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COMPARATIVE STUDIES OF RCC AND STEEL COMPOSITE STRUCTURES: A REVIEW

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Abstract-RCC structures have been a very popular method of constructing high rise buildings in India, but with the development of technology and equipment, composite structures are gaining attention. Composite columns like concrete filled steel tubesor encased steel members offer an excellent performance resulting from the confinement effect of steel with concrete and exhibits great design versatility. A composite structure definitely has a lot more advantages over anRCC structure. However, the study of the design and its behavior against different types of loading is at the center of all studies at the moment as it would suggest as to ow successful composite structures would be. This paper reviews the various comparison aspects of the composite structure and the traditional RCC structures.

Keywords—Composite structure, RCC structure, cost comparison, Composite beam, Composite column, Shear connectors

I. INTRODUCTION

RCC has been the mainstay for construction purposesfor the past many years. RCC has been used for structural purposes due to its unique properties of strength, resistance and versatility. Composite structures are created by binding along two heterogeneous materials effectively, in order that they work along as a unit from the structural point of view. In developing countries especially, the Asian continent, most of the buildings fall into the category of low-rise buildings. In these buildings, reinforced cement concrete and pure sectional steel constructions proves to be convenient / economical in nature and thus widely used. However, once there is a requirement for construction in densely populated cities, because of lack of land-space space and rapid increase of population, medium to high-rise buildings emerges as an answer to the construction industry. In recent past, the composite structures have gained many benefits as compared with the traditional system of construction. Composite structures bind steel and concrete i.e. it clubs the dynamic properties of each element (concrete in compression and steel in tension) and conjointly has same thermal enlargement. Increased use of steel increases the speed of construction. Thus, increasing the quantity of steel in construction of building structures is what fast developing countries want in this decade.

Composite structure is created to acquire the advantage of each of the materials. It has shown that the performance of the building in all parameters like stiffness, ductility, lateral strength is as good if not better that that of an RCC building. These buildings can resist all conventional forces as well forces due to earthquake or wind very efficiently.

II. COMPOSITE MULTI-STORIED STRUCTURES

The main construction components that a composite structure consists of are, Composite Deck Slab, Composite Beam, Composite Column, Shear Connectors etc as shown in Fig 1.

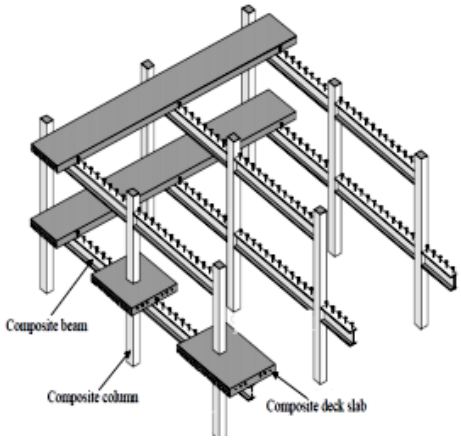

Fig.1 Components of Composite Structure

A. Composite Deck Slab

The metal deck typically spans unsupported between two steel members, it also provides a working platform for concreting work of the deck slab. The composite floor system produces a rigid horizontal diaphragm, providing stability to the overall building system, while distributing wind and seismic shears to the lateral load-resisting systems. Beam spans of 6 to 12 m can be created giving maximum flexibility and division of the internal space. Slab thickness may vary from 50-150mm as shown in Fig 2.

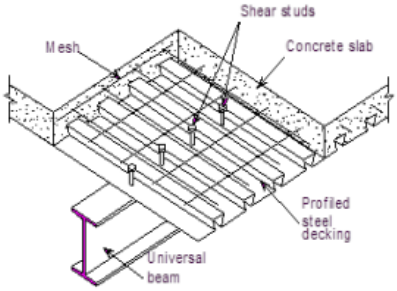

Fig.2 Composite Deck Slab

B. Composite Column

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 as shown in Fig 3.

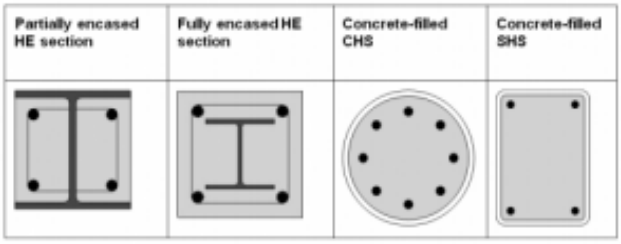

Fig.3 Types of Composite Columns

C. Composite Beam

A composite beam is a steel beam or partially encased beam which is mainly subjected to bending and it supports the composite deck slab as shown in Fig 4.

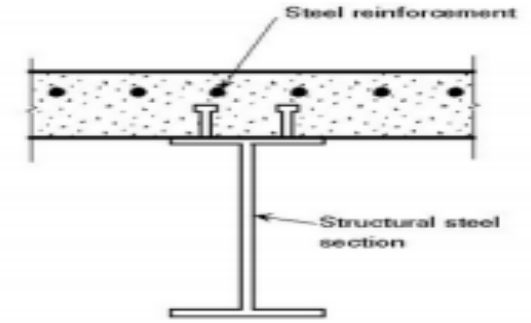

Fig.4 Composite Beam

D. Shear Connectors

Shear Connector (studs) are used to connect the concrete and structural steel and they give the sufficient strength and stiffness to the composite member. Shear connectors can be of three types.

