Comparative Study of Steel and Composite Structures for Building

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Abstract— Steel Concrete Composite construction has gained wide acceptance worldwide as an alternative to Steel construction. However, this system is relatively new concept for the construction industry. Reinforced concrete members are used in the framing system for most of the buildings since this is the most convenient & economic system for one storey buildings. However, for multi storeyed building this type of structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. And steel structure is also good for low load but Steel concrete composite frame system can provide an effective and economic solution to most of these problems in medium to high rise buildings. In the present work Concrete composite with RCC, Steel structure options are considered for comparative study of G+2 storey of building which is situated in earthquake zone-3 of IS 1893-2002 earth quake loading. Equivalent static method of analysis is used for modeling of Composite and Steel structures; STAAD-pro V8i Finite element software is used. In the composite structure Steel column is encased in PCC and RCC slab on steel girder are employed. 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). The result of this work shown that, the cost of the composite is less than the steel structure. The critical bending moment and Shear force values are more than steel structures due to decreased dead load. Composite structure is best solution for the multi storeyed Structure compared to Steel structure.

Keywords: Building, Cost Difference, Axial Force, Node Displacement, Max Bending Moment and Shear Force

I. INTRODUCTION

A. Steel Structures:

Steel structure is a metal structure which is made of structural steel* components connect with each other to carry loads and provide full rigidity. Because of the high strength grade of steel, this structure is reliable and requires less raw materials than other types of structure like concrete structure and timber structure.

In modern construction, steel structures is used for almost every type of structure including heavy industrial building, high-rise building, equipment support system, infrastructure, bridge, tower, airport terminal, heavy industrial plant, pipe rack, etc.

*Structural steel is steel construction material which fabricated with a specific shape and chemical composition to suit a project's applicable specifications.

Depending on each project's applicable specifications, the steel sections might have various shapes, sizes and gauges made by hot or cold rolling, others are made by welding together flat or bent plates. Common shapes include the I-beam, HSS, Channels, Angles and Plate.

1) Components of steel structure buildings:

There are five main types of structural components that make up a steel frame –

- Tension members
- Compression members
- Bending members
- Combined force members
- Connections

Tension members are usually found as web and chord members in trusses and open web steel joists. Ideally tension members carry tensile forces, or pulling forces, only and its end connections are assumed to be pinned. Pin connections prevent any moment (rotation) or shear forces from being applied to the member.

Compression members are also considered as columns, struts, or posts. They are vertical members or web and chord members in trusses and joists that are in compression or being squished.

Bending members are also known as beams, girders, joists, spandrels, purlins, lintels, and girts. Each of these members have their own structural application, but typically bending members will carry bending moments and shear forces as primary loads and axial forces and torsion as secondary loads.

Combined force members are commonly known as beam-columns and are subjected to bending and axial compression.

Connections are what bring the entire building together. They join these members together and must ensure that they function together as one unit.

B. Composite structure:

Structural members that are made up of two or more different materials are known as composite elements. The main benefit of composite elements is that the properties of each material can be combined to form a single unit that performs better overall than its separate constituent parts. The most common form of composite element in construction is a steel-concrete composite, however, other types of composites include; steel-timber, timber-concrete, plastic-concrete, and so on.

As a material, concrete works well in compression, but it has less resistance in tension. Steel, however, is very strong in tension, even when used only in relatively small amounts. Steel-concrete composite elements use concrete's compressive strength alongside steel's resistance to tension, and when tied together this results in a highly efficient and lightweight unit that is commonly used for structures such as multi-storey buildings and bridges.

The composite structure includes the Composite columns, Composite Beams and Composite floors used individually or in various combinations to make the design cost-effective and efficient to the service requirements and desired performance. The most commonly used sections are Steel beam anchored to Concrete slab by means of shear connectors of flexible, rigid, or cut channels, bearing types like studs etc.

