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Study of Seismic and Wind Effect on Multi Storey R.C.C. Steel and Composite Building

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Abstract: ***In India reinforced concrete structures are mostly used since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. So the Structural engineers are facing the challenge of striving for the most efficient and economical design solution. Also Wind & Earthquake engineering should be extended to the design of wind & earthquake sensitive tall buildings. 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. 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. This paper discusses analysis and design of G+15 stories R.C.C., Steel and Composite Building under effect of wind and earthquake using STAAD PRO; it proves that steel-concrete composite building is better option.***

Index Terms—**Earthquak effect, wind effect, Steel-Concrrete Composite Structure, STAAD PRO**

I. INTRODUCTION

In India reinforced concrete members are mostly used in the framing system for most of the buildings since this is the most convenient & economic system for low-rise buildings. However, for medium to high-rise buildings this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. But nowadays 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

- To provide a brief description to various components of steel-concrete composite framing system for buildings.
- To compare the analytical results of all three buildings models such as storey displacement, nodal displacement, maximum axial force, and maximum shear force and bending moments etc.
- To compare the cost effectiveness of steel-concrete composite frames over traditional R.C.C and steel frames for building structures.

  Procedure for Paper Submission

II. 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. It can also 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. Numbers of the studies are carried out on composite construction techniques by different researchers in different parts of the world and found it to be better earthquake resistant and more economical as compared to RCC construction.

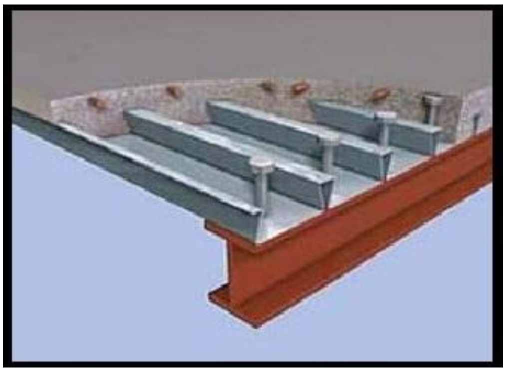

Fig 1: Typical Composite Beam Slab Details

ELEMENTS OF COMPOSITE CONSTRUCTION

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

2.1 Composite slab
2.2 Composite beam
2.3 Composite column
2.4 Shear connector

2.1 Composite slab

Traditional steel-concrete floors consist of rolled or built-up structural steel beams and cast in-situ concrete floors connected together using shear connectors in such a manner that they would act monolithically .The principal merit of steel-concrete composite construction lies in the utilization of the compressive strength of concrete slabs in conjunction with steel beams, in order to enhance the strength and stiffness of the steel girder. More recently, composite floors using profiled sheet decking have become very popular in the West for high rise office buildings. Composite deck slabs are particularly competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient. However, composite slabs with profiled decking are unsuitable when there is heavy concentrated loading or dynamic loading in structures such as bridges. The alternative composite floor in such cases consists of reinforced or pre-stressed slab over steel beams connected together to act monolithically. Advantages of using composite floors with profiled steel decking are

- Savings in steel weight are typically 30% to 50% over non-composite construction.
- Greater Stiffness of composite beams results in shallower depths for the same span. Hence lower storeys heights are adequate resulting in savings in cladding costs, reduction in wind loading and savings in foundation costs.
- Faster rate of construction.

2.2 Composite Beams

A steel concrete composite beam consists of a steel beam, over which a reinforced concrete slab is cast with shear connectors. 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.

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 columns with fully and partially concrete encased steel sections concrete filled tubular section are generally used in composite construction.

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, thus simplifying the construction and architectural detailing.
8) Erection of high rise building in an extremely efficient manner.
9) Formwork is not required for concrete filled tubular sections.

2.4 Shear Connectors

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.

Following are the commonly used types of shear connectors as per IS: 11384-1985

- rigid shear connectors,
- flexible shear connectors
- anchorage shear connectors

III. BUILDING DETAILS

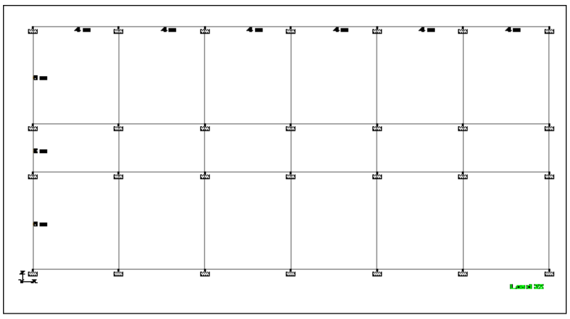

Fig.2 Plan showing typical floor

The building considered here is a commercial building. The plan dimension is 25.61mx15.92m. The study is carried out on the same building plan for both R.C.C and Composite

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construction. The basic loading on both types of structures are kept same.

