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Comparative Study on Structural Parameter of R.C.C and Composite Building

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Abstract

Steel-concrete composite construction has gained wide acceptance world wide as an alternative to pure steel and pure concrete construction. However, this approach is a relatively new concept for the construction industry. Steel-concrete composite elements are used extensively in modern buildings. Extensive research on composite column, composite beam and deck slab in which structural steel section are encased in concrete have been carried out. However, for medium to high-rise buildings R.C.C structure is no longer economic because of increased dead load, less stiffness, span restriction and hazardous formwork. The results of this work show that the Composite structures are the best solution for high rise structure as compared to R.C.C structure.

Keywords: Seismic response; composite beam/column; ETAB 13 Software; equivalent static analysis; dynamic analysis; composite floor; shear connector; natural period

1. Introduction

In today's modern era of innovation, two materials widely and inevitably used as construction material are steel and concrete for structures ranging from buildings to bridges. Though these materials may have different properties and characteristics, they both seem to complement each other in many ways. Steel has excellent resistance to tensile loading but lesser weight ratio so thin sections are used which may be prone to buckling phenomenon. On the other hand concrete is good in resistance to compressive force. Steel may be used to induce ductility an important criteria for tall building, while corrosion protection and thermal insulation can be done by concrete. Similarly buckling of steel can also be restrained by concrete. In order, to derive the optimum benefits from both materials composite construction is widely preferred**.**.

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 in the current development needs in India. Not exploring steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. Also, it is evident that now-a-days, 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.

The present research paper is an attempt to study the state of art of seismic performance evaluation of R.C.C and composite building. In the present work, an analytical study on the structural behavior of R.C.C and composite high rise buildings is under taken. The parameters considered are displacements, axial forces, base shear and natural period. The 3D analysis has been carried out using structural analysis software ETABS 2013 and the results such as maximum values of displacements, axial forces, base shear and natural periods are found out by analysis

1.1 Objectives Of The Study

Steel-concrete composite systems have become quite popular in recent times because of their advantages against conventional construction. Composite construction combines the better properties of the both i.e. concrete in compression and steel in tension, they have almost the same thermal expansion and results in speedy construction.

- To fix the preliminary dimension of component.

- To study the code requirements.
- Identify the performance of the structure.

1.2 Scope Of The Study

The present paper is an attempt to study the state of art of seismic performance evaluation of RCC and composite building. In the present work, an analytical study on the structural behavior of RCC and composite high rise buildings is under taken. The parameters considered are displacements, axial forces, base shear and natural period. The 3D analysis has been carried out using structural analysis software ETABS 2013 and the results such as maximum values of displacements, axial forces, base shear and natural periods are found out by analysis.

2. Composite Structures

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 multistoried 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. Steel and concrete although very different in nature, these two materials complement one another.

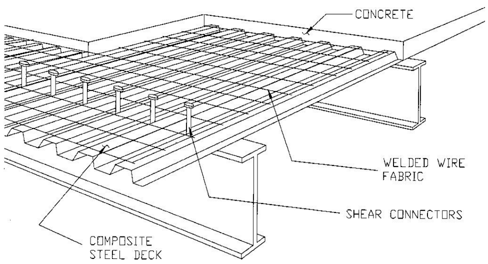


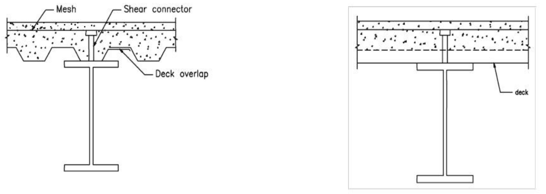
Fig. 1 - Typical Composite Floor Slab Details

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. However, the real attraction of such construction is based on having an efficient connection of the Steel to the Concrete, and this connection that allows a transfer of forces and gives composite members their unique behavior.

2.1 Profiled Deck

Composite floors using profiled sheet decking have become very popular in the West for high-rise buildings. Composite deck slabs are generally competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient. There is presently no Indian standard covering the design of composite floor systems using profiled sheeting.

In composite floors, the structural behavior is similar to a reinforced concrete slab, with the steel sheeting acting as the tension reinforcement.



(a) Ribs parallel to the beam (b) Ribs perpendicular to the beam

Fig. 2 - Typical Composite profiled deck

2.2 Shear Connectors

Shear connectors are steel elements such as studs, bars, spiral or another similar devices welded to the top flange of the steel section and intended to transmit the horizontal shear between the steel section and the cast in-situ concrete and also to prevent vertical separation at the interface.

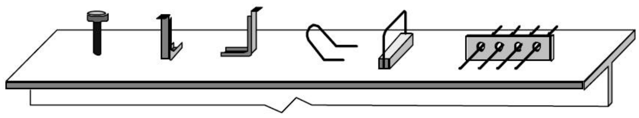


Fig. 3 - Types of Shear Connectors

2.3 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.

