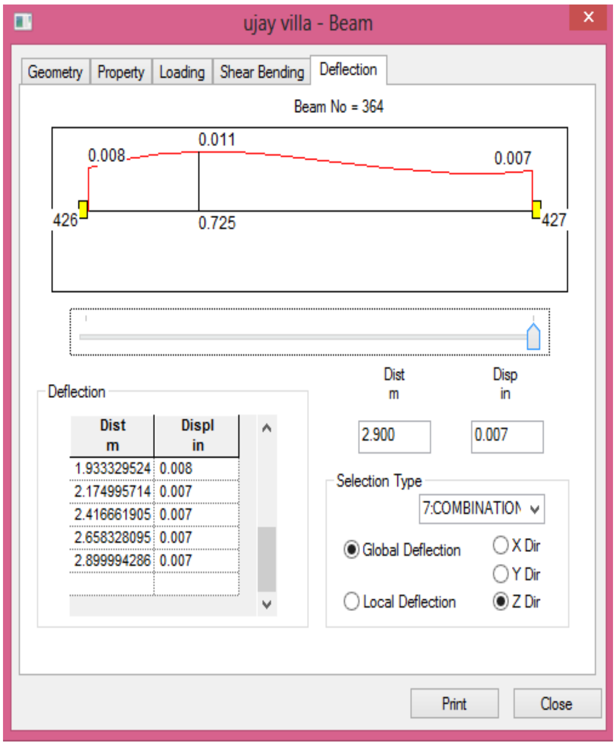


Fig.2 Deflection in Beam (steel-composite frame)

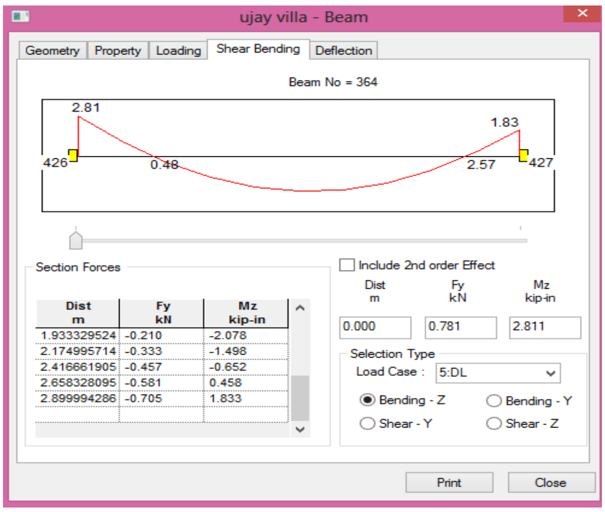


Fig.3 bending moment in Beam (steel-composite frame)

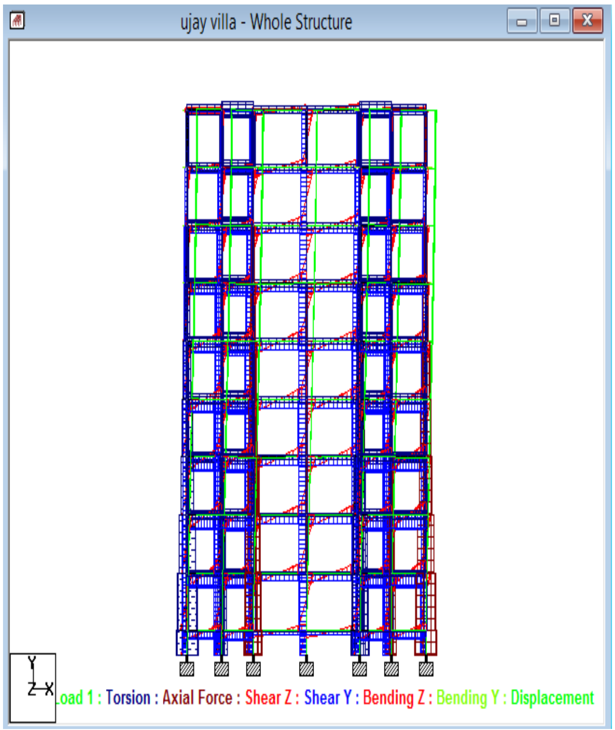


Fig.4 combined effect of torsion, axial force, shear, bending moment and displacement