1) Components of Composite Structure Buildings:

1) Composite deck slab- Composite floor system consists of steel beams metal decking and concrete. They are combined in 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 build up steel beam connected to a formed steel deck and concrete slab. The metal deck typically span unsupported between steel members, while also providing a working platform for concreting work. The composite floor system produce a rigid horizontal diaphragm, providing stability to the overall building system, while distributing wind and seismic shear to the lateral load-resisting system
2) Composite beams- In conventional composite construction, concrete slabs rest over steel beams and are supported by beam. Under load these to 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 there 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 Compression than in tension, and steel is susceptible to buckling in Compression. By the composite action between the two, We can utilize there respective advantage to the fullest extent. General in steel concrete composite beams, steel beams are integrally connected to pre-fabricated or cast in situ reinforced concrete slabs.
3) Composite columns- A steel concrete composite column is a Compression member, Comprising either of a concrete incased hot rolled steel section or a concrete filled hallow 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 design of composite column. The method of design in this report largely fallows EC4, Which incorporate latest research on composite construction. Indian standard for composite construction IS 11384-1985 does not make any specific reference to composite column. This method also adopt the European buckling curve for steel column as a basic of column design.
4) Shear connector- The total shear force at the interface between concrete slab and steel beam is approximately 8 times the total load carried by the beam. There for, mechanical shear connector is required at the steel concrete interface. These connector are designed to
   1) transmit longitudinal shear along the interface
   2) prevent separation of steel bean and concrete slab at the interface. Commonly used types of shear connector as per IS:11384-1985. There are three main types of shear connectors., rigid shear connector, flexible shear connector and Anchorage shear connectors.

2) Advantages of using composites in structures:

– Increased strength for a given cross sectional dimension.
– Increased stiffness, leading to reduced slenderness and increased buckling resistance
– Good fire resistance in the case of concrete encased.
– Corrosion protection in encased member.
– Superior seismic performance for lateral load.
– Significant economic advantages over either pure structural steel or reinforced concrete alternatives.
– 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.
  1) Erection of high rise building in an extremely efficient manner.
  2) Formwork is not required for concrete filled tubular sections
  3) Economical for High rise buildings

II. METHODOLOGY

1) In the present work it is proposed to prepare a finite element models of G+2 Storey Industrial building using STAAD Pro V8i with fixed base at ground level.
   – Steel Structure
   – Composite Structure
2) Apply Dead load, Live load and Wind load/Earth quake load as per IS 875-1987and IS 1893-2002 and Carry out the equivalent Static method of analysis.
3) Carry out Designs by Limit state method using IS 456-2000 and SP16-1980
4) Carry out quantity surveying for all the three type of buildings.
5) Estimate the cost using Karnataka State Schedule Rate – 2018 Book
6) Compares the result of both the type of structures.

III. MODELING AND ANALYSIS

The study has been carried out with some basic assumption in design criteria/parameters for (G+2) storied in building for Steel as well as Composite including relevant soil parameters, wind speed, landscape class and topography, earthquake zone and value of coefficient and acceleration based on available local data and stipulations of bureau of

Indian standards and euro codes. The dead burden and live burden has been consider dependent on the IS 875(part-1 and 2), wind load depends on IS-875(Part-3). For tremor stacking, the arrangement of IS-1893:2002 was considered.

The study has been carried out for the two variant
G+2 RCC, 4.5m height.
G+2 Steel Structure, 4.5m height.

A. Building Detail

The building considered here is an Industrial building having G+2 storied located in seismic zone 3 and for earthquake loading, the provisions of IS:1893(Part1)-2002 is considered. The wind velocity 39m/s. The line diagram plan of building is shown in fig.1 the building is planned to facilitate the basic requirements of an Industrial building. He plan dimension of the building is 12X42 m. Height of each storey for Composite and steel structure is 4.5 m. The study is carried out on the same building plan for steel and composite construction with some basic assumptions made for deciding preliminary sections of both the structures. The basic loading on both type of structures are kept same, other relevant data is tabulated in table1&2.

