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A Comparative Study on Seismic Analysis and Design of Various Types of Structures

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ABSTRACT
In India, most of the structures being constructed are Reinforced Concrete structures or Steel structures. In high rise RCC structures, the size of structural members (column, beam, and slab) increases. Due to this, self-weight of the structure also increases. Steel structures on the other hand, are ductile in nature and parameters like deflections, drifts, displacements are more compared with RCC structures. To solve these problems, composite structures might be suitable. Due to this, steel consumption in India also developed. A geometrically irregular residential building (G+18 storeys) is designed and analysed for cases of RCC, RCC with shear wall, steel and composite structures (considering earthquake zone III) using ETABS software. The structure is analysed using linear static, linear and non-linear dynamic methods, such as equivalent static method, response spectrum method and time history method. In this study, comparison of an RCC structure, steel structure and a composite structure is obtained for parameters like time period, storey displacement and storey drift, base shear, bending moment and shear forces of the structure. From the observed results, it may be clearly inferred that a steel composite, performs well in-terms of structural integrity when compared with an RCC structure.
Keywords - Composite structure, RCC structure, Time period, Storey displacement, Base shear, Storey drift.

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I. INTRODUCTION

RCC structures are common in India due to their adaptability to demand, availability of material and skilled man-power. This makes RCC more affordable, in comparison to its steel. In particular, steel structures do not require provision of huge dimensions than RCC structures because steel sections have higher strength. On the other hand, steel structures face thermal expansion and corrosion which causes reduction in the life span of the structure, when compared to an RCC structure. Hence, to eliminate such disadvantages of reduction in life span, composite structures play a major role.

For a composite structure, columns are casted in such a manner that standard steel I-sections are encased with concrete. Reinforcement bars placed with clear dimension to surround the I-section which eliminates the possibility of shear failure in columns and also avoids corrosion. By encasing the concrete around the steel section it gains more Strength and better fire resistance than a conventional steel structure section. A composite floor system consists of steel beam connected to steel deck and concrete layer. The concrete slab should be properly connected over steel beam to make it a composite beam, failure of which leads to a relative slip at the interface. Composite nature enhances the stiffness and load carrying capacity of the structure, in composite structures the self-weight of the structure decreases comparing an RCC structure because of the factors as discussed below. The storey displacement, storey drifts, storey shears, axial forces, bending moments and shear forces will vary due to the varying nature of different parameters as considered. From this it can be inferred that with the use of composite structures the requirement of steel will increase circumstantially in India.

K. Mukesh Kumar, H. Sudarsana Rao [1] considered low to high rise (5, 10, 15 storeyed) RCC and composite structures in zone-1V and conducted Response Spectrum, Non-linear time history analysis to attain various parameters and concluded that composite structures are superior to RCC structures(high raised structures).

Kumawat, Mahesh Suresh, L G Kalurkar [2] worked on the G+9 storey commercial building under seismic zone-III for Equivalent static and Response spectrum analysis of both RCC and Composite structure using SAP2000 software. It is concluded that Composite structure is more economical than RCC structure with the help of various parameters**.**

Rajendra R.Bhoir, Vinay Kamble, Darshana Ghankute [3] considered two residential

G+15 storeyed buildings. Composite and RCC structure are analysed and designed in ETAB software with two different storey heights, 3m and 4m. They found that compared to RCC structure the depth of beams in Composite structure is less with reduced cross-section of the composite column. The overall cost for RCC structure is more than the Composite Structure.

D.R. Panchal and P.M. Marathe [4] modeled a 30 storeyed building with composite and RCC structure in earthquake zone IV of India. As the load varies for different storey levels, different cross sections at the different storey levels are considered. From the results it is observed that, Composite structure is more suitable than the RCC structure.

Vinay Sanjeev Kumar Damam [5] considered G+15 storeyed building and analysed it for both composite column building and R.C.C building and concluded that the deflection and storey drift in Composite structure is twice than that of R.C.C. structure but the deflection is inside the permissible limit.

Shashikala. Koppad, Dr.S.V.Itti [6] considered 15 storeyed building with both RCC and Composite structures located in seismic zone III of India. Cost analysis is calculated for composite and RCC structures and concluded that cost is more for RCC system in comparison with Composite system.

Amit Singh, Himank Ghulyani [7] worked on the seismic response of the multi-storey building made up of different material, i.e. Concrete and Steel .To show importance of effect of infill masonry wall modelling is done with and without considering stiffness of infill wall. Usually infill is provided in RCC structures and thus RCC building will be stiffer than Steel building and therefore RCC structure is one of the best options for construction of multi-storey building as well as for earthquake resistant structure.

