Comparative study of cost and time evaluation in RCC, steel & Composite high rise building

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ABSTRACT

This paper deals with the study of composite structure as compare with the concrete and steel structure. The composite structure is far more advantageous over steel and concrete structure regarding Strength, Costs, and Time Period requirements. There is no need for formwork because the steel beam is able to sustain the self weight of steel and concrete, by itself or with the assistance of a few temporary props. Also this paper deals with the design of composite building with fixed base. 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. The cost effectiveness lies in composite option than R.C.C. option for static or dynamic analysis. Faster construction and better strength can be achieved through the composite construction, attracted us to conduct such comparative study. Effect of each building is studied with respect to time period, base shear, total dead load and most important cost of different schemes and time taken for the construction. Composite structures are the best solution for high rise structure as compared to RCC structure.

KEY WORDS: Composite Construction, Cost estimation, Time scheduling.

1. INTRODUCTION

Composite Steel-Concrete Structures are used widely in modern bridge and building construction. A composite member is formed when a steel component, such as an I-beam, is attached to a concrete component, such as a floor slab or bridge deck. In such a composite T-beam the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. The fact that each material is used to the fullest advantage makes composite Steel-Concrete construction very efficient and economical. One of the biggest revolutions came with introduction of hot-rolled steel section and cold-formed steel decking as a construction material for high-rise buildings. Steel framed structures with the composite floor would bring considerable economies to the overall cost of the project during its lifetime. In recent years significant development has taken place in the structural design of multistoried buildings, mainly based on the principles of composite construction. This will improve the speed of construction and reduce the overall construction cost. The main objective of steel framed composite floor construction is to provide a cost-effective alternative to the any other type of construction such as precast slab panel floor. 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. 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.

1.1. Objective: The composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges and high rise buildings. In due consideration of the above fact, this project has been envisaged which consists of analysis and design of a high rise building using Steel-Concrete composites. 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-Concrete composite structure and an equivalent R.C.C. & steel structure.

1.2. Elements of composite construction: In the past, for the design of a building, the choice was normally between a concrete structure and a masonry structure. But the failure of many multi-storied and low-rise R.C.C. and masonry buildings due to earthquake has forced the structural engineers to look for the alternative method of construction. Use of composite or hybrid 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. A need to study the composite design of the multi-story buildings keeping in view of the rapid development in this field. In India, it is comparatively new and no updated design codes are available for the same. 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. Formally the multi-story buildings in India were constructed with R.C.C framed structure or Steel frame structure but recently the trend of going towards composite structure has started and growing.

1.3. 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. 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.

1.4. Composite beam: 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.

1.5. 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. It is generally used as a load 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.

1.6. Shear connectors: Shear connections are essential for steel concrete construction as they integrate the compression capacity ofSupported concrete slab with supporting steel beams to improve the load carrying capacity as well as overall rigidity. 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 are Flexible shear connectors, Rigid shear connectors, Anchorage shear connectors.

2. METHODOLOGY

2.1. Construction methodology of steel framed Composite floor building: This is the one of the method of implementing composite elements in construction called as hybrid construction. Foundation of this building is normal box footings and RCC pedestals to hold steel columns. Anchor bolts of length 1200 mm is provided to hold huge steel columns in a position with special arrangement. Erection of column and beams of this building can be done in four stages. As shown in Figure 2, first lift includes the ground, first and second floor column and beams erection only. While second lift is in progress that time ground, first and second slab construction activities are in a progress. Likewise whole structure can be erected for all four lifts. Time scheduling gives clear idea about such simultaneous activities. After completion of column & beams erection for first lift, at one time construction of composite floor is progresses for three floors. On third floor deck sheet placing, on second floor shear stud welding and on first floor reinforcement lying is in progress. This type of system allows many work faces open together and huge amount of time saving can be achieved. Figure 6 shows the section of composite floor slab with all details. For pre-stressing of steel main beams, six cables on each side of the beam (includes six tendons in each cable) and for secondary beams, two cables on each side of the beam are placed with the help of fixtures. The construction activity of post-tensioning of composite steel beam is divided into three stages. In first stage, after 14 days of slab casting, the post-tensioning is with only 50% load. In second stage, after 21 days of slab casting, the post-tensioning is with 25% load. In third stage, after 28 days of slab casting, the post-tensioning is with 25% load. The full post-tensioning is done after 28 days of slab casting.