1) For Steel Structure:

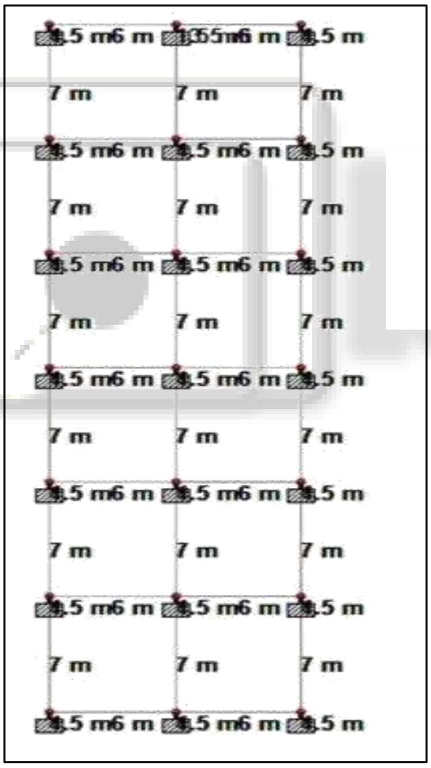

Fig. 1: Typical Plan of RCC Building

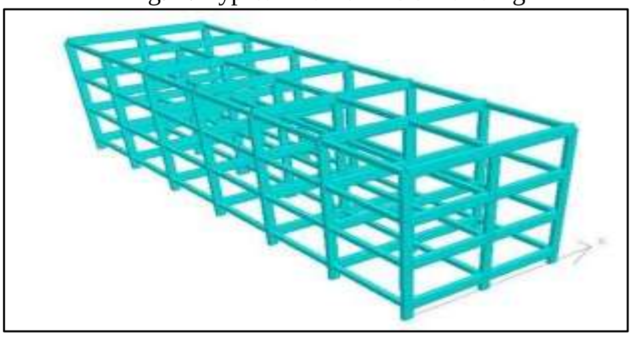

Fig. 2: 3D Model of Building

Plan Dimensions	12x42 m
Total height of the structure	15 m
Height of each storey	4.5 m
Height of parapet	1 m
Size of beams at plinth level	ISMB-450
Size of beam at floor level	ISMB-450
Size of column	ISMB-500
Thickness of the slab	0.150 mm
Thickness of wall	0.230 m
Seismic Zone	III
Wind speed	33 m/s
Importance factor	1
Zone factor	0.16
Floor Finish	1.5 KN/m2
Live load	7 KN/m2
Grade of concrete for slabs	M 30
Density of concrete	25 KN/m3
Density of brick	20 KN/m3
Damping Ratio	5%
Grade of structural steel	Fe250
Concrete cover to reinforcement for slab	0.025 m

Table 1: Data for the analysis of Steel structure

2) For Composite Structure:

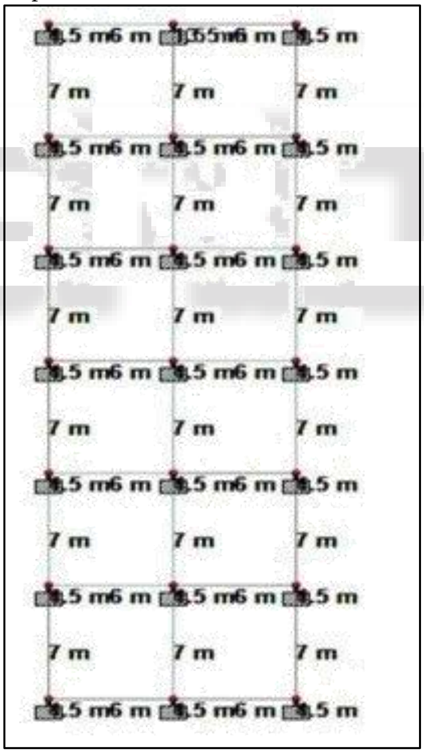

Fig. 1: Typical Plan of Building

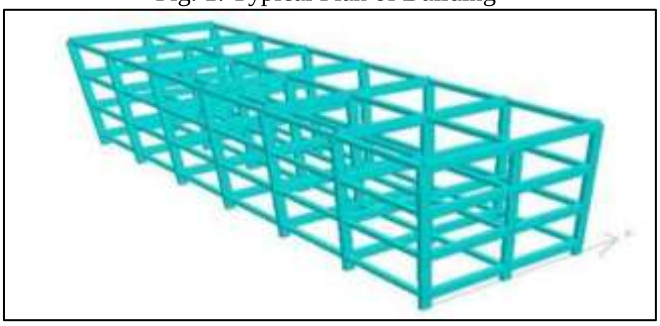

Fig. 2: 3D Model of Building

Plan Dimensions	12x42 m
Total height of the structure	15 m
Height of each storey	4.5 m
Height of parapet	1 m
Size of beams at plinth level	ISMB-300
Size of beam at floor level	ISMB-300
Size of column	ISMB-400
Thickness of the slab	0.150 m
Thickness of wall	0.230 m
Seismic Zone	III
Wind speed	33 m/s
Importance factor	1
Zone factor	0.16
Floor Finish	1.5 KN/m^2
Live load	7 KN/m^2
Grade of concrete for slabs	M 30
Grade of concrete for beams and columns	M 30
Grade of reinforcement steel	Fe415
Density of concrete	25 KN/m^3
Density of brick	20 KN/m^3
Damping Ratio	5%
Grade of structural steel	Fe250
Concrete cover to reinforcement for slab	0.025 m
Concrete cover to reinforcement for beam	0.025 m
Concrete cover to reinforcement for column	0.040 m

Table 2: Data for the analysis of Steel structure

B. 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 encased steel composite element. In Steel structure the beam and column is modeled as Steel beam element. The different parameters such as node displacement, maximum shear force, axial force and maximum bending moment, Cost are 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(part3).For earthquake loading IS:1893(Part1)-2002 is used.

IV. RESULTS AND DISCUSSION

In the present study the G+2 composite and steel multistory Industrial building is considered. An effort has been made to calculate the cost effectiveness of composite and steel structure elements. The parameter considered is nodal displacement, maximum shear force, axial force and maximum bending moment is considered and their variation in the form of graph is shown.

A. Cost of Beam

The quantity of composite and steel Beams is taken from design and calculated total quantity as shown below. The rate of Reinforcement steel, Structural Steel and concrete is obtained from the present market. The Cost of Steel beams and Composite beams as given in table-4 and graph variation of the cost of beam is shown in graph

Material	Composite Structure			Steel Structure		
	Quantity of beam	Rate	Amount	Quantity of beam	Rate	Amount
Structural Steel	60.81	60000	3648600	60.81	60000	3648600
Reinforce ment Steel	10.58	56000	592480	13.6	56000	761600
Concrete	302.4	4000 (for m work is not)	1209600	226.8	5000	1134000
Total Amount			5450680			5544200

Table 3: Cost of beams in different structures.

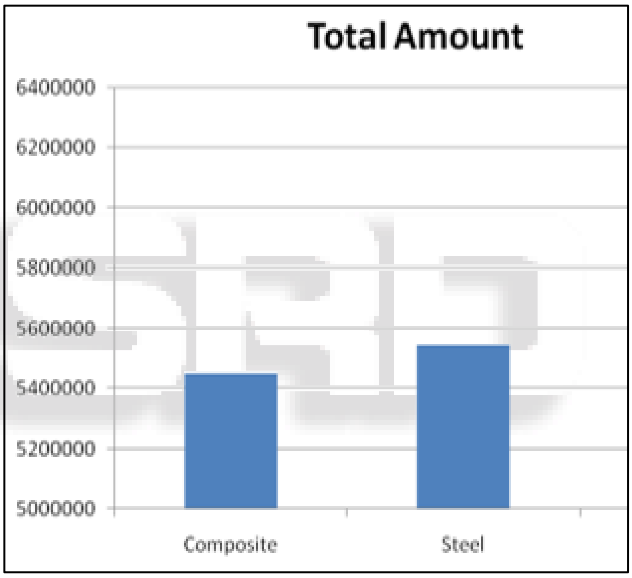

Fig. 1: Cost Variation Graph of Beams for Composite and Steel

B. Cost of Column

The quantity of column for Composite and Steel structure are taken from the design and total quantity is shown below. The rate of reinforcing steel ,Structural steel and concrete are taken from market. The table 4 show the total cost of columns for Steel and composite structure.