Mayur R. Rethaliya, Nirav S. Patel, Dr.R.P.Rethaliya [8] worked on Seismic Analysis of Multi-storey Buildings Using ETABS by static analysis.

II. COMPOSITE CONSTRUCTION

2.1. 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 are supported by steel beams. These two components act independently under the action of loads, because there are no connection between the concrete slabs and steel beam. This structure can give an economic credibility with high durability, rapid erection and better seismic performance characteristics. Co-efficient of thermal expansion of both steel and concrete is nearly the same, with this it inferences that due to higher percentage of steel in composite section, the structure behavior for thermal expansion is comparatively better to that of an RCC structure or a steel structure. When a shear connector is provided between concrete slab and steel beams, act as a composite beam. The behavior of a composite beam is just like a Tee beam. The basic concept of composite beam lies in the fact that the concrete is stronger in compression than steel (which is susceptible to buckling under compression) and steel is stronger in tension. By using the composite action of these two, the advantages of both materials i.e. steel and concrete are utilized to be fullest.

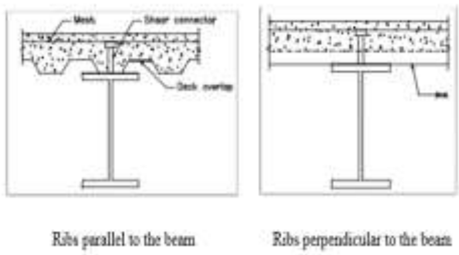

Fig 1: Various Types of Composite Beams

2.2Composite column: A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel. The presence of the concrete is allowed for in two ways. They are protection from fire, it is assumed to resist a small axial load to reduce the effective slenderness of the steel member, which increases its resistance to axial load.

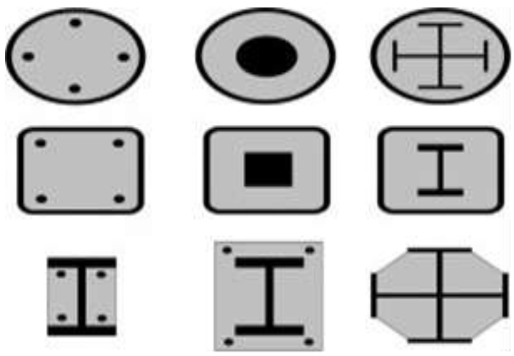

Fig 2: Various types of composite columns

The bending stiffness of steel columns of H-or I-section is much greater in the plane of the web (‘major-axis bending’) than in a plane parallel to the flanges (‘minor-axis bending’).

However, steel column design methods have differed from concrete design methods in a number of fundamental ways. Despite this, either design approach can be used as the basis for developing a design method for composite columns or this can be seen in the different methods.

Composite columns are designed by using European and USA standards. While the design approaches appear fundamentally different, the end results can be surprisingly similar. By understanding these design procedures, designers can use the full advantage of each approach for the effective use and economy of composite columns.

2.3 Composite slabs: It consists of profiled steel sheeting with an in-situ reinforced concrete topping. It is not only acts as permanent formwork to the concrete, but also provides sufficient shear bond with the concrete so that, when the concrete has gained strength, the two materials act together compositely. The distance between the walls or beams which supports the slabs are varies between 3 to 4.5 m. If the slab is unpropped during construction, the decking alone resists the self-weight of the wet concrete and construction loads. Subsequent loads are applied to the composite section. They are usually designed as simply supported members in the normal condition.

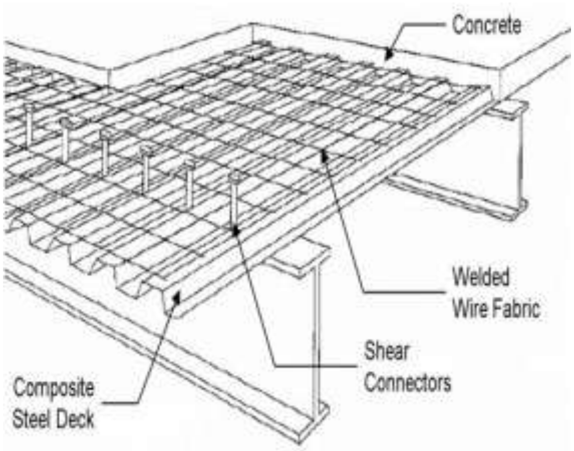

Fig: 3 Composite Floor System

2.4. Shear Connectors: A shear connection is a joint that allows the transfer of shear forces between two members. It is a connection with pure normal force load (tension joint), pure shear between two members. It is a connection with pure normal force load (tension joint), pure shear loading, or combination of normal and shear force. Shear connections are generally the most commonly used connections. They are typically used to connect beams with other beams or columns. This can help reduce the reliance on moment connections, which are often more complex and costly. Shear connectors are normally used in fabricated steel structures, such as railway bridges, deck slab, metro train platforms, etc...

