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Comparitive study on the behavior of R.C.C, Steel & Composite Structures (B+G+20 storeys)

Sattainathan.A, Nagarajan.N

***Abstract*—**Use of composite material is of particular interest, due to its significant potential in improving the overall performance through rather modest changes in manufacturing and constructional technologies. Steel concrete composite construction means the concrete slab is connected to the steel beam with the help of shear connectors so that they act as a single unit. In the present work, steel concrete composite with RCC options are considered for comparative study of B+G+20 storey of commercial building which is situated in earthquake zone 4 and for earthquake loading, the provisions of IS:1893(Part1)-2002 is considered. For modeling of composite, Steel and RCC structures, E-TABS analysis software is used. Steel-concrete composite construction system is an efficient, economical and innovative method for seismic resistance of multi storied buildings. Equivalent static method of seismic analysis used in the analysis of geometric models. In this study, the seismic design and performance of composite steel-concrete frames are discussed in particular. Comparison of parameters like time period, displacement, base shear and load carrying capacity is done with steel and R.C.C structures. The results are compared and it is found that composite structure are more good in several aspect.

***Keywords*—**Composite beam, Composite column, ETABS software, Shear Connectors

I. Introduction

Steel-concrete composite systems have become quite popular in recent times because of their advantages against conventional construction. Composite construction combines the better properties of the both i.e. concrete in compression and steel in tension, they have almost the same thermal expansion and results in speedy construction. The use of Steel in construction industry is very low in India compared to many developing countries. Experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially the current development needs in India. Engineers are familiar with the problems involved in constructing either steel or concrete building, as each of these materials has its own peculiarity. Steel structural members are generally fabricated as component consisting of thin plate elements, so they are prone to local and lateral buckling. Therefore, they are checked for the failure due to buckling and instability, while concrete structural members are generally thick and unlikely to buckle; but they are inclined to creep and shrinkage with time. Therefore, a system comprising steel-concrete-composite structure was developed to take benefit of both the material. For building systems, steel-concrete composite structures are known as the most economical solution to the diverse engineering design requirements of stiffness and strength. The strength and behavior of composite slabs are governed by the shear interaction between the concrete and the steel deck. By the composite action between the two, one can utilize their respective advantages to the fullest extent. Structurally robust and aesthetically pleasing buildings are being constructed now-a-days by composite steel concrete construction meeting the specific requirements of large span, building height, soil condition, time, flexibility and economy. The main benefits from the use of composite steel concrete construction are in terms of construction time and cost. The use of rolled steel section and prefabricated component makes the composite construction fast track construction compared to the cast in situ concrete.

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II. Objective

Steel-concrete composite systems have become quite popular in recent times because of their advantages against conventional construction. Composite construction combines the better properties of the both i.e. concrete in compression and steel in tension, they have almost the same thermal expansion and results in speedy construction. The objectives of the study are

1. To provide a brief description to various components of steel concrete framing system for buildings.
2. To investigate major parameters like cost, time, seismic response of steel-concrete composite frames over traditional reinforced concrete frames and steel frames for building structures

III. Composite Construction

Steel-concrete composite construction means steel section encased in concrete for columns & the concrete slab or profiled deck slab is connected to the steel beam with the help of mechanical shear connectors so that they act as a single unit. In India, many consulting engineers are reluctant to accept the use of composite steel-concrete structure because of its unfamiliarity and complexity in its analysis and design. But literature says that if properly configured, then composite steel-concrete system can provide extremely economical structural systems with high durability, rapid erection and superior seismic performance characteristics. The real attraction of composite 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 behaviour.

A. Elements of composite construction

1. Composite beam, slab & shear connectors

A steel concrete composite beam consists of a steel beam, over which a reinforced concrete slab is cast with shear connectors. The composite action reduces the beam depth. Rolled steel sections themselves are found adequate frequently for buildings and built up girders are generally unnecessary. The composite beam can also be constructed with profiled sheeting with concrete topping or with cast in place or precast reinforced concrete slab.

2. Composite Column

A steel – concrete composite column is conventionally a compression member in which the steel element is a structural steel section. There are three types of composite columns used in practice which are Concrete Encased, Concrete filled, Battered Section.

3. Shear Connectors

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. Therefore, mechanical shear connectors are required at the steel-concrete interface. These connectors are designed to

(a) Transmit longitudinal shear along the interface,

(b) Prevent separation of steel beam and concrete slab at the interface.