1)*Rigid type:*These connectors are very stiff and they sustain only a small deformation while resisting the shear force. They derive their resistance from bearing pressure on the concrete, and fail due to crushing of concrete. Shear connectors are essential for steel concrete composite construction as they integrate the compression capacity of supported concrete slab with supporting steel beams to improve the load carrying capacity as well as overall rigidity

*2)Flexible type:*Headed studs, channels come under this category. These connectors are welded to the flange of the steel beam. They derive their stress resistance through bending and undergo large deformation before failure. These types of stud connectors are used extensively. The shank and the weld collar adjacent to steel beam resist the shear loads whereas the head resists the uplift.

*3) Bond or anchorage type:*It resists horizontal shear and prevent separation of girder from the concrete slab from the interface through bond action. These connectors derived from the resistance through bond and anchorage action.

E. Advantages of Replacing RCC Structures with Composite Structures

1) Speed and simplicity of construction
2) Lighter construction
3) Good fire resistance
4) Corrosion protection
5) Reduction in overall weight of the structure and there by reduction in foundation cost.
6) Suitability against seismic and wind loads

III. LITERATURE REVIEW

There is a considerable research work that has been done in the direction of comparativeRCC structures and composite structures. It can be seen from the studied research work that to judge the suitability of construction material, it is very necessary to compare theRCC and composite buildings on various aspects. After this comparison, one should be able to decide which structure should be constructed under different conditions.

*A. Sharma, Priya &Thirugmana (2016)*compared a framed structure made by Reinforced cement concrete and Composite material located in earthquake zone IV (G+ 20 story) with the plan dimension is 30m x 24m. Various aspects like story displacement, story drift, deflection and stiffness were studied and compared. [2]

The major outcomes of their study are: -

1) There is reduction in dead weight of the composite structure as compared to the ones made with RCC. He concluded that the reduction in dead weight of composite structure varies from **20% to 25%**less than RCC structure thus resulting in reduction of seismic forces by**15%-20%**.
2) The story stiffness for the composite structures was found to be higher by **10-12%** in transversal direction and higher by **7-9%**in longitudinal direction, as compared to an RCC structure.
3) Lateral displacement in composite structure were slightly more than in RCC structure but is well under the permissible limit of **4%** in longitudinal and transversal direction.
4) The inter story drift was found to be higher in composite structure as compared to RCCstructure, but again it was found to be under the permissible limit of **4%** in both the direction.
5) The paper shows that using concrete filled steel tubular column in tall buildings was found to provide better results than RCC and was also found economically sound.
6) There was a considerable amount of reduction in MaximumShearForce,Maximum Axial Force and Maximum Bending Moment in a composite structure as compared to an RCC structure.

B. Aniket &Yogesh(2016) performed analysis on residential buildings with a steel-concrete composite and R.C.C. construction. They studied four multistoried buildings of G+9, G+12, G+15, G+18 stories, with 3.0m as the height of each story. The overall plan dimension of the building was 15m x 9m. The analysis involved load calculation and analyzing it by 2D modeling using software STAAD-Pro 2007. Analysis has been done for various load combinations as per the Indian Standard Code of Practice. The project also involved analysis 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. structure. [3]

The major outcomes of their study are: -

1) The cost comparison reveals that steel-concrete composite design structure is more costly. However, reduction in direct cost of steel-composite structure resulting from speedy erection will make the steel-composite structure economically viable. Further, under earthquake consideration, because of the inherent ductility characteristics, steel-concrete structure will perform better than a conventional R.C.C. structure.
2) The axial forces, bending moment and deflections in R.C.C. are somewhat more as compared to the Steel composite structure.
3) 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.
4) There is reduction in cost of steel structure as compared to R.C.C. structure due to reduction in dimensions of elements.
5) Story deflection was found to be more in composite structure but under the permissible limit.

C. Waghe&Waghe (2014) studied and analyzed four multistoried commercial buildings of G+12, G+16, G+20, G+24 stories. These buildings were analyzed by using STAAD-Pro software. Design and cost estimation were carried out using MS-Excel program and results compared between R.C.C and composite structure. [7]

The major outcomes of their study are: -

1) In case of a composite structural system because of the lesser magnitude of the beam end forces and moments compared to an R.C.C system, one can use lighter section in a composite structure. Thus, it reduces the self-weight and cost of the structural components.
2) In the cost estimation for building structure no savings in the construction time for the erection of the composite structure is included. As compared to RCC structures, composite structures require less construction time due to the quick erection of the steel frame and ease of formwork for concrete. Including the construction period as a function of total cost in the cost estimation will certainly result in increased economy for a composite structure.

