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Seismic analysis of RCC and composite structures

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Abstract

Composite structures made of steel and concrete are much admired owing to their compensation over RCC structures and steel structures. RCC constructions have more weight and larger cross sections for structural members. Steel structures have more deflections and are ductile in nature; this quality of steel structures is helpful in resisting earthquake loads. The acceptable properties of RCC and steel structures are combined in composite structures. In addition to that lesser cost, speedy construction, fire protection etc. are provided by them. In this comparative study RCC and composite structures are considered in seismic zone III. The seismic behavior of the study frames designed by the proposed methodology is evaluated by Response spectrum ETABS software is used for modeling and analysis.

Keywords: seismic analysis, composite structures, base shear, time period, response spectrum, non linear

1. Introduction

THE majority of building structures are designed and constructed in reinforced concrete, mainly owing to the availability of the constituent materials and the low level of skill required in construction, as well as the practicality of the existing design codes. Recent trends in construction industry is to use of steel, reinforced concrete and composite steel-concrete member which are functioning together and termed as composite, mixed or hybrid systems. Such systems make use of each type of member in most efficient manner to maximize the structural and economic benefit. An additional benefit provided by composite columns is derived from their excellent fire-resistant properties. Traditionally, steel frames have been encased in concrete for fire protection purposes with some allowance being made for the structural properties of the encasement. In composite structure the advantage of bonding property of steel and concrete is taken in to consideration so that they will act as a single unit under loading. These 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-torsional buckling. In conventional composite construction, concrete rests over steel beam, under load these two component acts independently and a relative slip occurs at the interface of concrete slab and steel beam, which can be eliminated by providing deliberate and appropriate connection between them. So that steel beam and slab act as composite beam and gives behavior same as that of Tee beam. In steel concrete composite columns both steel and concrete resists external loads and helps to limit sway of the building frame and such column occupies less floor area as compared to reinforced concrete. It should be added that the combination of concrete cores, steel frame and composite floor construction has become the standard construction method for multi-storey commercial buildings in several countries. The main reason for this preference is that the sections and members are best suited to resist repeated earthquake loadings, which require a high amount of resistance and ductility.

2. Significance

In composite structure the advantage of bonding property of steel and concrete is taken in to consideration so that they will act as a single unit under loading. These 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-torsional buckling. In general, since composite systems realize the most efficient use of steel, reinforced concrete, and composite members in a structural system, this type of construction is often more economical than traditional either all-steel or all-reinforced concrete construction. Among main advantages of RCS frames are the efficiency of concrete (versus steel) in carrying large column loads at much lower cost per unit strength and stiffness (Griffis, 1992), and the reduction in total construction time. Speed of construction may be achieved through separation of trades. Accordingly, construction activity can be spread vertically, with the help of the erection columns, thus allowing different trades to engage simultaneously in the construction of the building.

Moreover, steel and composite beams in a floor system lead to reduced floor depth, and lighter overall floor weights. This in turn leads to lower building mass and more economical foundations. Furthermore, having steel beams running continuous through the reinforced concrete columns offers stable hysteretic behavior of the joint region due to the presence of the steel web. This construction detailing permits the elimination of field welding at beam-column connections. This helps avoid fracture problems experienced with welded steel connections. Among the drawbacks of the RCS construction is the congestion in the connections regions with ties passing through steel beam webs or welded to them. In addition, more on site activities are required, although prefabrication techniques may alleviate this problem. Because of possible congestion, concrete mixes have to be highly workable. In addition, differential creep and shortening effects and slip between concrete and structural steel are other drawbacks of composite systems. Yet, even with these considerations, mixed construction remains a viable and efficient alternative to all- steel or all-reinforced concrete construction

3. Problem Statement

A G+5, G+10, G+15 RCC and composite structure having plan dimensions as 30mX30m is modelled and analysed in E-tabs. The total height of the building is 32.7m, 50.2m, 73.2m having typical story height of 4.5m. The size of beams are (300x750) mm and column sizes are taken as per concrete design calculations. For the composite structure the sizes of sections are taken according to ASCE-7. For the beam properties of W21X68 is taken and for interior and exterior columns W12X65 and W12X40 are taken. The structure is analyzed for seismic zone III under medium soil condition. The grade of concrete is M20 for RCC and M30 for Composite and grade of steel is Fe415.

The basic parameters considered for the design are
Live load: 2.394KN/sq.m
Floor finishes load: 0.957KN/sq.m
Wall load: 10 KN/m (230 mm wall)
Earthquake parameters considered are Zone: III
Soil type: Hard soil Importance factor: 1
Response reduction factor: 3
Earthquake loading as per ACI 318
Codes for analysis RCC design: ACI 314
Composite design: ASCE-7

The above mentioned building models are analyzed using Response spectrum method. The building models are analyzed using ETABS software. The different parameters such as time period/mode shapes, lateral displacement, story drift, axial forces, bending moments, base shear of the structure are compared for composite and RCC structures.

