Comparison of Seismic Analysis of a Residential Composite and Rcc Structures

T.G.N.C.Vamsi Krishna, S.V.Surendhar, M. Shiva Rama Krishna

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. A geometrically irregular residential building (G+18 storeys) is designed and analysed for both cases of RCC 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 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.***

Index Terms: Composite structure, RCC structure, Time period, Storey displacement, Base shear, Storey drift.

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] modelled 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.

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T.G.N.C.Vamsi Krishna, P.G.Student, VFSTR University, Vadlamudi, Guntur, Andhra Pradesh, 522213 (Email: tgncvamsikrishna@gmail.com)

S.V.Surendhar, Asst.Professor, VFSTR University, Vadlamudi, Guntur, Andhra Pradesh, 522213 (Email: svsurendhar@gmail.com)

M. Shiva Rama Krishna, Asst.Professor, VFSTR University, Vadlamudi, Guntur, Andhra Pradesh, 522213 (Email: shivaram.vu@gmail.com)

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Objective: A geometrically irregular structure with variation of sectional properties in longitudinal direction and transverse direction, belonging to seismic zone-III, medium soil conditions is considered for analysis. A comparison in various parameters is performed for an RCC structure with a Composite structure considering residential building (G+18 storeyed) using ETAB software. Equivalent static analysis, response spectrum analysis and time history analysis are performed to analyse the seismic nature of the building.

Composite construction: A composite structure is being constructed with a combination of steel member and concrete member so as to make them act as one unit. 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 behaviour for thermal expansion is comparatively better to that of an RCC structure or a steel structure. Composite structure due to its bonding nature and composition result for higher strength, durability and performance. Composite deck slab, composite beam, composite column, shear connector are basic structural elements in a composite structure.

The composite floor system is nothing but a composite deck slab which consists of metal deck that is connected to a steel beam with the help of shear studs, where a concrete slab is laid on the metal deck. The metal deck is placed between two steel beams where it helps to with stand the concrete work; it can produce a rigid horizontal diaphragm while distributing wind and seismic shears to the lateral load-resisting systems. The composite deck slab and composite beam are shown in Fig-1

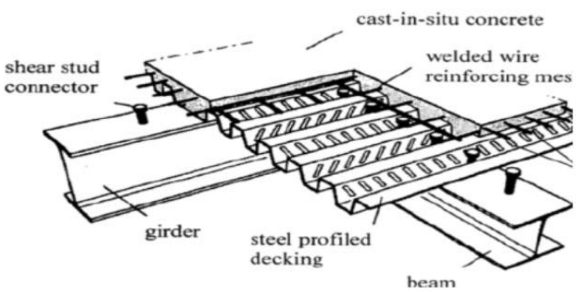

Fig. 1 Composite floor system

Composite beam consists of placing a concrete slab on a steel beam with shear connectors which act similar to T-beam. In architectural design, the long span beam constructions are the modern trend; this section has fire resistance, corrosion resistance, reduced buckling and in turn reduces the overall weight of the structure. In addition, it can resist repeated earthquake loadings and also have high stiffness and low deflection values compared to the steel sections.

Composite columns are constructed with hot rolled steel sections encased with concrete. These composite columns are of three types; they are concrete-encased section, concrete filled and battered section as shown in Fig. 2. Due to the reduced size of columns in composite structures, usable floor area increases, foundation cost decreases, stiffness increases, buckling resistance increases, leading to reduction in slenderness ratio.

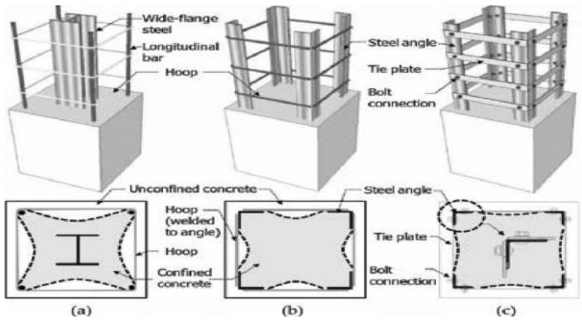

Fig. 2 Composite columns

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. Based on their suitability many types of shear connectors are available as shown in Fig. 3.