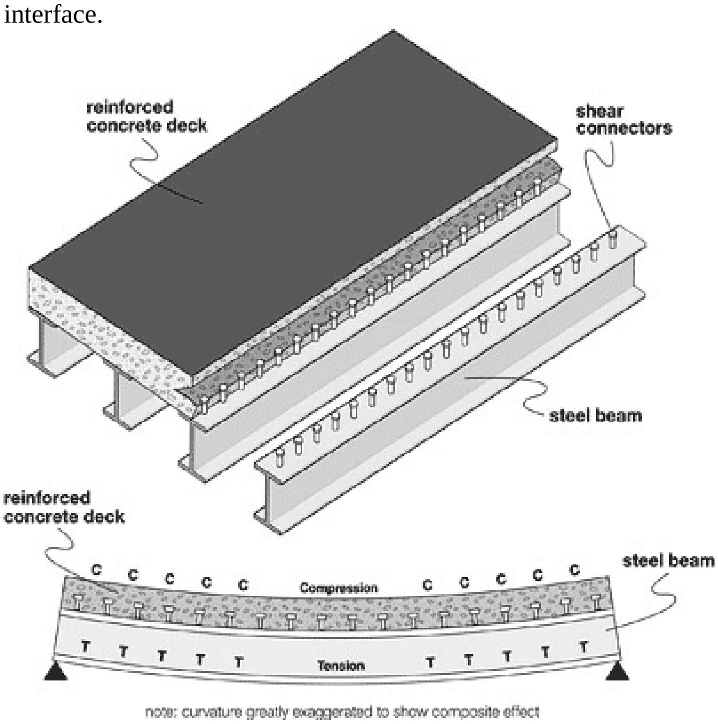

Fig. 1 Typical Composite Beam Slab Details with shear connectors

IV. BUILDING DETAILS

The building considered here is a commercial building. The plan dimension is 30m x 24m. The study is carried out on the same building plan for both R.C.C, Steel and Composite construction. The floor plans were divided into five by six bays in such a way that center to center distance between two grids is 6 meters by 4 meters respectively as shown in Figure 2. The basic loading on both types of structures are kept same.