4. Material Properties

Composite beams, subjected mainly to bending, section consist of composite action with flange of reinforced concrete. To act together, mechanical shear connectors are provided to transmit the horizontal shear between the steel beam and concrete slab, ignoring the effect of any bond between the two materials. These also resist uplift forces acting at the steel concrete interface. If there is no connection between steel beam and concrete slab interface, a relative slip occurs between them when the beam is loaded. Thus, each component will act independently. With the help of deliberate and appropriate connection between concrete slab and steel beam the slip can be minimized or even eliminated altogether. If slip at the interface is eliminated or drastically reduced, the slab and steel member will act together as a composite unit.

In composite columns both the steel and concrete would resists the external loading by interacting together by bond and friction. Additional reinforcement in the concrete encasement prevents excessive spalling of concrete both under normal load and fire condition. 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 deck slab 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. However, composite slabs with profiled deck slab is 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

5. Modelling and Analysis

The modelling for both RCC and composite structures are carried out in Etabs. Given below are the screenshots of the structure modelled in software.

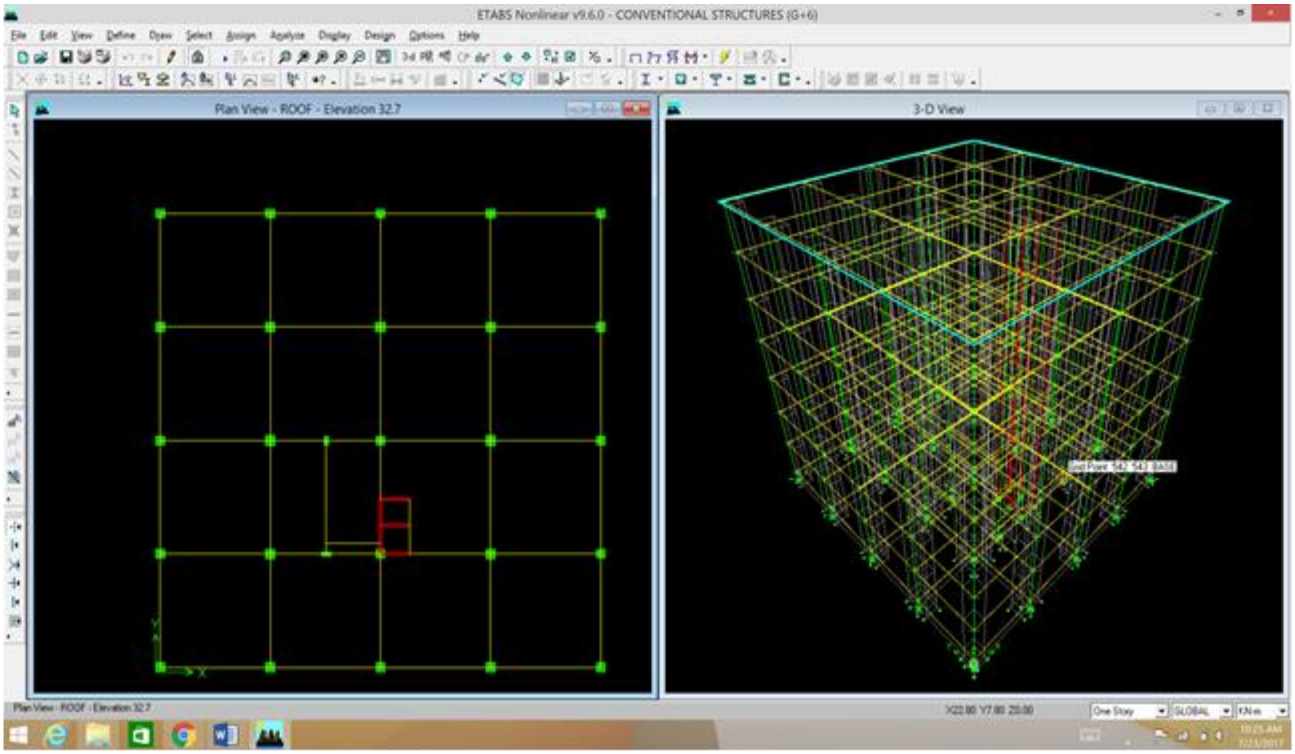

Fig 1: screenshot of G+6 RCC model in ETABS

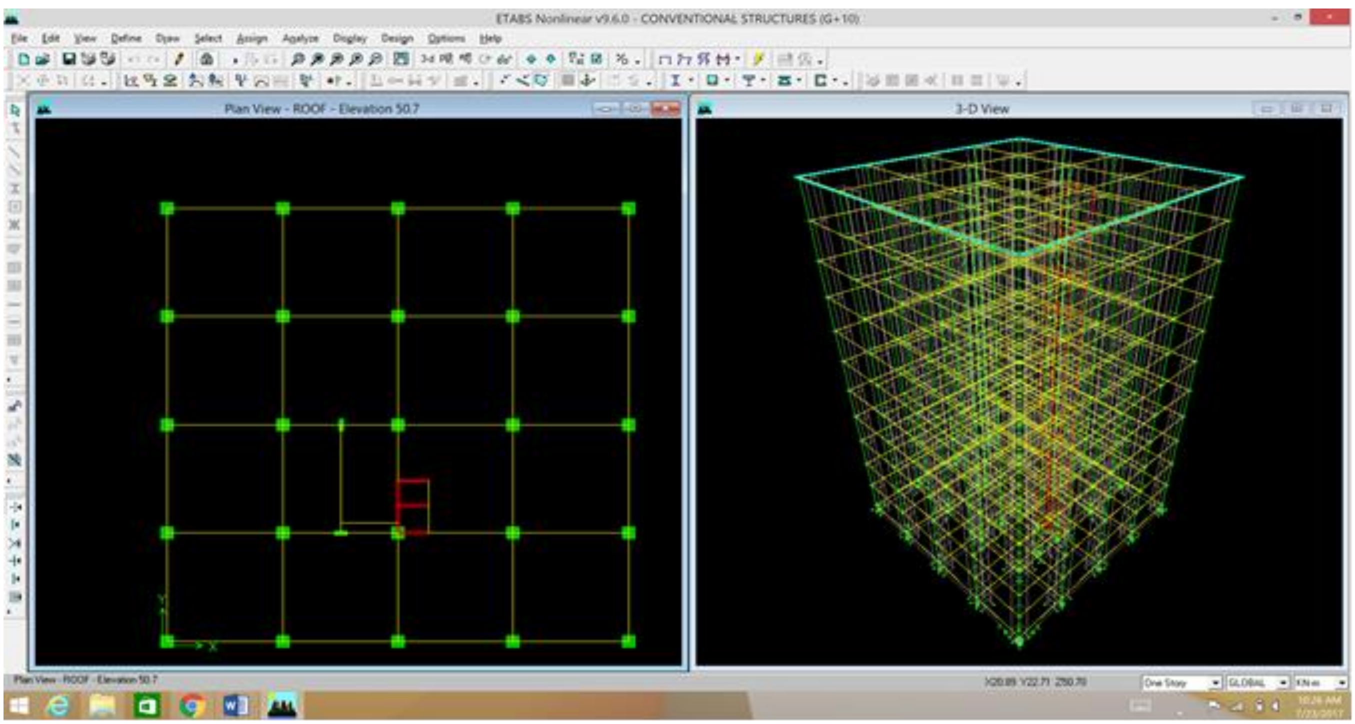

Fig 2: screenshot of G+10 RCC model in ETABS

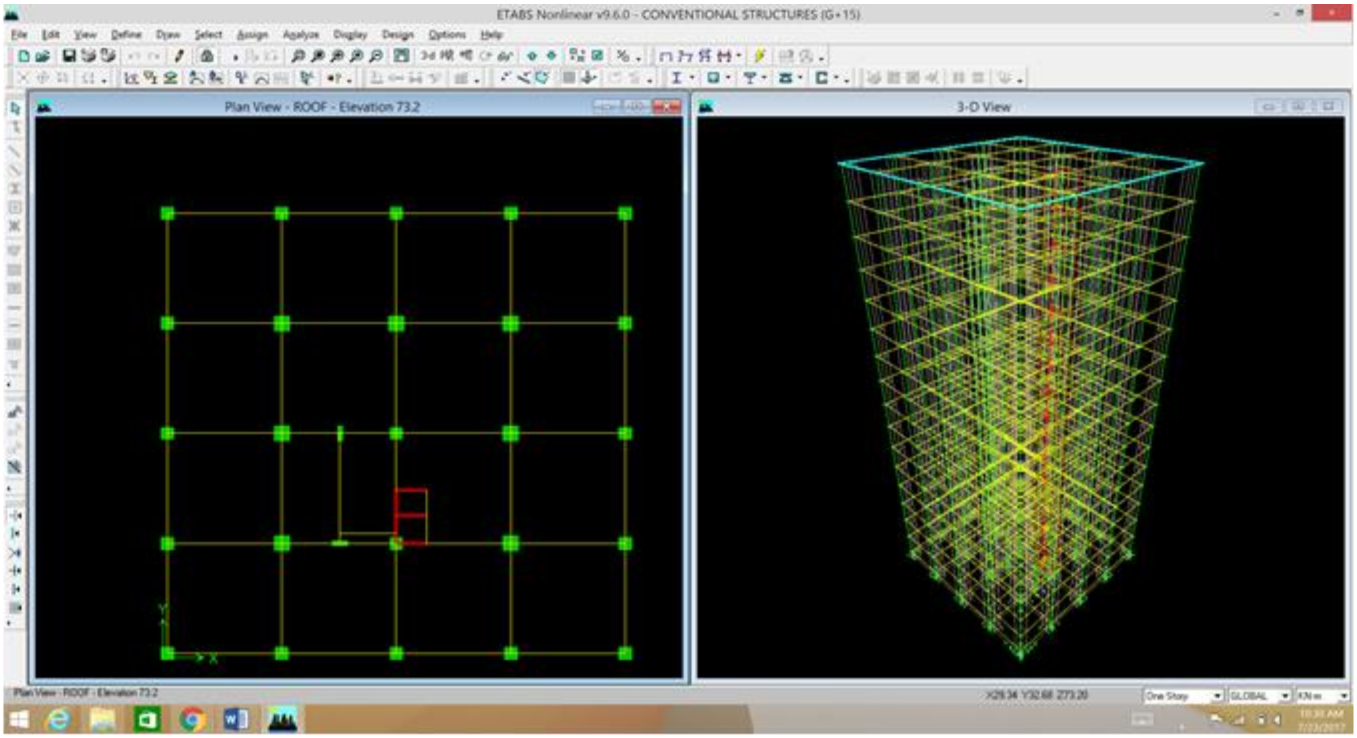