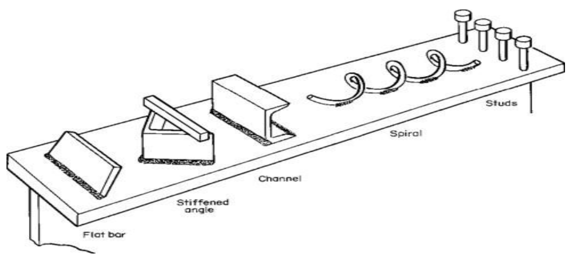

Fig. 3 Shear connectors

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. 4. The same building plan is used to model and design an RCC structure and a composite structure. The floor to floor height, dead loads, live loads and seismic analysis data remains same for both the structures. The structure consists of G+18 storeys. The Equivalent static analysis, Response spectrum analysis and Non-linear time history analysis are performed using ETAB software.

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 62m respectively. The height of plinth and each floor is 2m, 3m respectively. 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.

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Composite beam dimensions are ISWB 400, 500. Composite column dimensions are ISHB 350 (0.40m X 0.60m), ISHB 450 (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. The modelled Composite and RCC structures are shown in Fig. 5 and Fig. 6 respectively.

II. RESULTS & DISCUSSIONS

1. In composite structure, the storey displacement in X-direction is more when compared to RCC structure as shown in Fig. 7 but in Y-direction it is mostly similar to RCC structure as shown in Fig. 8.
2. In X-direction, the storey drift is less for RCC structure than Composite structure as shown in Fig. 9.