2.2. Construction methodology of steel frame with precast concrete floor: All the structural members are designed and constructed according to Eurocode-4, IS 13990 and IS 13994. As compared with precast frame with precast concrete floor method, shear studs take the function of the dowel bar for beams. The composite action between steel beam and concrete slab through the use of shear connectors is responsible for a considerable increase in the load-bearing capacity and stiffness of the steel beams, which when utilized in design, can result in significant savings in steel weight and construction depth (Figure 3). The headed shear studs as shown in Figure 3, are used with spacing 318 mm c/c. The shear stud welding is done by self-taping machine, which reduce the time of activity; but this method is costly than normal welding method . The screed of 50 mm thickness is placed with the nominal reinforcement of 8 Φ @ 250 mm c/c having M25 grade of concrete. The post-tensioning of steel beam is divided into three lifts, similar to the construction of steel framed composite floor building.

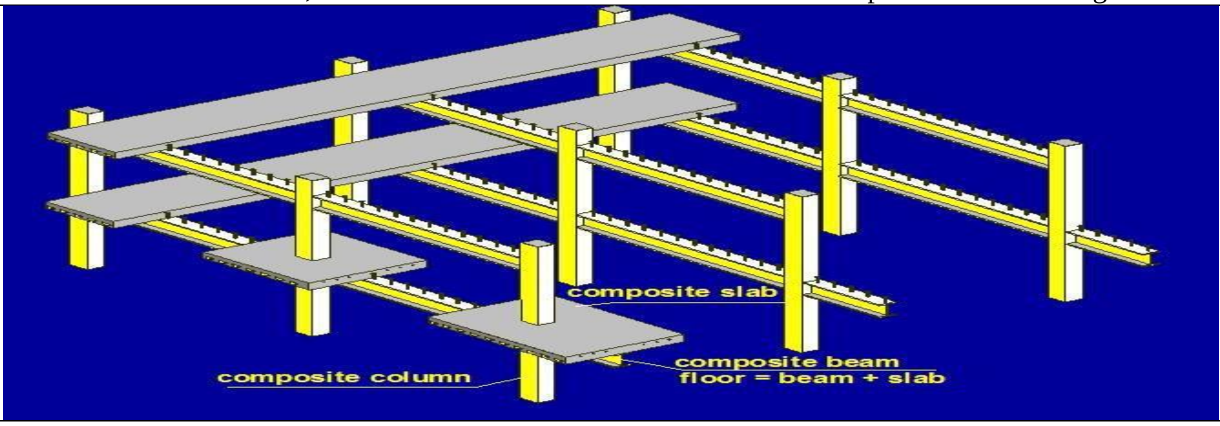

Fig.1.Composite beam, column and slab along with shear connections

Fig.2 Erected Frame after 1st Lift

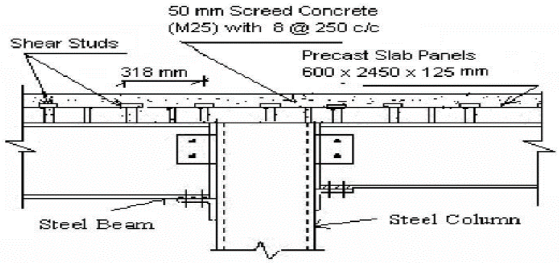

Fig. 3 Section of Steel Frame Beam Slab Panel with Precast Concrete Floor

2.3. Cost evaluation:

Table.1.Cost of Composite beams

Material	Quantity	Rate	Amount (Indian Rupees)
Structural steel	293.753 ton	60500/MT	17772056
Reinforcing steel	72.89 ton	52800/MT	3848592
Concrete	3087.63 m^3	6000	18525600
Total cost of composite beams			40146248

Table.2.Cost of RCC beams

Material	Quantity	Rate	Amount (Indian Rupees)
Structural steel	675 ton	60500/MT	40837500
Steel for connectors	115 ton	60500/MT	6957500
Total cost of steel beams			4779500

Table.3.Cost of steel beams

Material	Quantity	Rate	Amount (Indian Rupees)
Reinforcing steel	219 ton	60500/MT	13249500
Concrete	575.3m^3	6000	3450000
Total cost of steel beams			4779500