Fig 3: screenshot of G+15 RCC model in ETABS

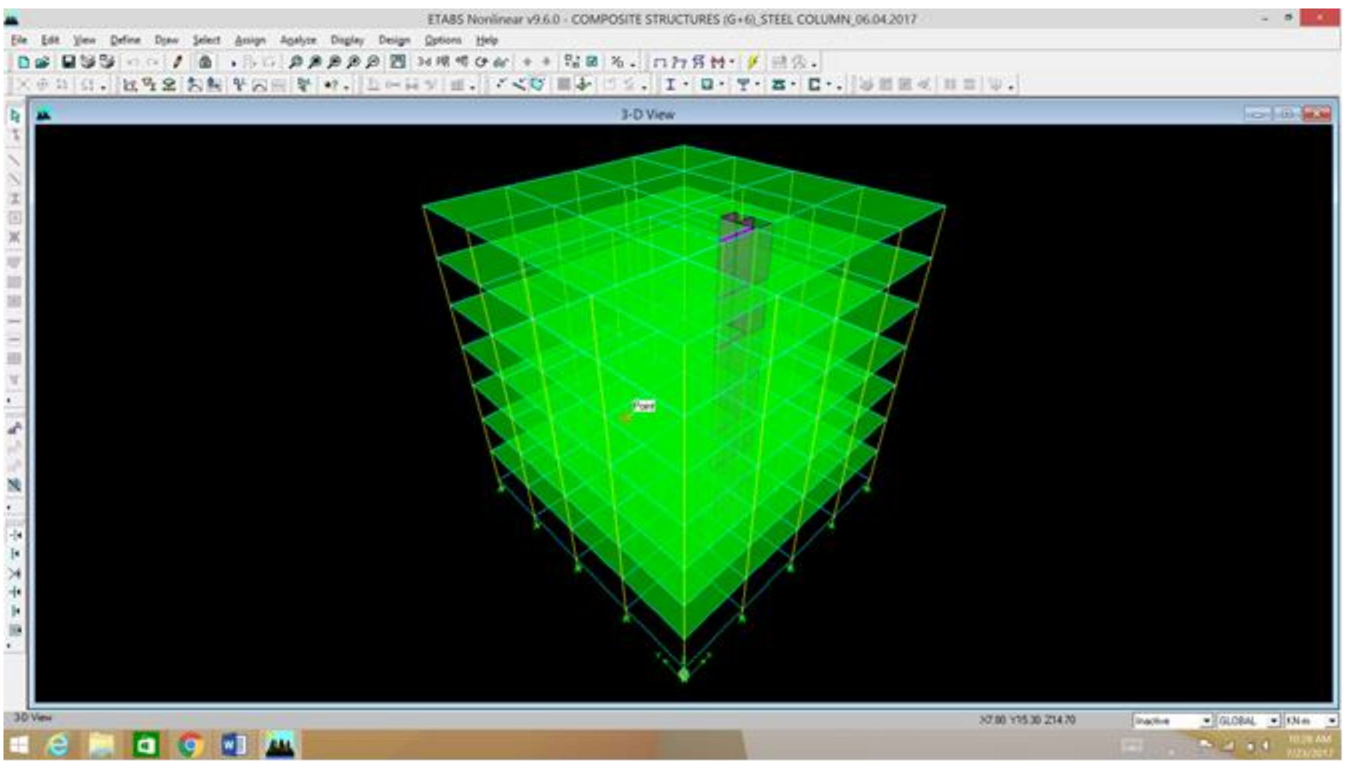

Fig 4: screenshot of G+6 Composite model in ETABS

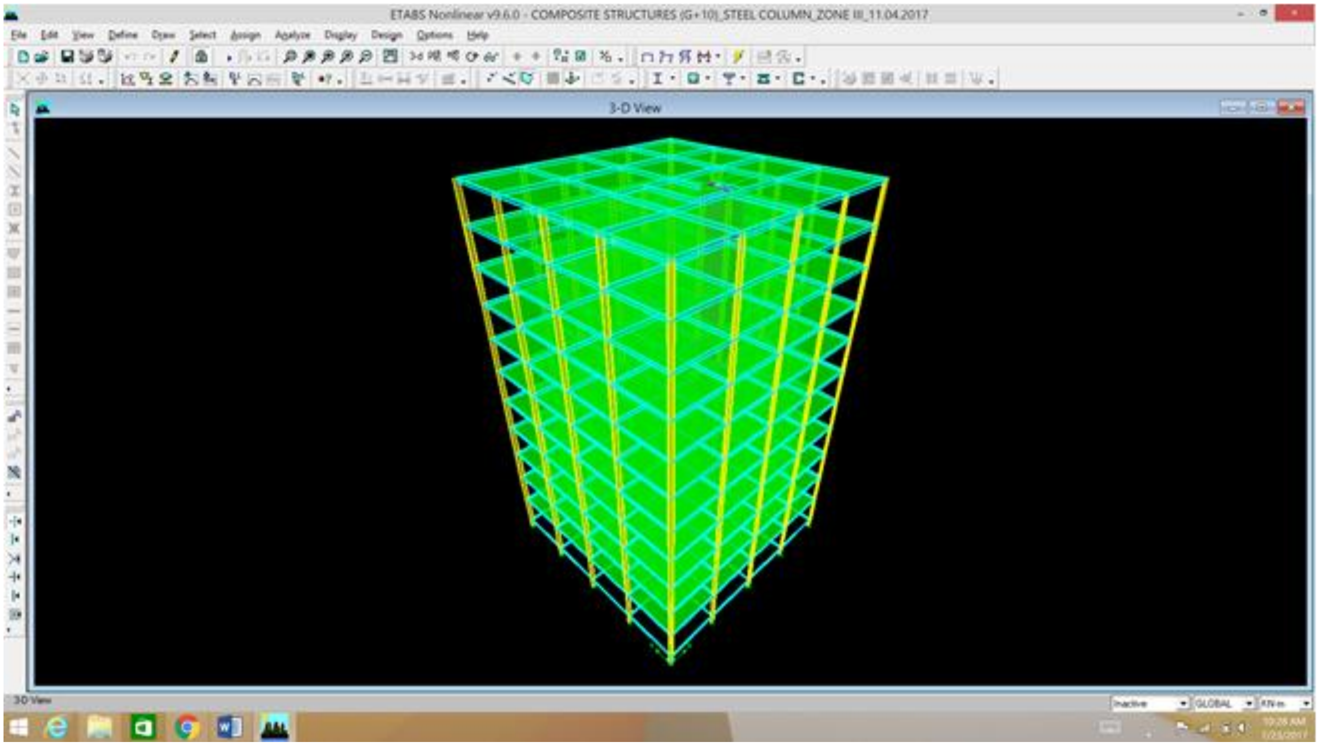

Fig 5: screenshot of G+10 Composite model in ETABS

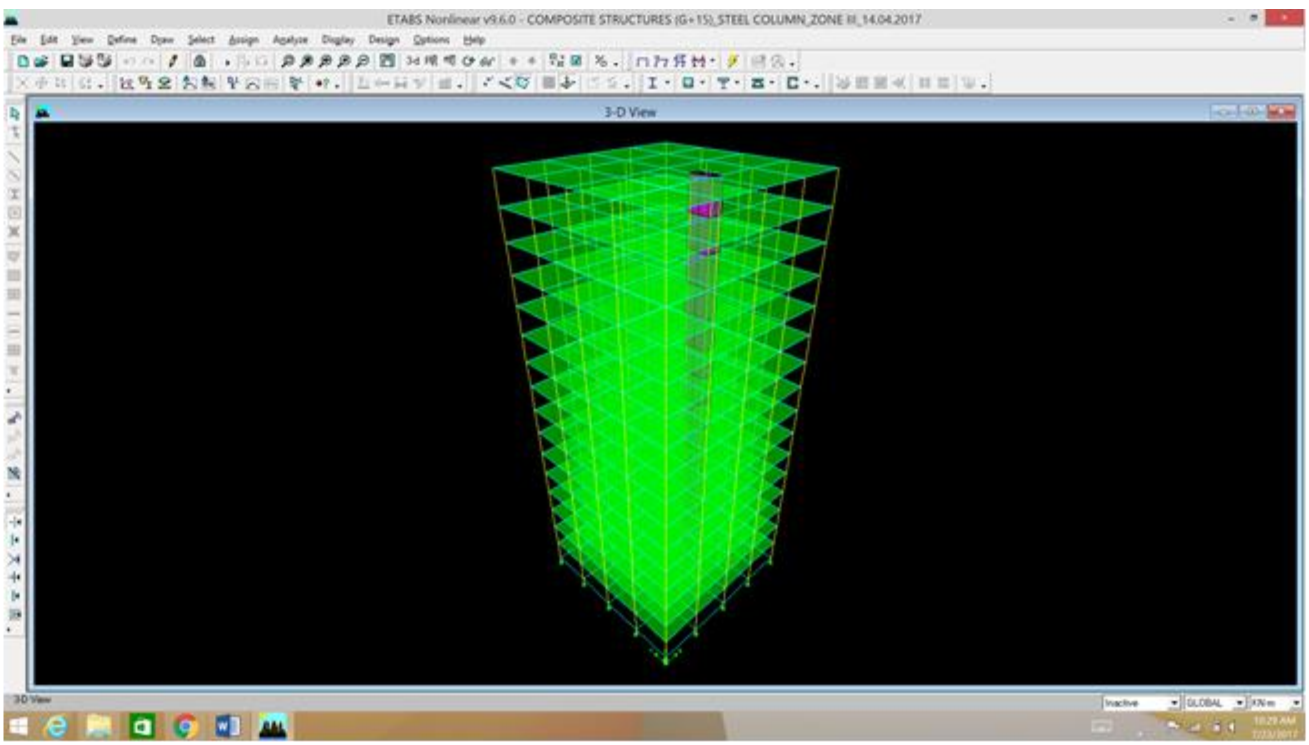

Fig 6: screenshot of G+15 Composite model in ETABS

6. Result and Discussions

Two types of buildings are analyzed i.e. conventional beam-column building and composite building using code response spectrum. The results were analysed for both RCC and Composite Structure and the Suitability of structure is given.