6. EXPERIMENTAL RESULTS:

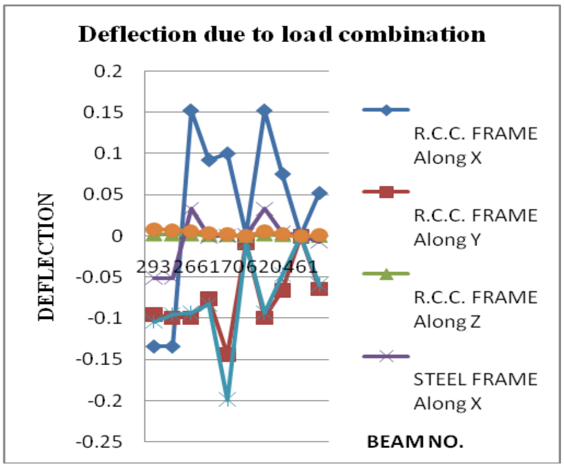
The results of analytical parameters such as deflections, axial forces and bending moments of R.C.C. and steel-composite frame are carried out. These results are shown in tabular form. The interpretations of these results are compared graphically. Also cost comparison of steel-composite elements with convectional R.C.C elements are done by taking out unit element of both frames.

6.1 Deflection due to load combination

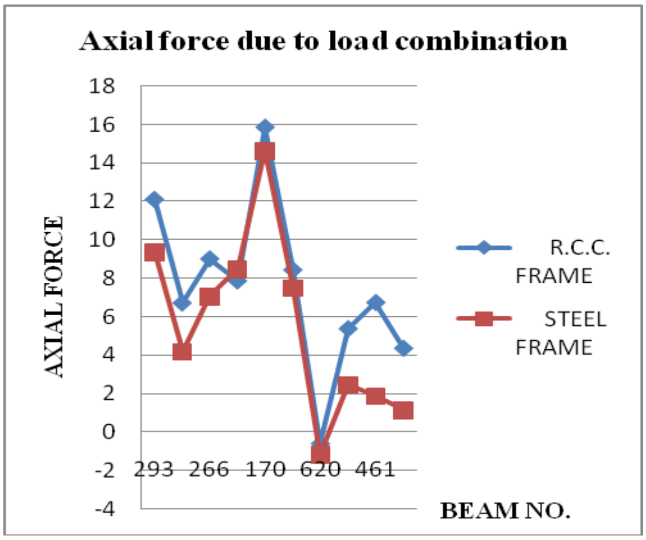
Table No. 1

Beam No.		Deflection (inch)		
	R.C.C. Frame			Steel Frame

	Along X	Along Y	Along Z	Along X	Along Y	Along Z
293	-0.134	-0.095	0.002	-0.051	-0.104	0.008
294	-0.134	-0.099	0.002	-0.051	-0.095	0.007
266	0.152	-0.099	0.002	0.033	-0.093	0.006
173	0.092	-0.076	0.001	-0.001	-0.083	0.003
170	0.1	-0.144	0.001	0	-0.199	0.002
023	0.002	-0.008	0	0.001	-0.008	0
620	0.152	-0.099	0.002	0.033	-0.093	0.006
476	0.075	-0.066	0.001	0.004	-0.047	0.002
461	0	0	0	0	0	0
605	0.052	-0.064	0	-0.007	-0.059	0.001