Shear Connector is the main component in the composite floor system which transfers the shear between the concrete slab and the steel beam to the steel beam. Shear connectors are integrated to improve the compressive capacity of concrete slab and steel beam and in turn it improves load carrying capacity as well as rigidity of shear connector.

2.5. Shear Wall: Shear wall is a structural member used to resist lateral forces.

The design of shear walls is done according to the recommendation of the International residential code or International building code. These walls are constructed with materials such as (concrete, steel, bricks, wood etc.) and located in the parameter or centre of the building, especially in the lift sections or sometimes in stairwell.

III. MODELLING & ANALYSIS

Description of the model: In this study, residential Building is considered. The structure has geometric irregularities such as varying spacing between columns in X & Y directions. The AutoCAD plan of the structure is shown in Fig. The same building plan is used to model and design an RCC structure, RCC with shear wall, steel structure and a composite structure. The floor to floor height, dead loads, live loads and seismic analysis data remains same for these structures. The structure consists of G+18 storeys. The Equivalent static analysis, Response spectrum analysis and Non-linear time history analysis are performed using ETABS software.

IV. DETAILS OF THE STRUCTURE

G+18 storey building is considered, the grade of concrete and steel are M30 and Fe500 respectively. The overall length, width, depth of the building is 53m X 33m X 62mrespectively. The height of plinth and each floor is 2m, 3mrespectively. The thicknesses of slab, shear wall, deck slab are 0.125m, 0.23m, and 0.15m respectively. Sizes of RCC beams are 0.23m X 0.50m, 0.30m X 0.50m. Sizes of RCC columns are 0.23m X 0.90m, 0.23m X 0.75m X 0.75m (L-Column), 0.30m X 1.0m, 0.30m X 1.20m, 0.40m X 1.20m. Composite beam dimensions are ISWB 400, 500. Composite column dimensions are ISHB 350 (0.40m X 0.60m), ISHB450 (0.45m X 0.65m). The dead loads, live loads, wind loads are taken from IS code

(IS: 875:2015) part I, II, III respectively. The location of the structure is Guntur, zone type III is considered. The seismic zone is taken from IS: 1893:2016. Equivalent Static analysis, Response spectrum analysis, Non-linear time history analysis are carried out on the structure. The structure is designed for both RCC and composite according to IS: 456:2000, IS: 11384:1985 and AISC 360-10 respectively.