Following tables shows the different parameters of results.

6.1 Axial force

Table 1: Values of Axial Forces for RCC and Composite structure for different stories

NO OF STOREY	RCC	CS
6	8887.62	7198.31
10	13183.2	11107.2
15	20687.6	15651

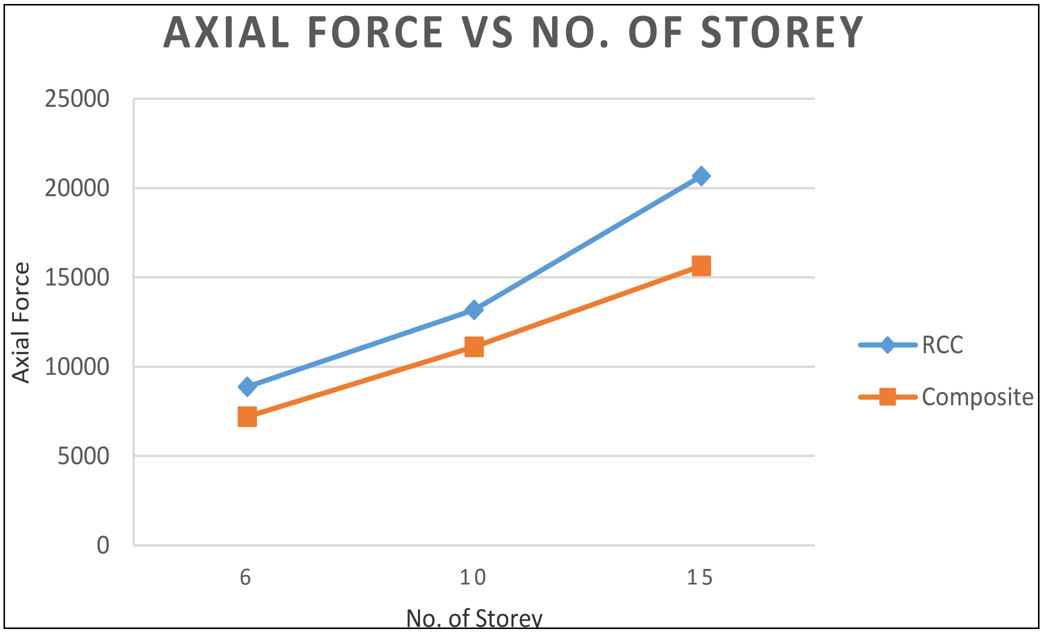

Fig 7: Comparison of Axial Forces of RCC and Composite Structure

6.2 Maximum shear force

Table 2: Values of Shear Forces for RCC and Composite Structures for different stories

NO. OF STOREY	RCC	CS
6	384.96	326.97
10	328.03	307.81
15	384.9	418.46

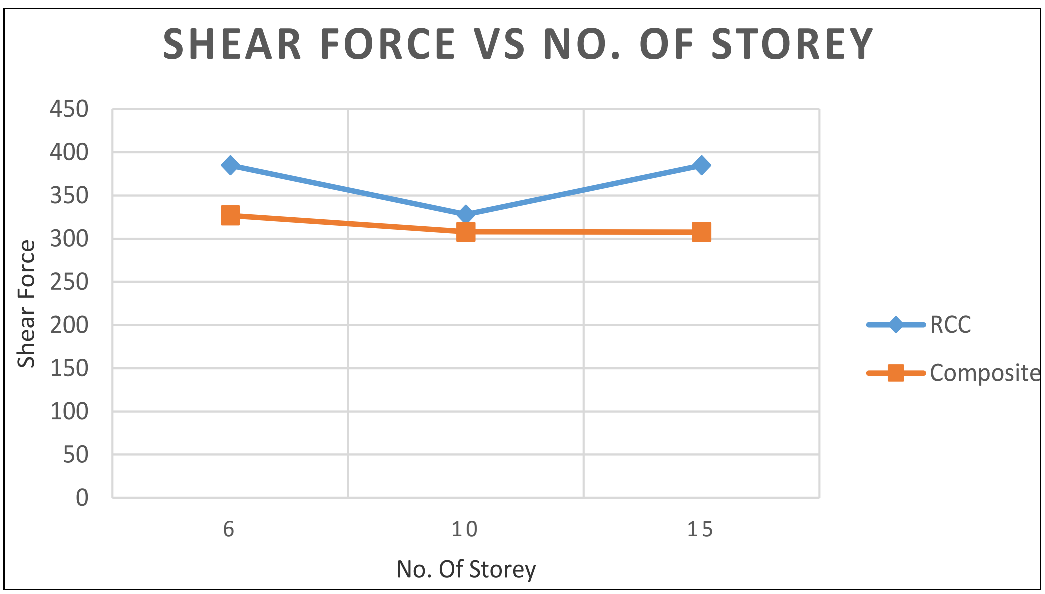

Fig 8: comparison of Shear Forces for RCC and Composite Structures

6.3 Maximum Bending Moment

Table 3: Values of Maximum Moment for RCC and Composite Structures for different Stories