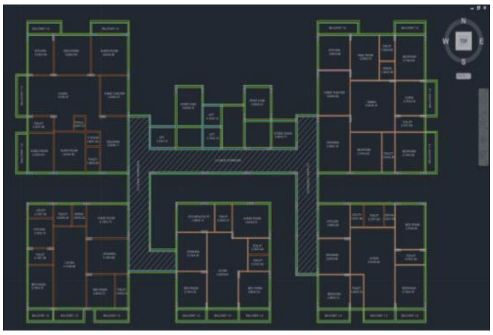

Fig. 4 AutoCAD plan of the structure

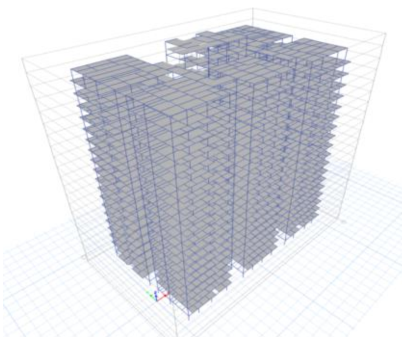

Fig. 5 Modelled Composite Structure

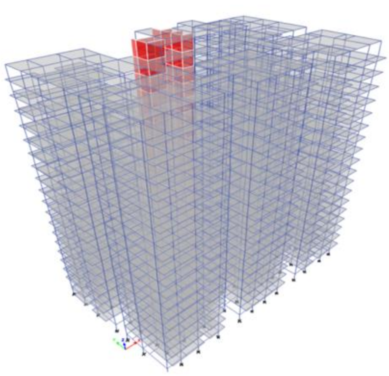

Fig. 6 Modelled RCC Structure

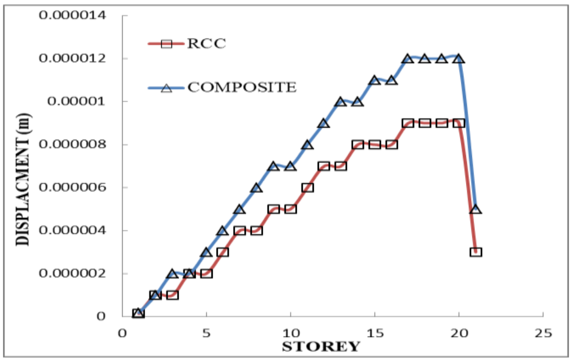

Fig. 7 Displacements in X Direction

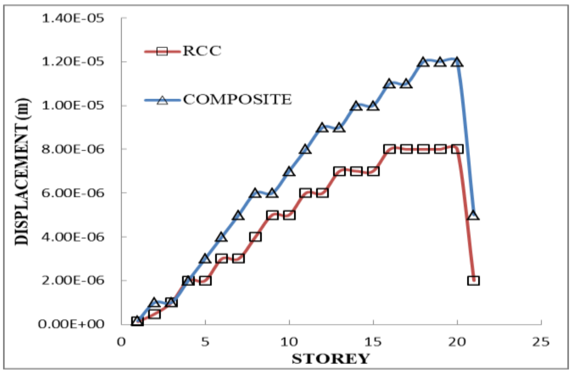

Fig. 8 Displacement in Y Direction

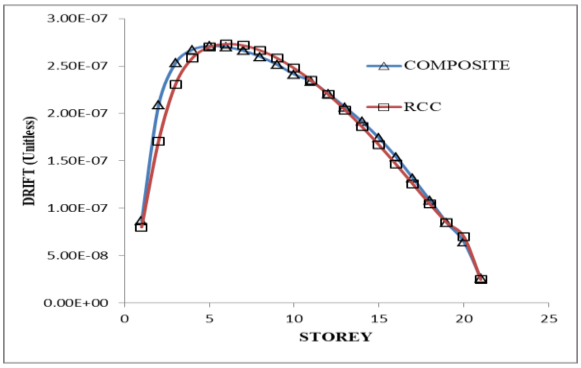

Fig. 9 Storey Drift in X Direction

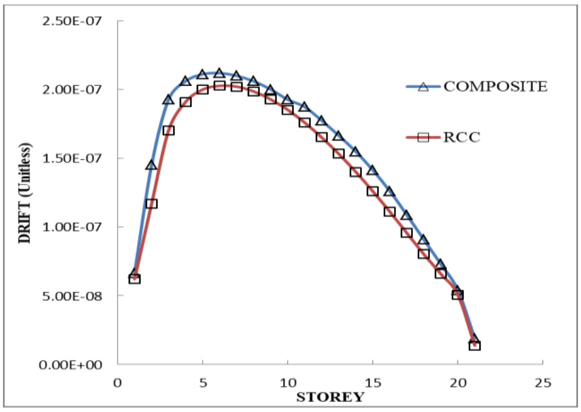

Fig. 10 Storey Drift in Y Direction

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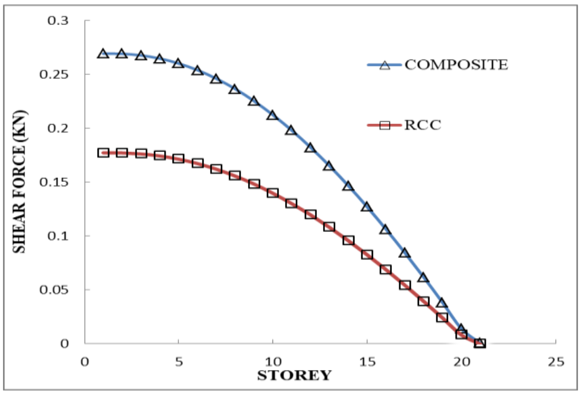