Material	Composite Structure			Steel Structure		
	Quantity of column	Rate	Amount	Quantity of column	Rate	Amount
Structural Steel	16.5	60000	960000	24.97	60000	1498200
Reinforcement Steel	-	56000	0	-	56000	0
Concrete	36.3	400	14520	-	500	0

		0	0		0	
Total Amount			1105200			1498200

Table 4: Cost of Columns in different structures.

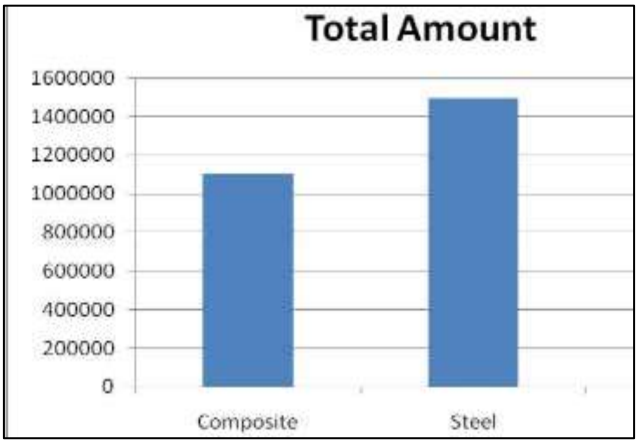

Fig. 2: Cost Variation Graph of Columns for Composite and Steel

C. Axial Force

From the analysis results axial forces are taken for composite and Steel at different floor. The table 5 shows the maximum axial forces in Composite and steel structure

Type of floor	Maximum Axial Force in Composite	Maximum Axial Force in Steel
Plinth	1800	1600
Gr. Floor	1450	1450
1st Floor	1260	900
2nd Floor	900	520

Table 5: Maximum Axial force in different structures.

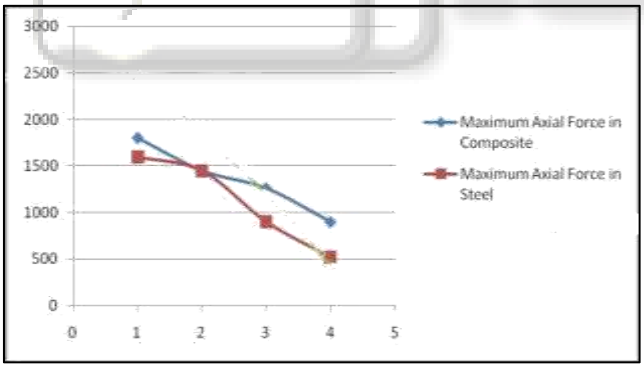

Fig. 3: Axial forces variation graph for Steel and composite structure

D. Node Displacement

From the analysis results of node displacement are taken for composite and steel structure. The node displacement for composite and steel structure are given in table-6

Type of floor	Composite Structure	Steel Structure
Plinth	1.5	2.3
Gr. Floor	15	24
1st Floor	27	31
2nd Floor	41	49

Table 6: Node Displacement in different structures.