Table.4.Cost of composite columns

Material	Quantity	Rate	Amount (Indian Rupees)
Reinforcing steel	390 ton	60500/MT	23595000
Concrete	4222.3m^3	6000	25333800
Total cost of composite columns			48928800

Table.5.Cost of RCC Columns

Material	Quantity	Rate	Amount (Indian Rupees)
Structural steel	202.45 ton	60500/MT	12248225
Concrete	410 m^3	6000	2460000
Total cost of RCC columns			14708225

Table.6.Cost of steel column

Material	Quantity	Rate	Amount (Indian Rupees)
Structural steel	450 ton	60500/MT	27225000
Steel for connectors	34 ton	60500/MT	2057000
Total cost of steel columns			2982000

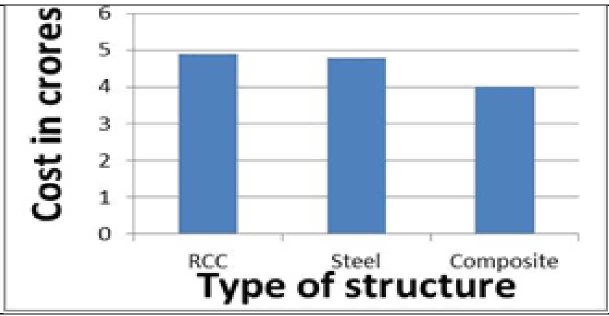

Figure.4.Cost comparison in beams

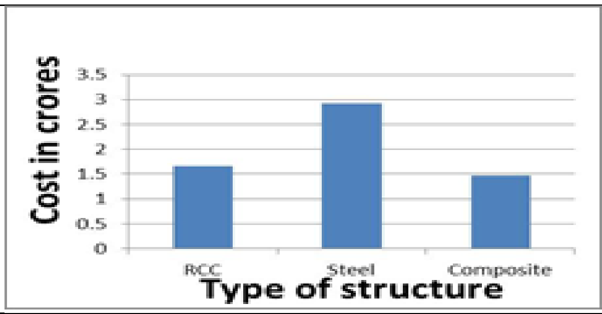

Figure.5.Cost comparison in columns

2.4. Time evaluation: Time scheduling is done using Microsoft Project 2003. In time scheduling some starting activities such as PCC (7 days), Footing (30 days), and Pedestal (15 days) goes individually but after completing column and beam erections for first lift (60 days), activities for composite floor construction goes simultaneously with second lift erection. Likewise whole structure can be erected with; so many works faces open together. For the construction of composite floor for all levels, requires 135 days as per time scheduling. It shows that ground and first floor slab activities and for all remaining floors activities are same as first floor. Considering time required for all floors, the building is completed in 240 working days (Figure 9). Total 285-290 days are required including holidays. The construction of multilevel building with steel frame composite floor (240 days) saves 55% time than precast frame with precast concrete floor (280 days) and 13% time than steel frame with precast concrete slab (205 days).

3. CONCLUSION

The study shows that the time savings of 55.3% is achieved due to use of steel framed composite floor construction rather than precast framed with precast concrete floor and 14.3% time than that of steel framed with precast concrete slab. The construction of steel framed composite floor building saves time, which leads to an overall savings in net cost.

The direct cost required for steel framed with composite floor is 23.10%, higher than precast frame with precast concrete floor and only 0.52% higher than steel framed with precast concrete floor. Considering time related savings, the net cost required for steel framed with composite floor is 12.99%, more than precast frame with precast concrete floor and 2.32% less than steel frame with precast floor.

The steel framed with precast concrete floor saves 35.83% construction time than precast frame with precast concrete floor, which required extra 22.70% of direct cost and 14.96% of net cost.

Presents work shows the use of concrete filled steel tube columns has been consistently applied in the design of tall buildings as they provide considerable 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.

However, study is restricted to structural frame only. If other items are also considered in the study like excavation work, finishing items, services, cladding etc. and also during construction preliminaries such as labour accommodations, their travelling and food expenses and many other factors related to time, then definitely, steel framed composite floor building option will become cost effective. 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.

In present Indian construction sector, there are very less cold-formed trapezoidal profiled steel deck manufacturers. Obviously due to less competition, material rates are much higher. But from present status and already announced investment, future of Indian steel production industry is very bright for cold-formed steel deck sections. So in near future definitely, steel prices will be reduced and steel framed composite floor construction will become competitive in Indian construction sector.

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