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

Plan dimension	25.61mx15.92m
Total height of building.	56.5m.
Height of each storey	3.35m
Height of parapet	1.0m
Depth of foundation	2.9m
Size of beams 6.0m span	300x650
Size of beams 3.0m span	300x450
Size of beams 4.0m span	230x500
Size of outer columns	450x850
Size of internal columns	450x1100
Thickness of slab	140mm
Thickness of internal & external	230mm
Seismic zone	IV
Wind speed	39 m/s
Soil condition	hard soil
Importance factor	1.0
Zone factor	0.24
Floor finish	1.0 kN/m^2
Live load at all floors	4.0 kN/m^2
Grade of concrete	M30
Grade of reinforcing steel	Fe415
Density of concrete	25 kN/m^3
Density of brick	20 kN/m^3
Damping ratio	5%

Table 2: Data for Analysis of Steel Structure

Plan dimension	25.61mx15.92m
Total height of building.	56.5m.
Height of each storey	3.35m
Height of parapet	1.0m
Depth of foundation	2.9m
Size of beams 6.0m span	W24x76
Size of beams 4.0m span	W21x48
Size of beams 3.0m span	W24x76
Size of columns upto 10th floor	W21x248
Size of columns for remaining floor	W18x158
Thickness of slab	140mm
Thickness of internal & external	230mm
Seismic zone	IV
Wind speed	39 m/s
Soil condition	hard soil
Importance factor	1.0
Zone factor	0.24
Floor finish	1.0 kN/m^2
Live load at all floors	4.0 kN/m^2
Grade of concrete	M30
Grade of reinforcing steel	Fe415
Density of steel	7850 kg/m^3
Density of brick	25 kN/m^3
Damping ratio	5%

Table.3: Data for Analysis of Composite Structure

Plan dimension	25.61mx15.92m
Total height of building.	56.5m.
Height of each storey	3.35m
Height of parapet	1.0m
Depth of foundation	2.9m
Size of beams 6.0m span	ISMB 450
Size of beams 4.0m span	ISMB 300
Size of beams 3.0m span	ISMB 200
Size of outer columns	320X580(ISMB 400)
Size of internal columns	330X630(ISMB 450)
Thickness of slab	140mm
Thickness of all walls	230mm
Seismic zone	IV
Wind speed	39 m/s
Soil condition	hard soil
Importance factor	1.0
Zone factor	0.24
Floor finish	1.0 kN/m^2
Live load at all floors	4.0 kN/m^2
Grade of concrete	M30
Grade of reinforcing steel	Fe415
Density of concrete	25 kN/m^3
Density of brick	20 kN/m^3
Damping ratio	5%

IV. ANALYSIS

The explained 3D building model is analyzed using Equivalent Static Method. The building models are then analyzed 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 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	0.131 (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

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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

QUANTITIES:

Table 6: Quantities of Various Materials

	Concrete	Reinforcement	Structural
R.C.C	2096.3	146.96	-
Steel	913.27	63.92	796.76
Composite	1121.61	56.88	327.72

VI. DISCUSSION

- Through Staad Pro, 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.
- From table 6, the storey drift i.e the displacement of one level relative to the other level above or below, is double in composite building in comparison with Steel and R.C.C buildings.
- From table 6, 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.
- From table 7 and figure 20 it is clear that the axial forces in R.C.C. column is maximum and nearly equal in steel and composite column. This is because, RCC sections are bulky in size thus their self-weight as compared to thin steel and composite sections is more. This results in the higher axial force on the columns in case of RCC frame structure.
- From table 7 it is clear that the maximum shear force and maximum bending moment in composite beam is less compared to RCC beam. This is because; the dead load of composite sections is less, as compared to RCC sections. Also the stiffness of the composite sections is less as compared to RCC sections, thus less bending moment is transferred to the beam from the beam-column joint.
- As the dead weight of a composite structure is less compared to an R.C.C. and Steel structure, it is subjected to fewer amounts of forces induced due to the earthquake.
-

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.