Fig: 4 Auto CAD plan of the structure

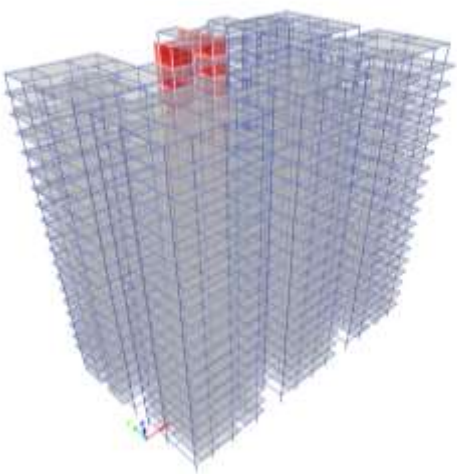

Fig: 5 Modeled RCC Structure

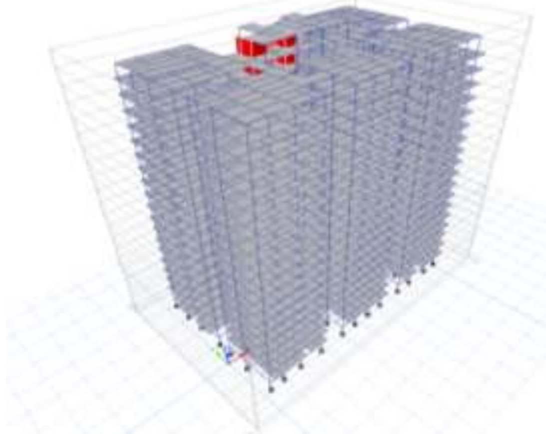

Fig: 6 Modeled Composite Structure

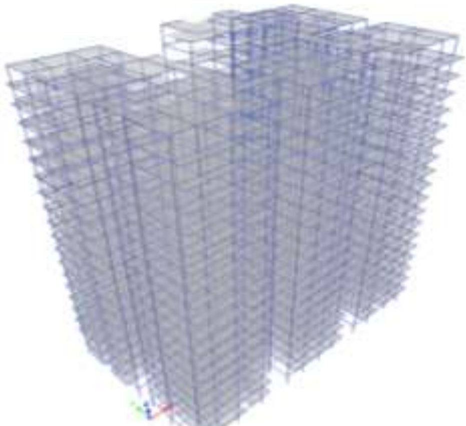

Fig: 7 Modeled Steel Structure

V. RESULTS AND DISCUSSIONS

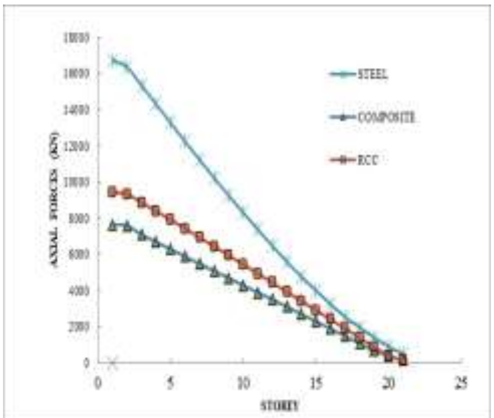

Fig: 8 Column Axial Forces

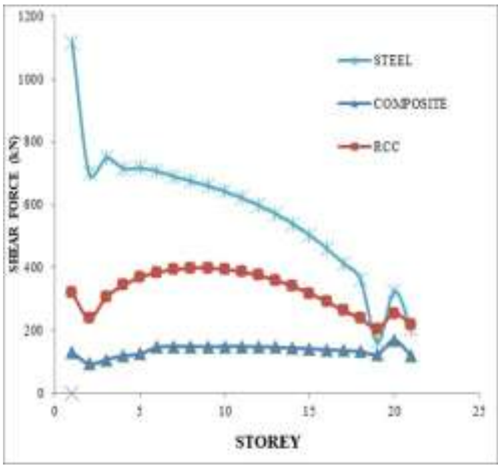

Fig: 9 Column Shear Forces

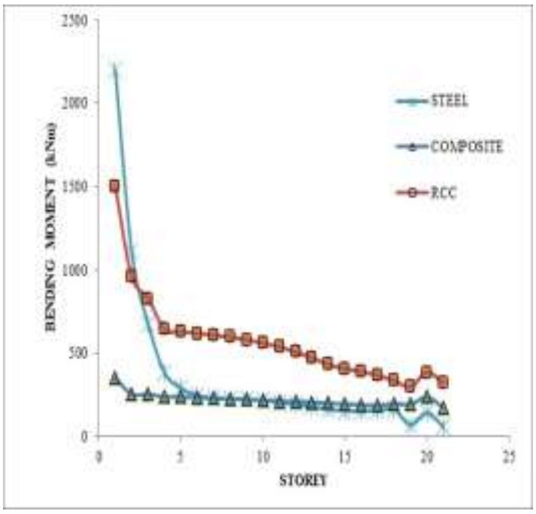

Fig: 10 Column Bending Moments

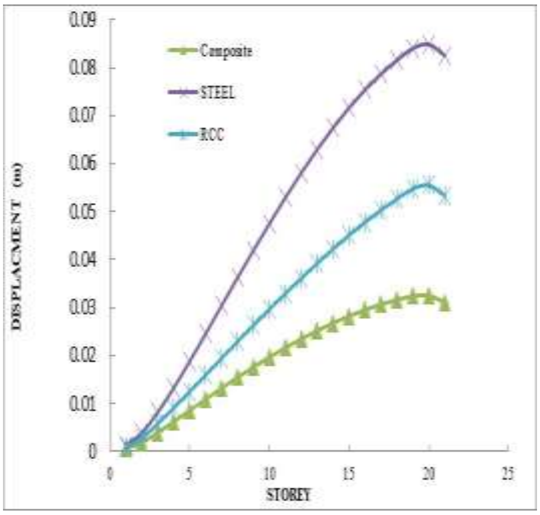

Fig: 13 Displacements in X Direction

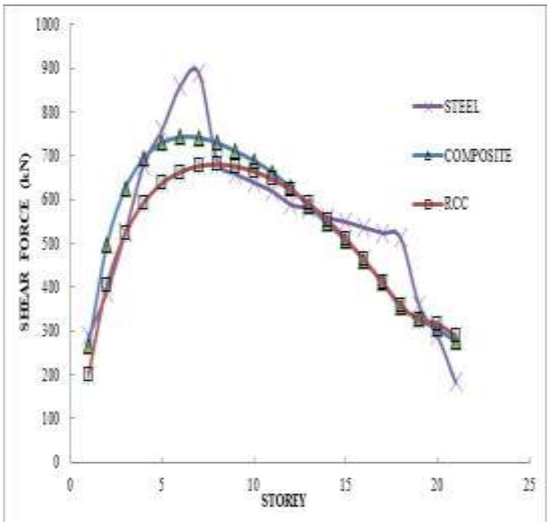

Fig: 11 Beam Shear Forces

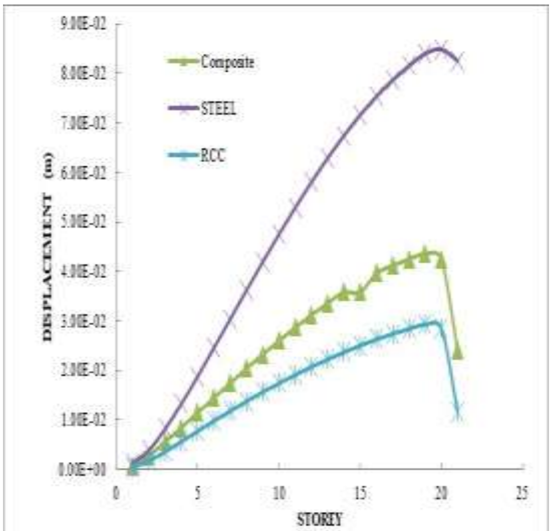

Fig: 14 Displacements in Y Direction

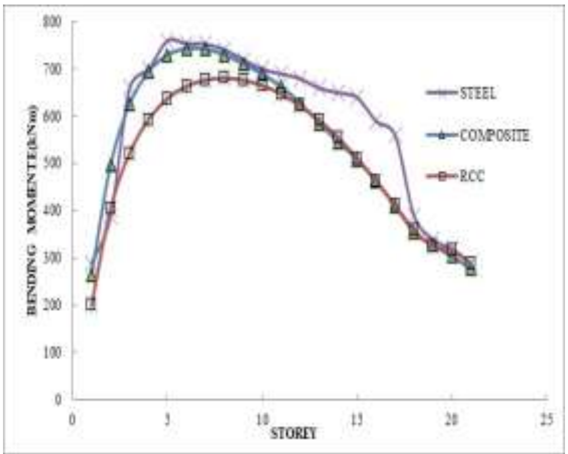

Fig: 12 Beam Bending Moments

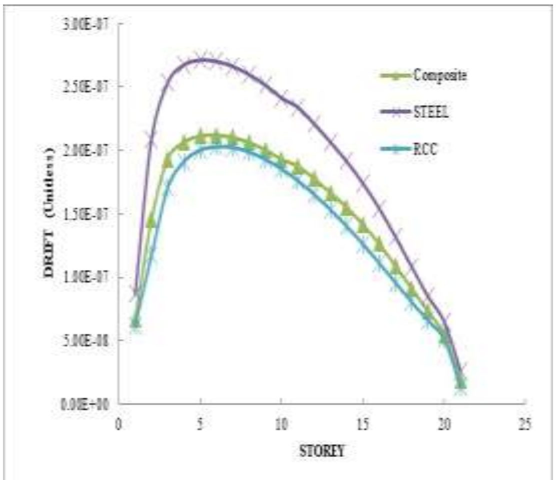

Fig: 15 Storey Drift in X Direction

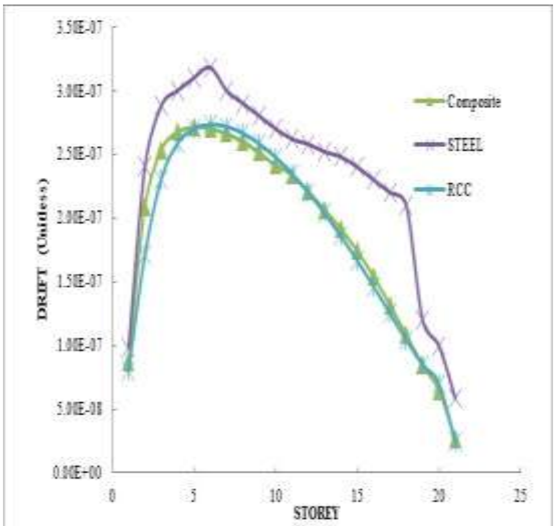

Fig: 16 Storey Drift in Y Direction

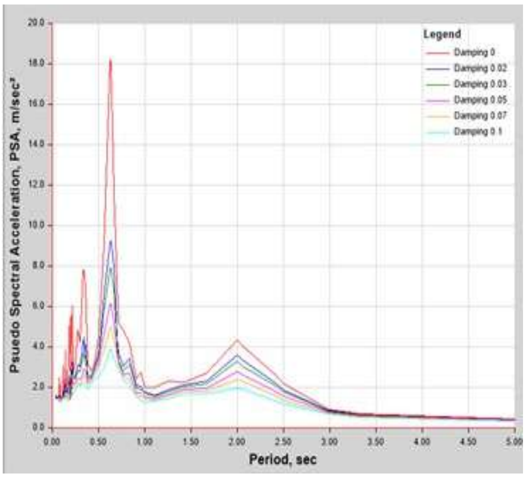

Fig: 17 RCC Response Spectrum Curves in X Direction

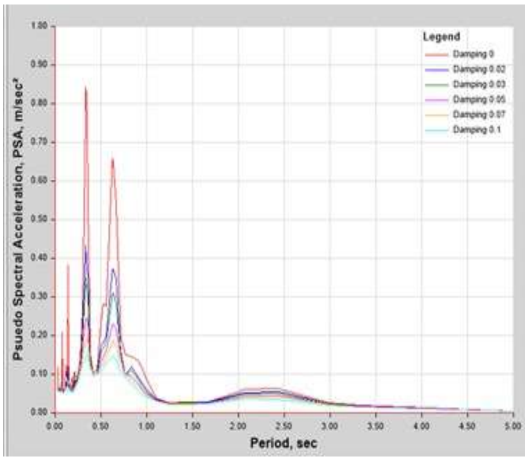