NO OF STOREY	RCC	CS
6	384.29	364.71
10	610.997	383.95
15	636.237	540.92

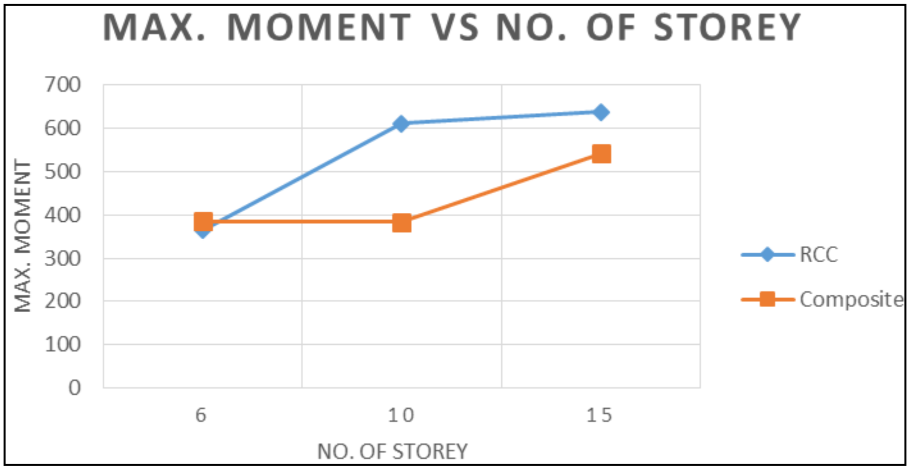

Fig 9: Comparison of Maximum Moment for RCC and Composite Structures.

6.4 Maximum Lateral Displacements

Table 4: Values of Maximum Displacements along X and Y for RCC and Composite Structures

NO OF STOREY	RCC(X)	RCC(Y)
6	18.7	15.8
10	46.4	38.9
15	109.1	95.9

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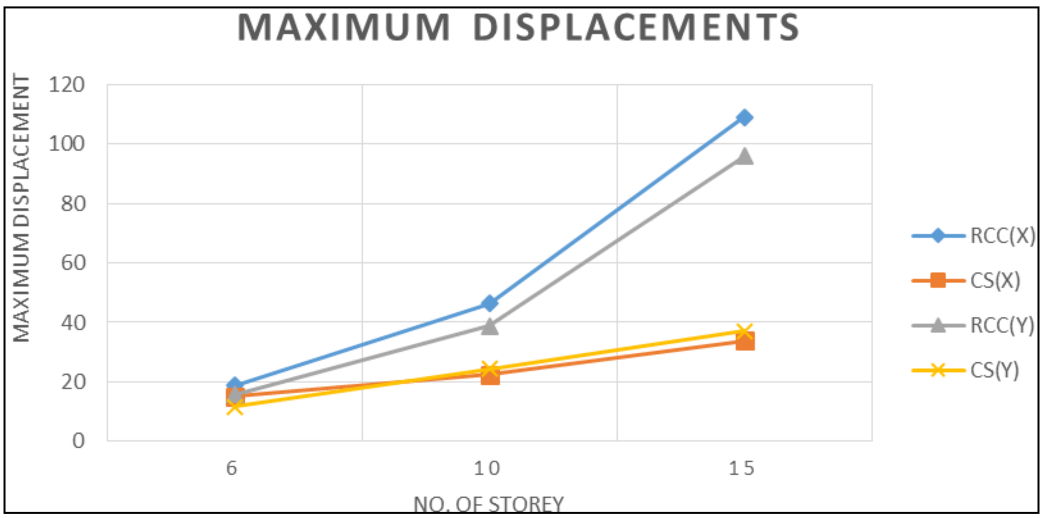

Fig 10: Comparison of Maximum Displacements along X and Y for RCC and Composite Structures.

6.5 Storey Drift

Table 5: Values of Storey Drifts along X and Y for RCC and Composite Structures.

NO. OF STOREY	RCC(X)	RCC(Y)
6	2.4	3
10	3.8	4
15	5.2	5.4

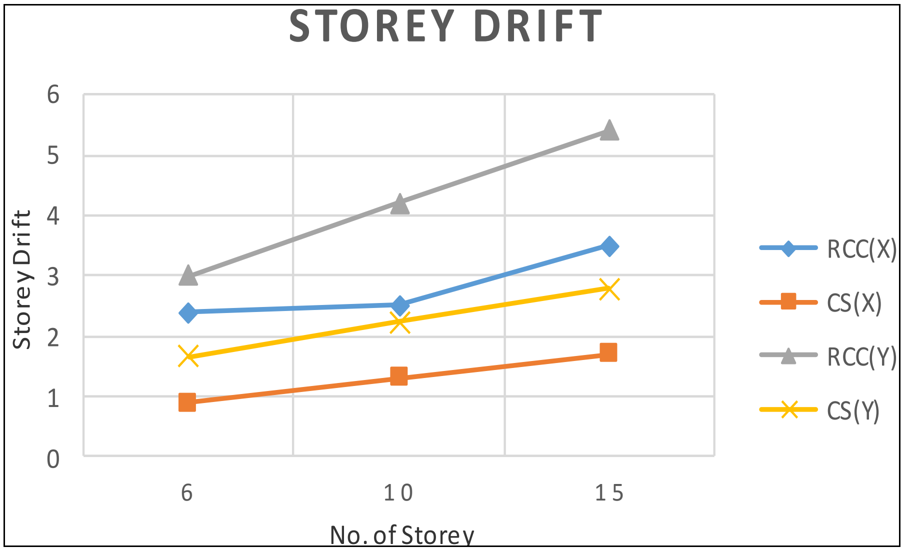

Fig 11: Comparison of Storey Drifts along X and Y for RCC and Composite Structures.