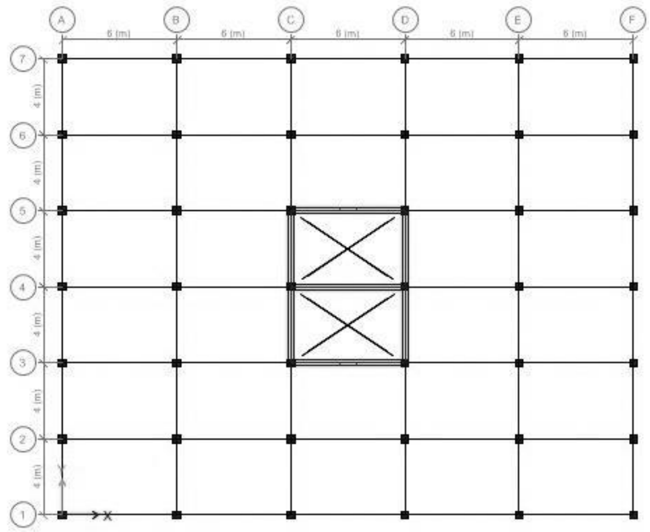

Fig.2 Plan showing typical floor

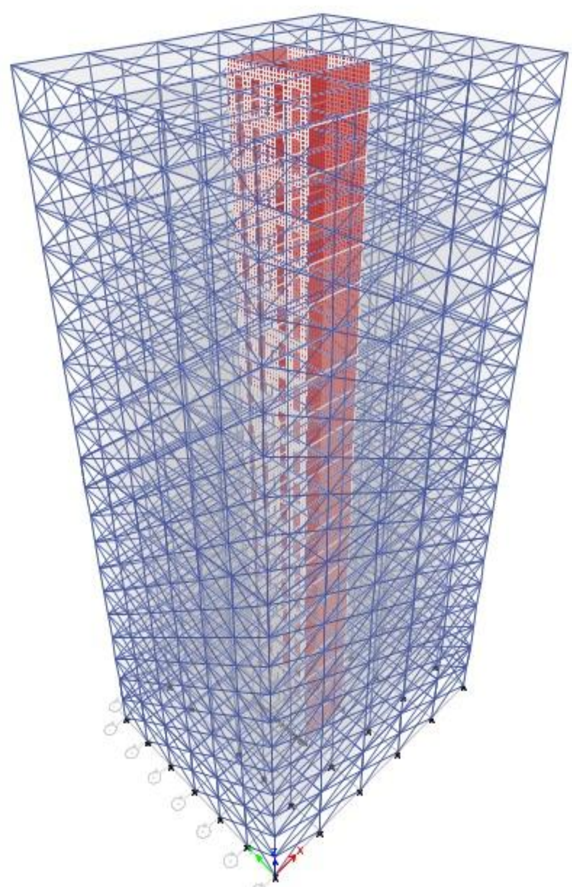

Fig.3 3-D ground level view from E-TABS

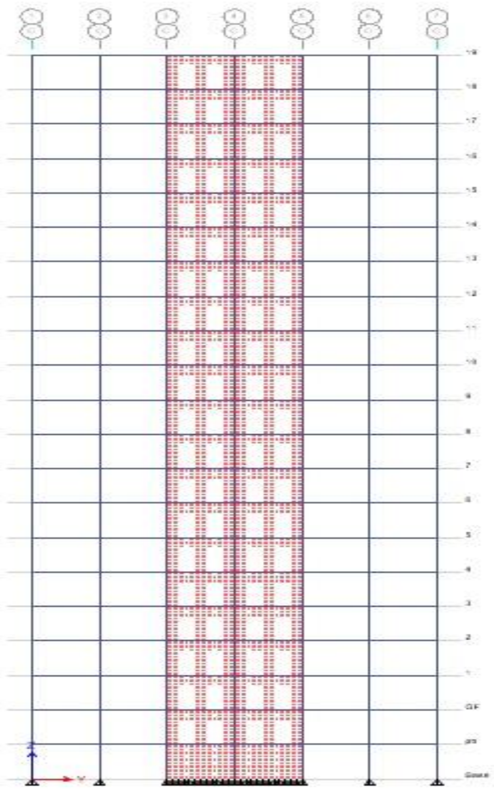

Fig.4 Elevation showing the shear wall

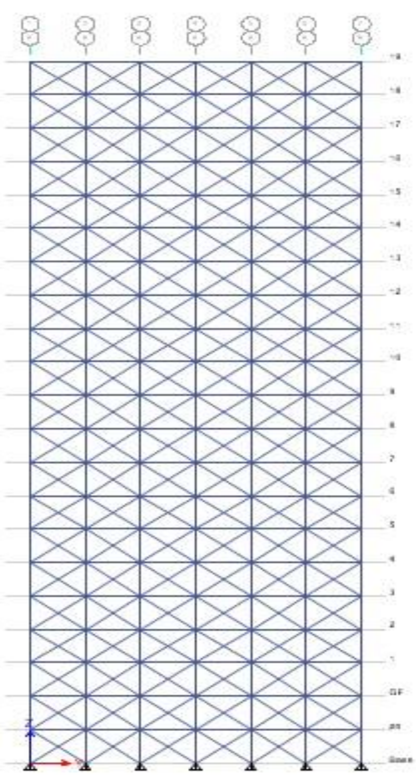

Fig.5 Elevation showing the Cladding(Bracing) arrangements

Table 1: Data for Analysis of R.C.C. Structure

S.I No	Particulars	Dimension/Value
1	Plan Dimension	30x24 m
2	Total height of the building	60 m
3	Height of each storey	3 m
4	Height of parapet	1 m
5	Depth of foundation	3 m
6	Size of beams 6.0m span Size of beams 4.0m span	450x600 300x450
7	Size of outer columns Size of internal columns	450x1000 450x850
8	Thickness of slab Thickness of walls	140mm 230mm
9	Seismic zone Wind speed Importance factor Zone factor Damping ratio	IV 50 m/s 1.0 0.16 5%
10	Floor finish Live load at all floors Density of concrete Density of brick	4.0kN/m2 1.0 kN/m2 25 kN/m 3 20 kN/m 3
11	Grade of concrete Grade of reinforcing steel Soil condition	M30 Fe500 hard soil

Table 2: Data for Analysis of Steel Structure

S.I NO	Particulars	Dimension/Value
1	Plan Dimension	30x24 m
2	Total height of the building	60 m
3	Height of each storey	3 m
4	Height of parapet	1 m
5	Depth of foundation	3 m
6	Size of beams 6.0m span Size of beams 4.0m span	ISMB 450 ISMB 300
7	Size of columns	ISMB 450
8	Thickness of slab Thickness of walls Thickness of bracing	140mm 230mm
9	Seismic zone Wind speed Importance factor Zone factor Damping ratio	IV 50 m/s 1.0 0.16 5%
10	Floor finish Live load at all floors Density of steel Density of brick	1.0 kN/m2 4.0 kN/m2 7850 kg/m3 20 kN/m3
11	Grade of concrete Grade of reinforcing steel Soil condition	M20 Fe415 hard soil