Fig. 11 Storey Shear in X Direction

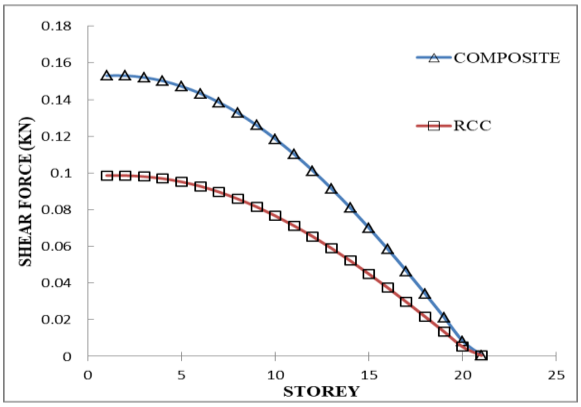

Fig. 12 Storey Shear in Y Direction

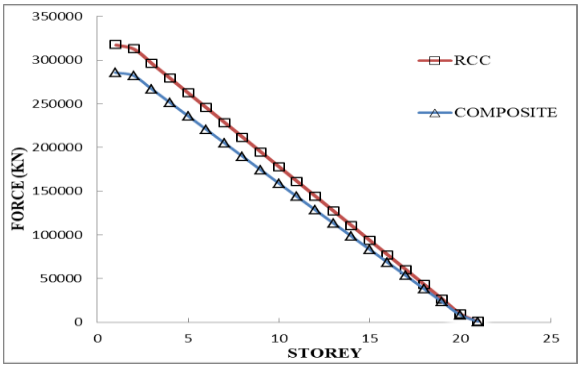

Fig. 13 Storey Forces

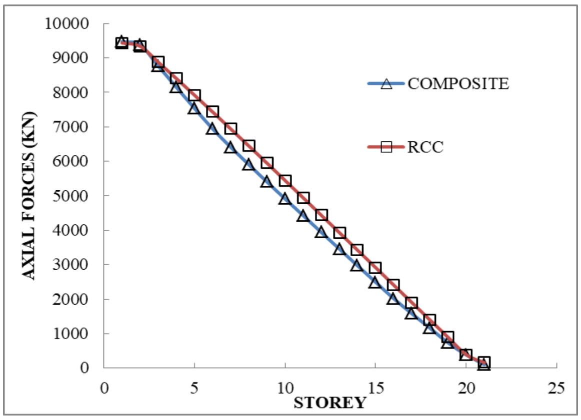

Fig. 14 Column Axial Forces

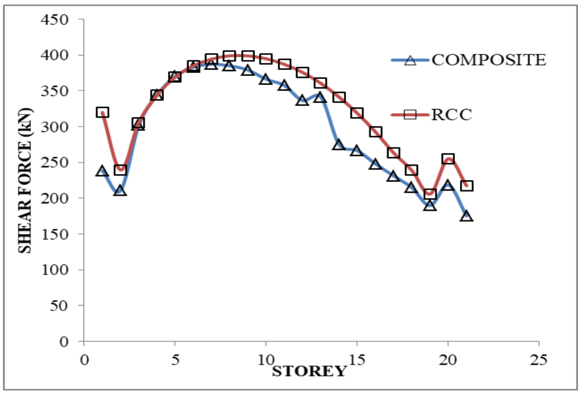

Fig. 15 Column Shear Forces

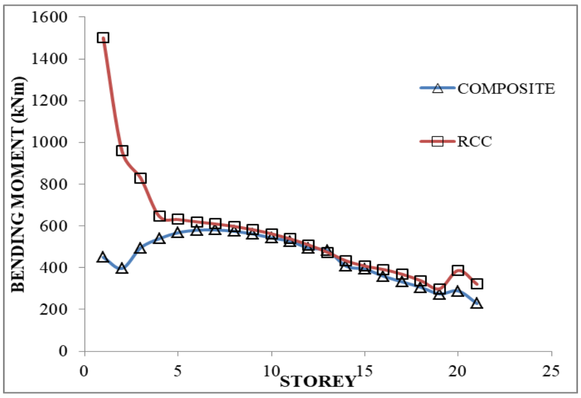

Fig. 16 Column Bending Moments

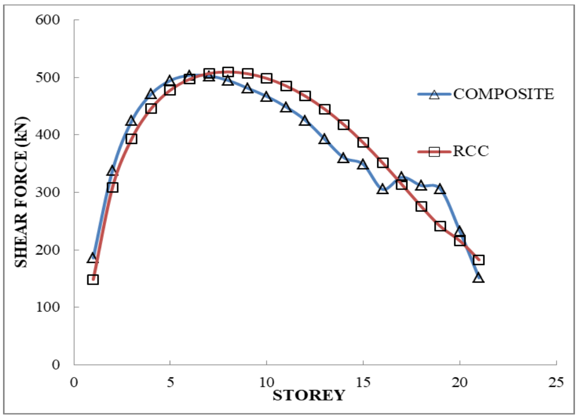