6.6 Base Shear

Table 6: Values of Base Shear calculated using software for RCC and Composite Structures.

NO OF STOREY	RCC	CS
6	1425.06	1080.3
10	1571.64	1226.88
15	1718.22	1357.44

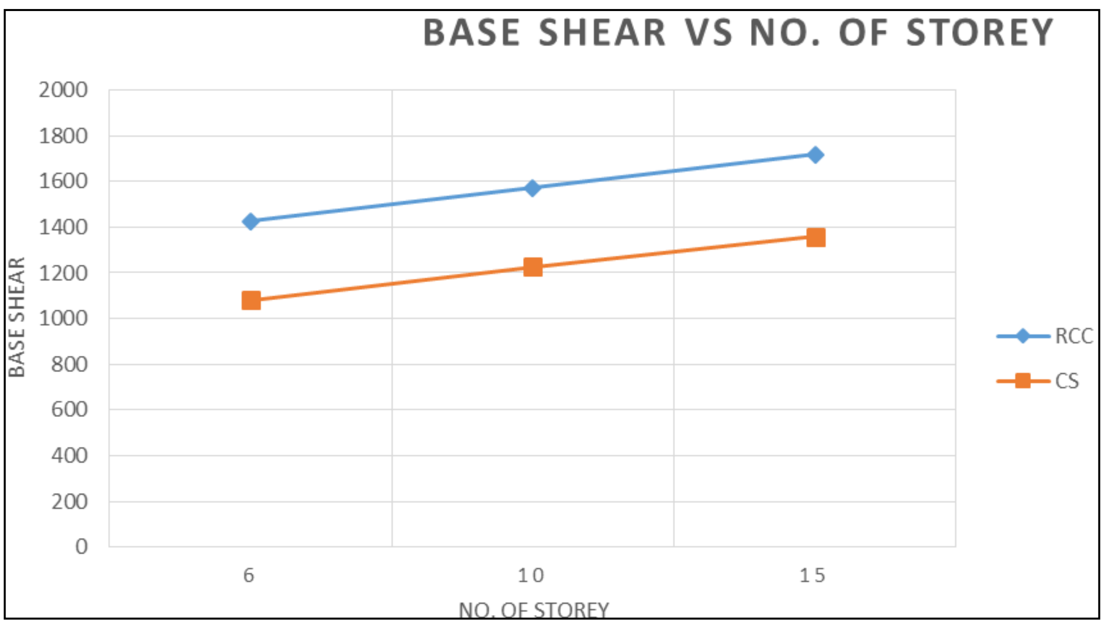

Fig 12: Comparison of Base Shear Using Software for RCC and Composite Structures.

7. Discussions

- RCC structures have higher values of Axial Forces due the increased weight and less ductile nature of structural elements than composite structures. Percentage difference between 19% to 24%.
- As the number of storey increases difference between both values goes on increasing.
- From Fig 7 Composite structure shows uniform behavior than RCC structure.
- RCC structures have higher values of Shear Force and bending moment due to increased dead weight of the structure. Percentage difference varies from 18% to 21%.
- As the number of storey increases difference between both values of shear force goes on increasing.
- RCC structures have higher values of Bending Moment due the increased weight and less ductile nature of structural elements than composite structures.
- Fig 10 shows the variation of displacements in RCC and Composite structures. Percentage difference between the both is 20%.

- Fig 11 shows the variation of storey drifts in top two floors of RCC and Composite structures. Percentage difference between the both is 67%.
- Base Shear is the component of Weight hence RCC structures have higher values of Base Shear than Composite Structure.
- Fig 12 shows the variation of base shear according to increased storey levels for both RCC and Composite Structures. Percentage difference between the both is 13%.

8. Conclusions

- As the results, show the composite option is better than R.C.C. Because Composite option for high rise building is best suited. Weight of composite structure is quite low as compared to RCC structure which helps in reducing the foundation cost
- The reduction in the total weight of the Composite framed structure for 6 storey, 10 storey and 15 storey are 22.64%, 24.19% and 28.95% with respect to R.C.C. frame Structure. As the dead weight of a composite structure is less compared to an R.C.C. structure, it is subjected to less amount of forces induced due to the earthquake
- It is clear that the nodal displacements in a composite structure, by both the methods of seismic analysis, compared to an R.C.C. structure in all the three global directions are less which is due to the higher stiffness of members in a composite structure compared to an RCC structure
- Axial forces in column have been reduced by average 24.55%, 27.28% and 40.61% in Composite framed structure as compared to R.C.C. framed structure
- Composite structures are more economical than that of RCC structure. Composite structures are the best solution for high rise structure as compared to RCC structure. Speedy construction facilitates quicker return on the invested capital and benefits in terms of rent.

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