V. Modeling & Analysis

The explained 3D building model is analyzed using Equivalent Static Method. The buildings models are analyzed by using Staad-Pro V8i software. In composite structure the beam is modeled as composite beam element and column is modeled as RCC beam element and shear wall is modeled as RCC plate element. In RCC structure the beam and column is modeled as RCC beam element and shear wall is modeled as

RCC plate element. In Steel structure, the elements are modelled similar to thatof in RCC structure with the parent material change(steel). The different parameters such as node displacement, maximum shear force, axial force and maximum bending moment, Time period and few more parameters were studied for the models. The dead load and live load are considered as per IS-875(part 1 &2) and wind load is considered as per IS-875(part 3).For earthquake loading IS: 1893 (Part1)-2002 is used.

Table 3: Data for Analysis of Composite Structure

S.I NO	Particulars	Dimension/value
1	Plan Dimension	30x24 m
2	Total height of the building	60 m
3	Height of each storey	3 m
4	Height of parapet	1 m
5	Depth of foundation	3 m
6	Size of beams 6.0m span Size of beams 4.0m span Cold form Deformed bars	ISMB 450 ISMB 300 Based on requirements
7	Size of columns Cold form Deformed bars	ISMB 450 Based on requirements
8	Thickness of slab Thickness of profiled deck Thickness of walls	140 mm 75-100 mm 230 mm
9	Seismic zone Wind speed Importance factor Zone factor Damping ratio	IV 50 m/s 1.0 0.16 5%
10	Floor finish Live load at all floors Density of concrete Density of steel Density of brick	1.0 kN/m2 4.0 kN/m2 25kN/m2 7850 kg/m3 20 kN/m3
11	Grade of concrete Grade of reinforcing steel Soil condition	M20 Fe415 hard soil

VI. RESULTS

Analysis of all three types buildings is done and the results are as follows

Table 4: Comparisons of Composite, R.C.C. And Steel Buildings

Factor	Composite Building	R.C.C. building	Steel Building
Time period	5.91 (sec)	3.48 (sec)	3.77 sec
Max nodal displacement	0.129 (X-dir)m 0.131 (Z-dir)m	0.049 (X-dir)m 0.048 (Z-dir)m	0.061 (X-dir)m 0.046 (Z-dir)m
Max support rection	6017.81 kN	7987.02 kN	688.43kN
Story drift	X-dir =0.012 M Z-dir =0.0109 m	X-dir =0.0045m Z-dir =0.0037m	X-dir =0.0053m Z-dir =0.0032m
Actual weight of column and beam	8252.554 kN	27873.627kN	9967.65kN

Table 5: Comparisons of Composite, R.C.C. and Steel Beams ans Columns

Factor	Composite Building	R.C.C. building	Steel Building
Time period	5.91 (sec)	3.48 (sec)	3.77 sec
Max nodal displacement	0.131 (X-dir)m 0.131 (Z-dir)m	0.059 (X-dir)m 0.048 (Z-dir)m	0.067 (X-dir)m 0.046 (Z-dir)m
Max support rection	6288.81 kN	7726.02 kN	6198.43kN
Story drift	X-dir =0.012 m Z-dir =0.0109 m	X-dir =0.0045m Z-dir =0.0037m	X-dir =0.0053m Z-dir =0.0032m
Actual weight of column and beam	7952.554 kN	27873.627 kN	7967.65kN

Table 6 : Quantities of materials

Type	Concrete in Cub.mt	Reinforcement in ton	Structural steel in ton
R.C.C	5550	276	-
Steel	1400	74	1580
Composite	2300	120	715

Table 7 : Comparison of various parameters

PROPERTY	RCC	STEEL	COMP.	SAVE in %	
				RCC	**STEEL**
Max.Axial Force (kN)	7987.1	6848.4	6017.81	24.65	12.12
Max.Shear Force (kN) x-axis y-axis	 166.9 131.1	 145.2 120.45	 113.45 100.25	 32.02 23.53	 21.86 16.77
Max.B.M (kN.m) (x-axis) (z-axis)	 510.4 581.2	 471.6 456.28	 434.7 441	 14.83 24.12	 7.97 3.34