Fig. 17 Beam Shear Forces

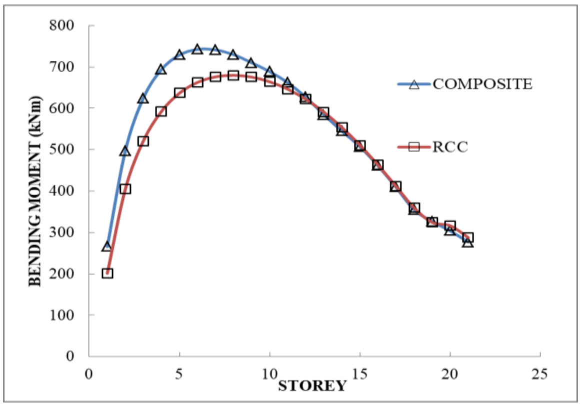

Fig. 18 Beam Bending Moments

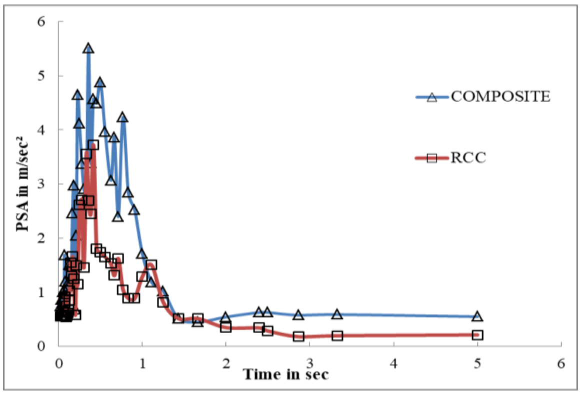

Fig. 19 Damping Ratio 0% in X Direction

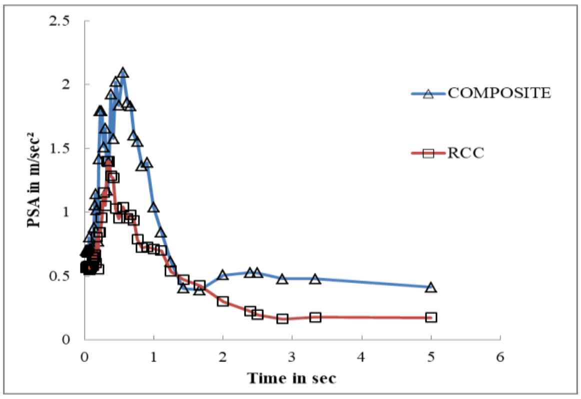

Fig. 20 Damping Ratio 5% in X Direction

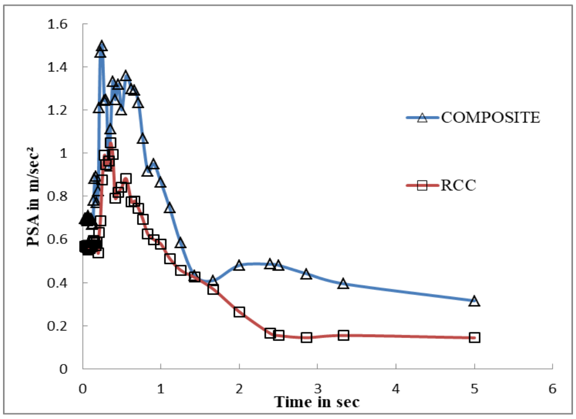

Fig. 21 Damping Ratio 10% in X Direction

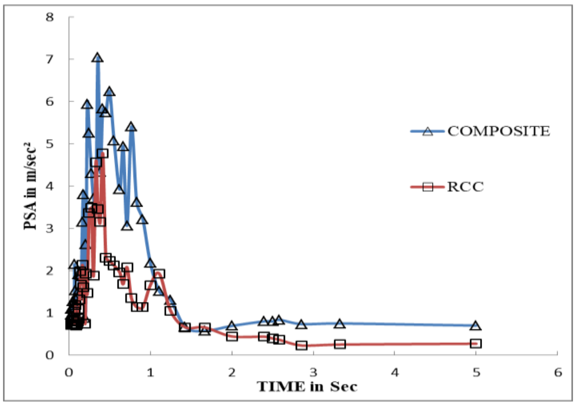

Fig. 22 Damping Ratio 0% in Y Direction