GRAPHS

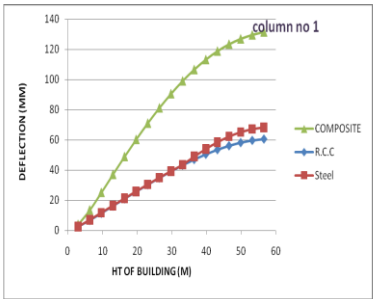

Fig. 3: Comparison of Deflection

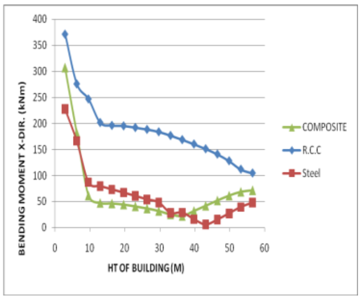

Fig. 4: Comparison of Bending Moment X-Direction

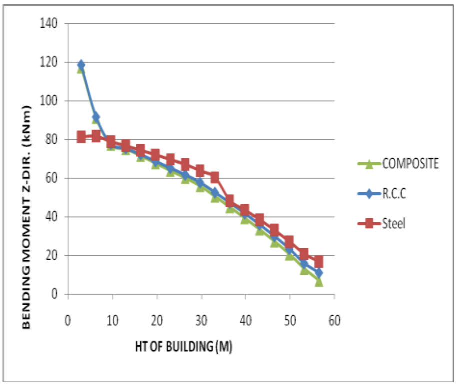

Fig. 5: Comparison of Bending Moment Z-Direction

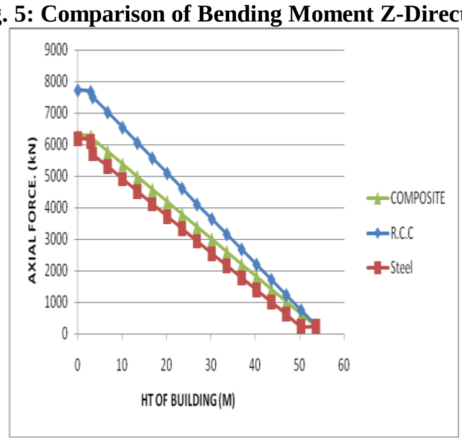

Fig. 6: Comparison of Axial force

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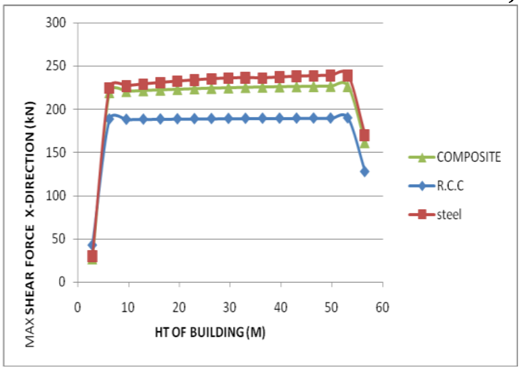

Fig. 7: Comparison of Shear force in X-direction

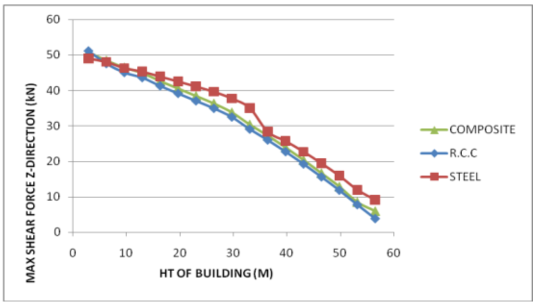

Fig. 8: Comparison of Shear Force in Z-Direction

VII. CONCLUSIONS

Analysis and design results of G+15 storied Composite, R.C.C and Steel buildings is given in chapter. The comparison of results of all three building shows that:-

1) The deflection & storey drift in Steel and R.C.C. Structures are nearly same but it is double in composite structure thin the limit. This is because; composite structure is more flexible as compared to RCC structure and steel structures.
2) The graph shows that there is significant reduction in bending moments of columns in X Direction from R.C.C to steel and composite structure.
3) The graph shows that there is no significant difference in bending moments of columns in Z Direction in all three type of structure.
4) Axial Force in R.C.C. structure is on higher side than that of composite structure and least in steel structure.
5) Weight of composite structure is quite low as compared to RCC structure which helps in reducing the foundation cost.
6) Composite structures are more economical than that of R.C.C. structure as shown in earlier chapter.
7) Speedy construction facilitates quicker return on the invested capital & benefit in terms of rent.
8) Weight of composite structure is quite low as compared to R.C.C. structure which helps in reducing the foundation cost.
9) Composite structures are the best solution for high rise structure.

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