Fig**: 18** RCC Response Spectrum Curves in Y Direction

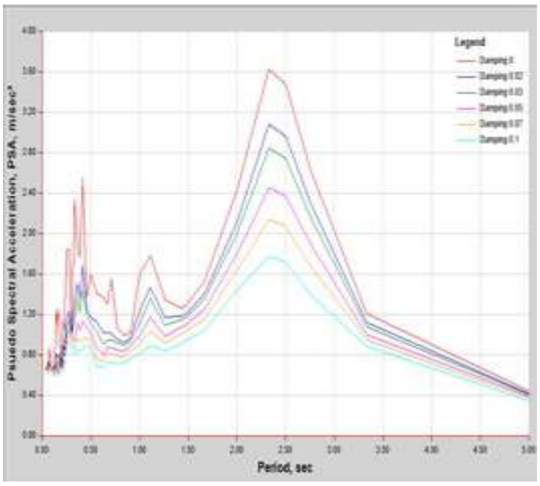

Fig:19 Composite Response Spectrum Curves In X Direction

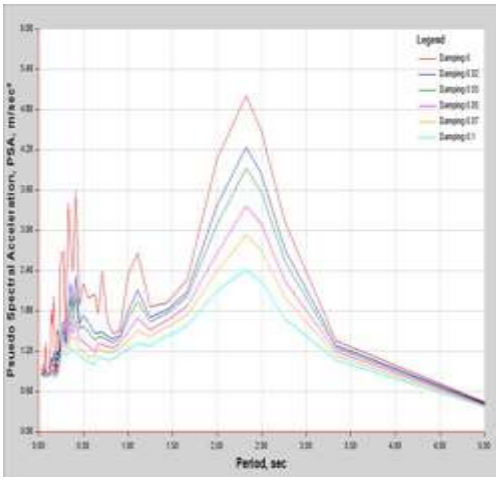

Fig:20 Composite Response Spectrum Curves in Y Direction

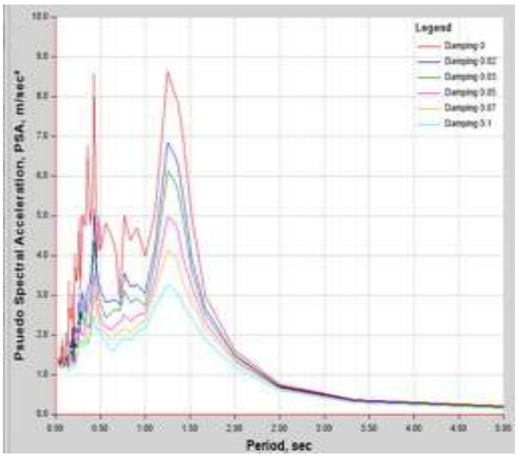

Fig:21 Steel Response Spectrum Curves in X Direction

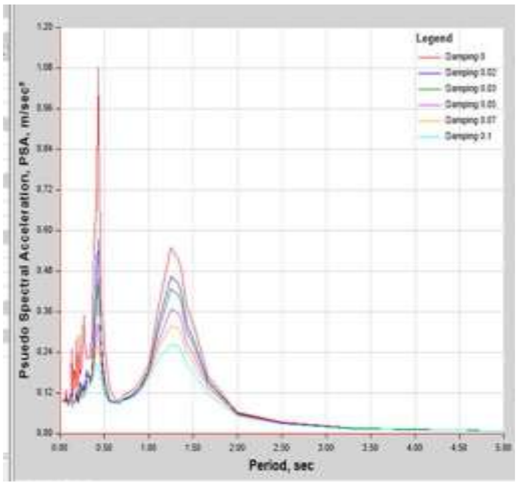

Fig:22 Steel Response Spectrum Curves In Y Direction

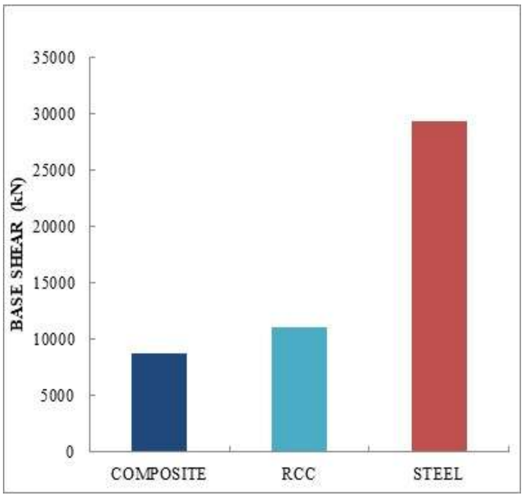

Fig:25 Base Shear in Y Direct ion

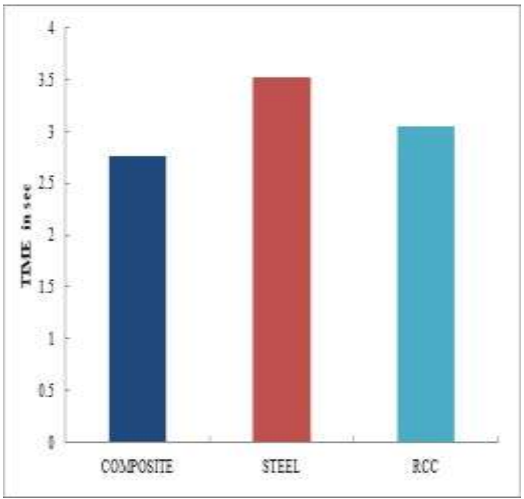

Fig: 23 Time Period of the Structure

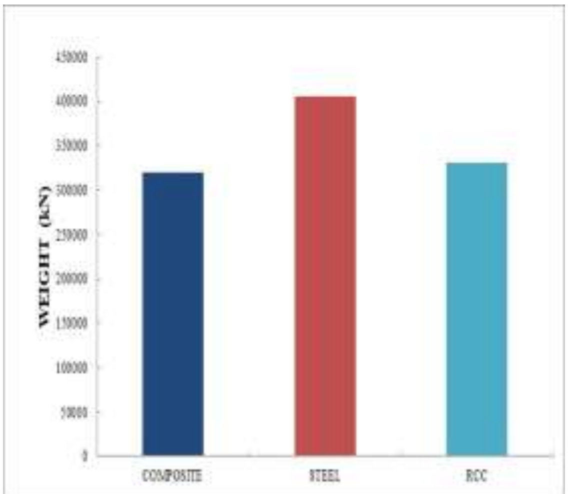

Fig: 26 Self-Weight of the structure

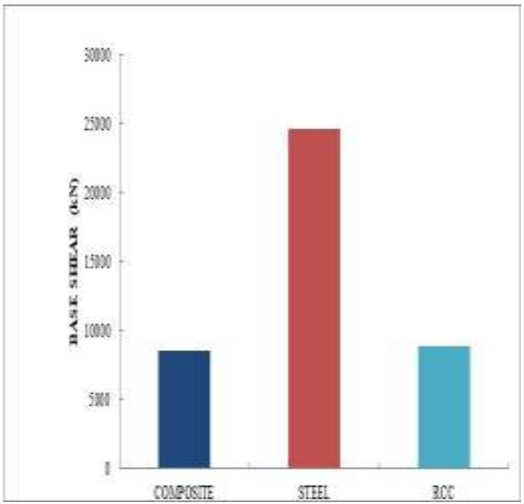

Fig:24 Base Shear in X Direction

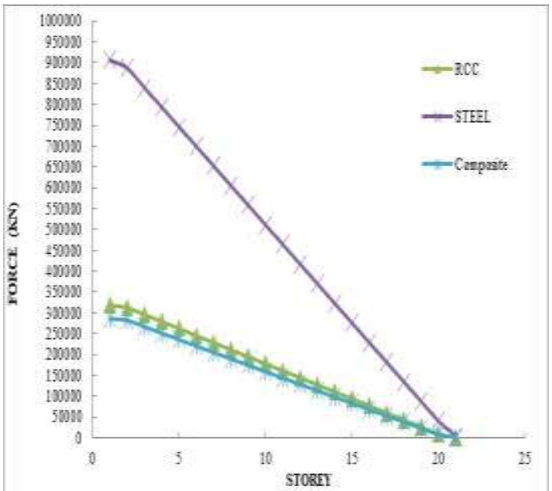

Fig: 27 Storey Forces

1. In columns and beams of steel structure, axial forces, shear forces and bending moments are higher than composite and Rcc structures as shown in Fig: 8, 9,10,11,12.

2. In columns of RCC structure, the maximum axial forces, shear forces, bending moments are more than the Composite structure as shown in Fig. 8,9,10.