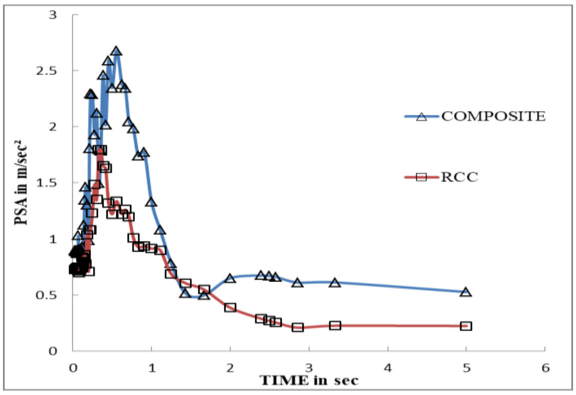

Fig. 23 Damping Ratio 5% in Y Direction

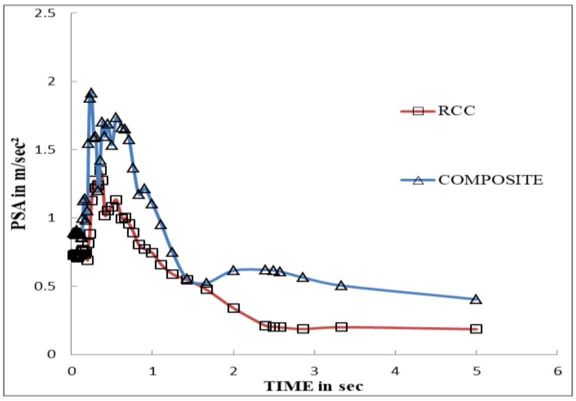

Fig. 24 Damping Ratio 10% in Y Direction

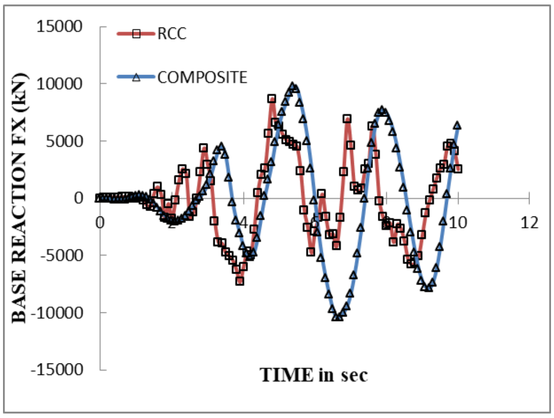

Fig. 25 Time History Curve in X Direction

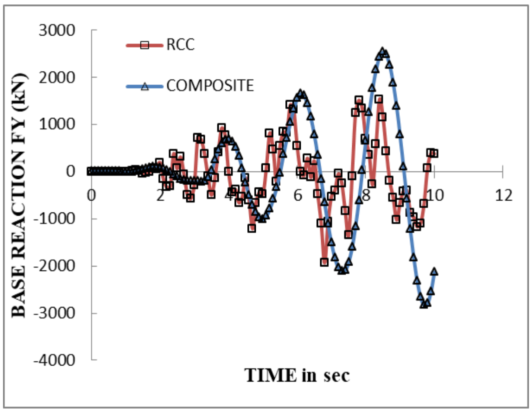

Fig. 26 Time History Curve in Y Direction

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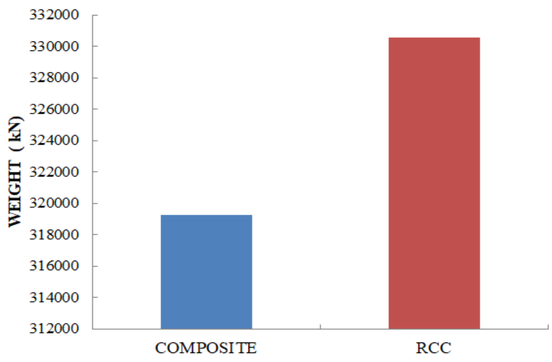