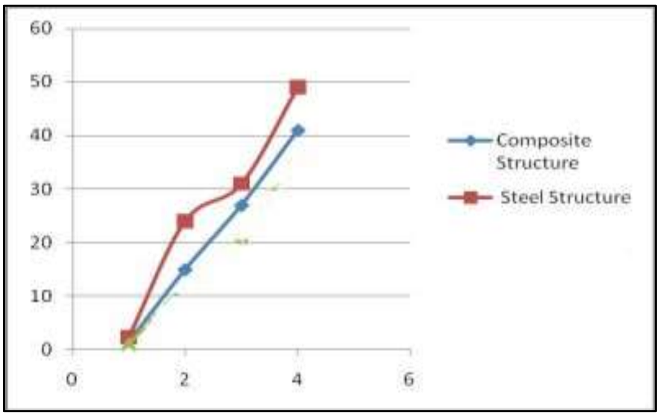

Fig. 4: Node Displacement for RCC, Steel and composite structure

E. Maximum Bending Moment And Shear Force

From the analysis results maximum bending moment and shear force are taken for composite and Steel structure. The table 7 and 8 shows the maximum bending moment and shear force in composite and steel structure.

Comparison property	Composite beam	Steel beam
Max Shear force (KN)	370	280

Table 7: Max BM and SF in RCC, steel and composite structure

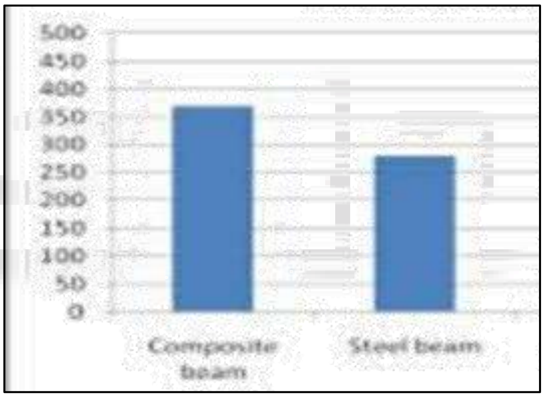

Fig. 5: Max shear force(KN) for RCC Steel and composite structure

Comparison property	Composite beam	Steel beam
Max Bending moment in Z-direction (KN-m)	410	321

Table 8: Max BM and SF in RCC, steel and composite structure

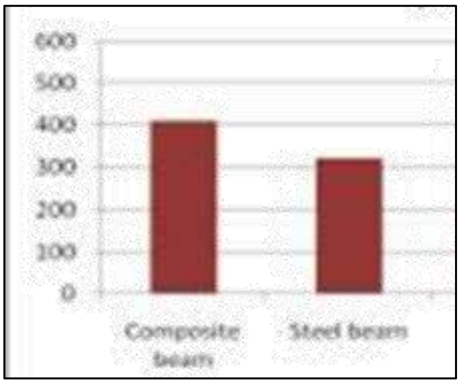

Fig. 6: Max Bending Moment for Steel and composite structure

V. DISCUSSION

1) From the beam cost comparison chart and table it is clear that the cost of the Composite beam is 1.7% less than Steel Structure beam. This is because, the Composite beam does not required bar bending and form work.
2) From the Column cost comparison chart and table it is clear that the cost of the Composite beam is 35% less than Steel Structure Column. This is because, the Composite beam does not require bar bending and steel binding of column.
3) Fr0m the Axial force chart and table it is clear that axial force of Composite structure is quite more than the Steel Structure.
4) From node displacement table and chart, it is clear that Composite Structure has less displace of node compare to Steel Structure.
5) From the maximum bending moment and shear force chart and table it is clear that the max bending moment and shear force in composite beam is quite more than the Steel structure.

VI. CONCLUSION

In this work. The comparative study of Steel and Composite Structure for industrial building (G+2) is presented. The parameter considered are cost of beam, cost of column, node displacement, member deflection, maximum bending moment, maximum shear force is considered. Thus based on the analysis results discussed in previous chapter fallowing conclusions drawn.

1) The axial force in Composite structure is quite higher than the Steel Structure.
2) Composite Structures are more economical than Steel Structure.
3) Mass of composite structure is more than the Steel structure.
4) Speed of work and speedy erection facilitates quicker return on the invested capital and benefit in terms of rent in composite structure.
5) Deflection in composite structure is less compared to steel structure.
6) The maximum bending moment and shear force is quite less than the steel structure.

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