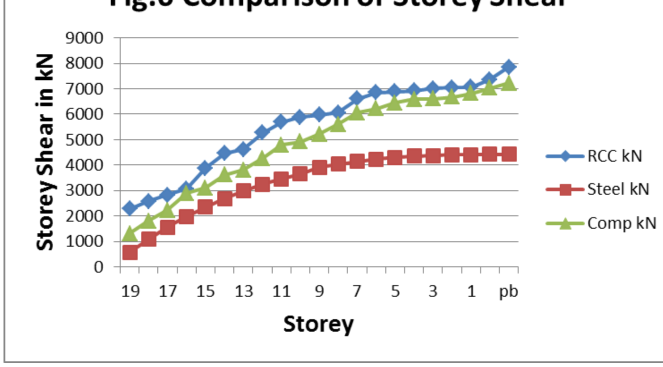

Fig.6 Comparison of Storey Shear

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Fig : 7 Comparison of storey stiffness X- direction

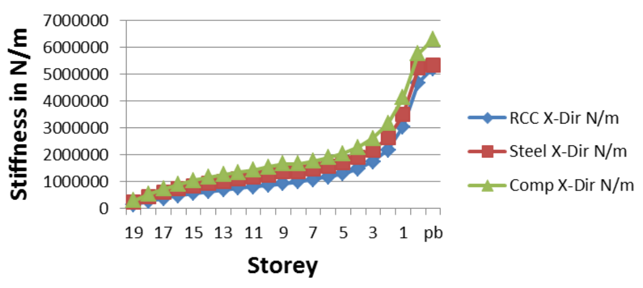
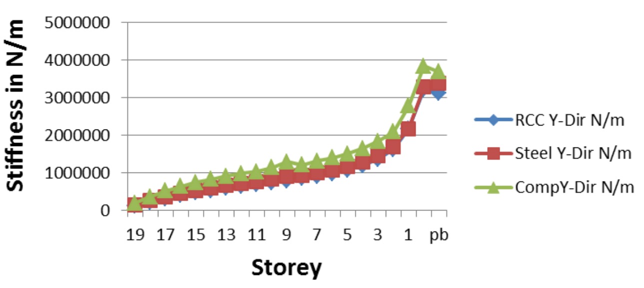


Fig : 8 Comparison of storey stiffness Y-direction



VII. Discussion

1- Through E-TABS, values of the time period of all three structures are extracted .The maximum time period is of composite building, it means it is more flexible to oscillate back and forth when lateral forces act on the building. Also results show that R.C.C building has least time period which says it is very less flexible amongst all three structures.

2- From table 4&5, the maximum nodal displacement in Steel and R.C.C. structures are nearly same but it is double in composite structure but within the limit. This is because; composite structure is more flexible as compared to RCC structure and steel structures

3- The maximum axial force, shear force, twisting moment and bending moment in columns in transverse and longitudinal direction are analysed and studied thoroughly and it is found that axial force in all composite columns is reduced by 18% to 30% than RCC columns. The shear force in exterior columns is observed to be more than interior columns in transverse direction and for composite columns it is reduced by 31% to 47%. Shear force in longitudinal direction is also more for exterior columns than interior columns and for composite columns it is reduced by 30% to 45%. Twisting moment in columns of composite structure is reduced from 40% to 66% and about 39% to 65% in transverse and longitudinal directions respectively as compared to RCC structure. It can be seen that the bending moment in composite columns in transverse direction is reduced by 24% to 41% whereas in longitudinal direction it is reduced only by 25% to 42%.

4- From table 6&7, it is been observed that on using composite stuctures for high rise buildings will save more percentage of quantity and can get effectiveness in terms of structural behavior.

VIII. Conclusion

Analysis and design results of B+G+20 storied Composite, R.C.C, Steel and composite buildings is given in Paper. The comparison of results of all three building shows that:-

- As the results show the Steel option is better than R.C.C. But the Composite option for high rise building is best
- In all the options the values of story displacements are within the permissible limits as per code limits.
- Steel and composite structure gives more ductility to the structure as compared to the R.C.C. which is best suited under the effect of lateral forces.
- The dead weight of composite structure is found to be 20% to 25% less than RCC structureand 16%- 18% and hence the seismic forces are reduced by 15% to 20%.
- Presents work shows the use of concrete filled steel tube columns has been consistently applied in the design of tall buildings as they provide nsiderable economy in comparison with conventional steel building. Also performance wise result good compared to RCC and Steel building.
- Weight of composite structure is quite low as compared to R.C.C. structure which helps in reducing the foundation cost.
- Composite structures are the best solution for high rise structure.
- Composite structures are more economical than that of R.C.C. structure.
- Speedy construction facilitates quicker return on the invested capital & benefit in terms of rent.

Acknowledgment

This paper too could not be completed without the help and support of many special persons.

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