Fig. 27 Self-Weight of the structure

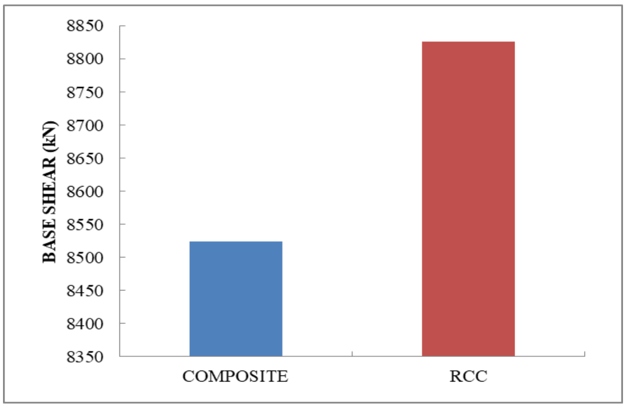

Fig. 28 Base Shear in X Direction

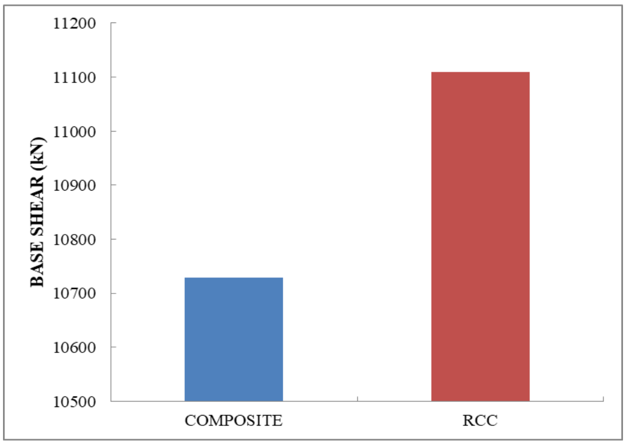

Fig. 29 Base Shear in Y Direction

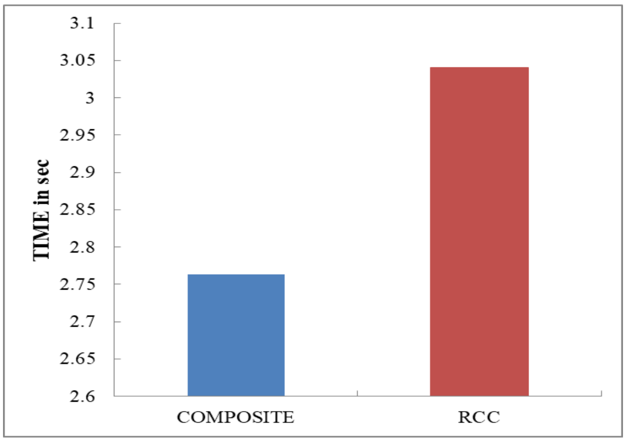

Fig. 30 Time Period of the Structure

3. In Y-direction, the storey drift is more or less similar for both RCC and Composite structures as shown in Fig. 10.
4. The storey shears of Composite structure in both directions are greater than the RCC structure as shown in Fig. 11, 12.
5. The storey forces in RCC structure is more when compared to Composite structure as shown in Fig. 13.
6. In columns of RCC structure, the maximum axial forces, shear forces, bending moments are more than the Composite structure as shown in Fig. 14, 15, 16.
7. 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 Fig. 17.
8. 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. 18.
9. For different damping ratios in response spectrum curves of Time history analysis, the Pseudo spectral acceleration in RCC structure is less than Composite structure as shown in Fig. 19, 20, 21, 22, 23, 24.
10. The time history curve represents base reactions varying with time in both directions; composite structure has more well defined time history curve than the RCC structure as shown in Fig. 25, 26.
11. The self-weight, time period, base shears of Composite structure are lesser than the RCC structure as shown in Fig. 27, 28, 29, 30.

III. CONCLUSION:

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 structures.
3. The storey forces in Composite structure are less than the RCC structure. Therefore composite structure can give better performance than RCC structure.
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.

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9. 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 structure.

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