3. The maximum shear force in beams varied to each storey but is mostly similar up to storey 7 and from storey 8 to storey 17 RCC structure have more shear forces than the Composite structure and for remaining storeys shear forces are similar for both RCC and Composite structures as shown in Fig11.
4. The composite structure have maximum bending moments in beams up to storey 12 than the RCC structure and for remaining storeys both structure have same moments as shown in Fig 12.
5. In composite structure, the storey displacement in X-direction is more when compared to RCC structure as shown in Fig. 13 but in Y-direction it is mostly similar to RCC structure as shown in Fig. 14.
6. In X-direction, the storey drift is less for RCC structure than Composite structure as shown in Fig 15.
7. In Y-direction, the storey drift is more or less similar for both RCC and Composite structures as shown in Fig. 16.
8. In steel structure both displacements and drifts are high compared to composite and steel structures as shown in Fig. 13, 14,15,16.
9. The storey forces in steel structure are more when compared to Composite structure and RCC structures as shown in Fig. 27.
10. For different damping ratios in response spectrum curves of Time history analysis, the Pseudo spectral acceleration in RCC structure is less than Composite structure and steel structure as shown in Fig. 17, 18, 19, 20, 21, 22.
11. The self-weight, time period, base shears of Composite structure are lesser than the RCC structure as shown in Fig. 23,24,25,26.

VI. CONCLUSIONS

1. The displacements in composite structure are more than the RCC structure, but it is safe as it is in permissible limits.
2. The storey drifts are similar in both RCC and composite structures. Column forces, beam forces, structural weights, time periods of the steel structure are high compared with RCC and composite structures.
3. The storey forces in Composite structure are less than the RCC structure. Therefore composite structure can give better performance than RCC structure. Storey forces, drifts, displacements and time periods of steel structure are higher than concrete and composite structures.
4. The axial forces, shear forces, bending moments of composite structure in columns are lesser when compared to RCC structure and it can give more strength and stability to the structure.
5. The beam shear forces are higher in RCC structure with increase in height compared to Composite structure. Whereas the beam bending moments are similar in both RCC and Composite structure.
6. The base reaction obtained from time history analysis is greater in composite structure compared to RCC structure and the pseudo-spectral acceleration (PSA) obtained from response spectrum analysis establishes that Composite structure has more PSA compared to RCC structure.
7. The self-weight of the structure is more in RCC structure than the Composite structure, due to this; base shear is less in composite structure than the RCC structure.
8. The time period of the composite structure is less than the RCC structure.

Taking all the above cases in consideration, it can be concluded that composite structures have better performance in terms of structural integrity compared to RCC and steel structures.

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