Graph No. 1



Graph No. 2

6.2 Axial force due to load combination

Table No. 2

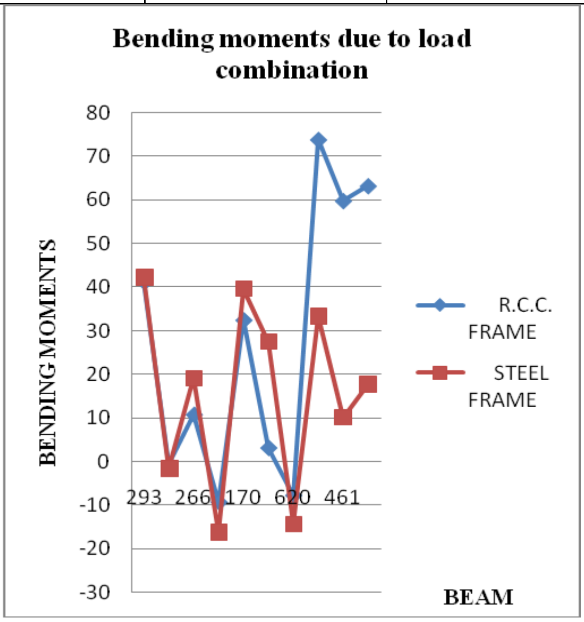
Beam No.	Axial Forces (kN)	
	R.C.C. Frame	Steel Frame
293	12.105	9.370
294	6.709	4.190
266	9.007	7.059
173	7.860	8.493
170	15.864	14.645
023	8.433	7.509
620	-0.621	-1.185
476	5.372	2.479
461	6.738	1.884
605	4.351	1.151

6.3 Bending moments due to load combination

Table No. 3

Beam No.	Bending Moments (kip-in)	
	R.C.C. Frame	Steel Frame
293	41.174	42.180
294	-0.782	-1.659
266	10.737	19.026
173	-9.356	-16.298
170	32.417	39.529
023	3.117	27.365

620	-7.784	-14.359
476	73.819	33.250
461	59.775	10.082
605	63.191	17.689



Graph no. 3

6.4 Cost comparison of steel-composite elements with convectional R.C.C elements

Table No.4 Slab:

Material	Rate	Quantity		Amount	
		R.C.C.	STEEL	R.C.C	STEEL
Steel	Rs.45/kg	112 kg	109 kg	5040	4905
Concrete	Rs.5680/m^3	1.12 m^3	1.12m^3	6362	6362
Form work	Rs.80/m^2	9.28 m^2	9.28 m^2	743	743

Table No. 5 Beam:

Material	Rate	Quantity		Amount	
		R.C.C.	STEEL	R.C.C	STEEL
Steel	Rs.45/kg	76 kg	140 kg	3420	6300
Concrete	Rs.5680/m^3	0.25 m^3	-	1420	-
Formwork	Rs.80/m^2	7.18 m^2	-	575	-

Table No. 6 Column:

Material	Rate	Quantity		Amount	
		R.C.C.	STEEL	R.C.C	STEEL
Steel	Rs.45/kg	108 kg	158 kg	4860	7110
Concrete	Rs.5680/m^3	0.4m^3	-	2272	-
Formwork	Rs.80/m^2	10.24 m^2	-	820	-

Total Cost for elements of R.C.C. frame – Rs. 25512

Total Cost for elements of steel-composite frame – Rs. 25420

(Above estimate and cost is only for single element of both the frames).

7. CONCLUSIONS

- A G+9 structure of plan dimensions 19.94 M x 11.86 M has been analyzed, designed and cost per unit quantities are worked out.
- The cost comparison reveals that steel-composite design structure is somewhat same as R.C.C. structure. But 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.
- The axial forces, bending moment and deflections in R.C.C. are somewhat more as compared to the Steel-composite structure.
- Also we have analyzed the connection between elements like beam and column in ANSYS software which gives somewhat same deflections as done in STADD-Pro 2007.
- 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.
- There is the reduction in cost of steel structure as compared to R.C.C. structure due to reduction in dimensions of elements.
- 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.

- 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.
- 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.
- Composite structures are 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.
- To increase the life of steel elements in steel-composite structure, it necessary to apply anti corrosive materials to them.
- To avoid the temperature increase in these steel elements, it is necessary to make them fire resistant using various insulators.

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