*D. Mohite, Joshi &Deulkar (2015)*in their paper "Comparative Analysis of RCC and Steel-Concrete Composite (B+G+ 11 Story) Building"analyzed a (B+G+11) story commercial building with steel concrete composite and RCC structure and compared them on the aspects of deflections, base shear, story drifts, axial forces and bending moments. Equivalent linear static method in ETABS ver. 15 was used for the comparison. [4]

The major outcomes of their study are: -

1) Base shear was found to be more in the RCC structure than in composite structure.
2) Story drift in RCC was found to be higher than in composite structure subjected to both the loads(earthquake and wind loads).
3) Story shear was also found to be higher in the RCC structures.
4) Axial forces, shear forces and bending moments for RCC was higher.

E. Ganwani&Jamkar (2016) in their paper "Comparative Study of RCC and Steel-Concrete Composite Building based on Seismic Analysis" analyzed in3D a (G+8) storyRCC and steel concrete composite structure in earthquake zone IV. Equivalent static method and response spectrum method wereused for comparison using ETABS 2015. [5]

The major outcomes of their study are: -

1) RCC frames have higher value of stiffness compared to the composite structure because of larger dimensions and heavy weight of sections.
2) Story drift was found to be higher in RCC in X direction when compared to composite structure because of higher stiffness.
3) The natural time period of composite structures was found to be higher which concludes that the composite structures is more flexible when compared to RCC structure which have lesser natural time period.
4) Base shear came out to be on the higher side in the RCC structure due to heavy weight of RCC.
5) Lateral forces in RCC were found to be more than composite structures. Hence less suitable for seismic forces.

F. Imran, Abdulla &Hasmi (2017) in their paper "Comparative Analysis of Reinforced Concrete & Composite Structures Subjected to Static & Dynamic Loads" performed seismic analysis ona G+18 story model ofRCC and Composite structure. ETABS was the software used for the analysis. [6]

The major outcomes of their study are: -

1) Base shear for the composite structure was found to be lesser than that of RCC structure.
2) Displacement of the composite structure was higher.
3) Drift in both the structures were within permissible limits.
4) Column forces and beam moments were reduced in composite structures considerably.

IV.RESULTS AND DISCUSSION:

A. Reduction in Forces in Composite Structures

TABLE I

REDUCTION IN FORCES IN DIFFERENT PAPERS DISCUSSED ABOVE

Authors	Max axial force	Max shear force	Max B.M
Sharma, Priya & Thirugmana	20-30%	x-axis: 2.05% y-axis: 23.56%	x-axis: 14.76% y-axis: 24.12%
Aniket &Yogesh	25%	16.64%	18.10%
Waghe&Waghe	41%	x-axis: 50.91% z-axis: 17.49%	19.31
Mohite, Joshi &Deulkar	9.08%	Main beams: -39.43% Secondary beams:14.39%	Main beams:-52.57% Secondary beams:28.93
Imran, Abdulla &Hasmi	7.18 %	x-axis: 40.58% y-axis: 41.16%	x-axis: 56%% y-axis: 45.4%%

B.Weight of the Structure

TABLE II

PERCENTAGE WEIGHT REDUCTION OF THE COMPOSITE STRUCTURE AS COMPARED TO RCC STRUCTURES

Authors	Weight reduction %age
Sharma, Priya &Thirugmana	22.48%
Mohite, Joshi &Deulkar	9.48%
Imran, Abdulla &Hasmi	25%

C. Cost Comparison

TABLE III

PERCENTAGE REDUCTION IN COMPOSITE STRUCTURES

Author	Cost difference
Aniket &Yogesh	43.1%
Waghe&Waghe	7.76%

IV. CONCLUSIONS

A. Base shear for the RCC structure is higher than the composite structure in every paper.
B. Story drifts are different but are under permissible limits in both the cases.
C. Story stiffness is high in the composite structure.
D. The composite structure is found to be more suitable against seismic as well as wind loads.
E. The axial forces, bending moment and deflections in R.C.C. are somewhat higher as compared to the composite structure.
F. The dead weight of the composite structure is less than the RCC structure due to larger dimensions of the beams and columns.
G. The RCC structure has a higher stiffness due to heavy and bigger dimensions of structural members.
H. The cost of the composite structure was found to be more viable when building a high rise structure as the cost difference percentage rises as the building story increases.
I. As axial forces and reactions are less in composite columns as compared to RCC columns, the cost of composite columns is less.
J. Composite structure produces less displacement and resists more structural forces.
K. Completion time of composite structures is less than traditional RCC structures due to speedy erection and less formwork required.

V. SCOPE OF FUTURE WORK

In these review papers it has beenseen that, RCC and steelcomposite structures have been compared for different number of stories and for all kinds of loads and their resultant forces. But soil conditions have not beenchanged, it would be good if the two types of constructions are also compared for different soil conditions.Similarly, practical comparisonsof these types of constructions, especially in terms of cost, pay back periods and time for completion, with funding at the standard rates would be more meaningful.

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