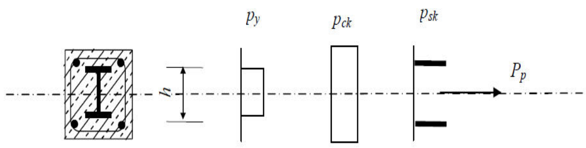


Fig. 4 - Stress distribution of the plastic resistance to compression of an encased I section

The plastic resistance of an encased steel section or concrete filled rectangular or square section (i.e. the so-called "squash load") is given by the sum of the resistances of the components as follows:

$$Pp = Aa.fy / \gamma_a + \gamma_c.Ac.\ (fck)cy / \gamma c + As\ .fsk / \gamma s \quad \text{-(1)}$$

$$Pp = Aa.fy / \gamma_a + \gamma_c\ .Ac.[0.80*\ (fck)cu] / \gamma c + As\ .fsk / \gamma s \quad \text{- (2)}$$

where

Aa, Ac and *As* are the areas of the steel section, the concrete and the reinforcing steel respectively

fy , *(fck)cy* and *fsk* are the yield strength of the steel section, the characteristic compressive strength (cylinder) of the concrete, and the yield strength of the reinforcing steel respectively.

(fck)cu the characteristic compressive strength (cube) of the concrete

γc strength coefficient for concrete, which is *1.0* for concrete filled tubular sections, and *0.85* for fully or partially concrete encased steel sections.

2.4 Design Method

As there is no Indian standard covering profile decking, Eurocode 4 (EC4) provisions are considered. The design method defined in EC4 requires that slab be checked firstly for bending capacity, assuming full bond between concrete and steel, secondly for shear bond capacity and, finally, for vertical shear. The analysis of the bending capacity of the slab may be carried out as though the slab was of reinforced concrete with the steel deck acting as reinforcement. However, no satisfactory analytical method has been developed as far for estimating the value shear bond capacity. Based on test data available, the loads at the construction stage often govern the allowable span rather at the composite slab stage.

3. Determination Of Design Lateral Force

The procedures to determine lateral forces in the code, IS 1893 (Part-1): 2002[14] are based on the approximation effects, yielding can be accounted for linear analysis of the building using the design spectrum. A simplified method may also be adopted that will be referred as lateral force procedure or equivalent static procedure.

The main difference between the equivalent static analysis procedure and dynamic analysis procedure lies in the magnitude and distribution of lateral forces over the height of the buildings. In the dynamic analysis procedure, the lateral forces are based on properties of the natural vibration modes of the building, which are determined by distribution of mass and stiffness over height. In the equivalent lateral force procedure, the magnitude of forces is based on an estimation of the fundamental period and on the distribution of forces as given by a simple formula that is appropriate only for regular building.

4. Building Details

These days, high-rise buildings are different in shape, height and functions. This makes each building characteristics different from each others. There are some standards for each kind of high-rise buildings, such as residential, official and commercials. However for model designing main factors such as grid spacing, floor shape, floor height and column section were considered. Three models with different number of stories with 10 storey, 20 storey and 30 storey having same floor plan of 30m x 24m dimensions were considered for this study.The floor plans were divided into five by six bays in such a way that center to center distance between two grids is 6 meters by 4 meters respectively as shown in Figure 5. The floor height of the building was assumed as 3.2 meters for all floors and plinth height is 4.2 meters above from foundation base as shown in Figure 6.

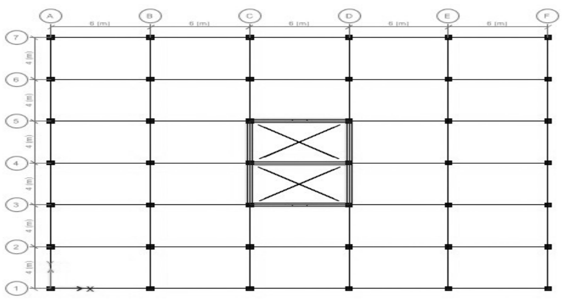


Fig. 5 - Typical Plan of 10 storey building

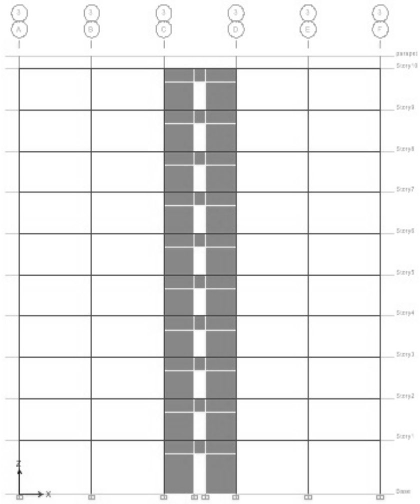


Fig. 6 - Elevation of Building

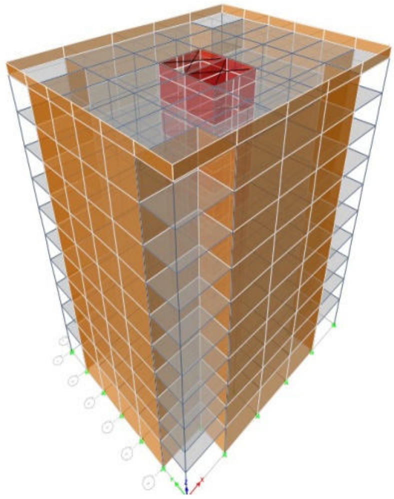


Fig. 7 - 3D Model of Building

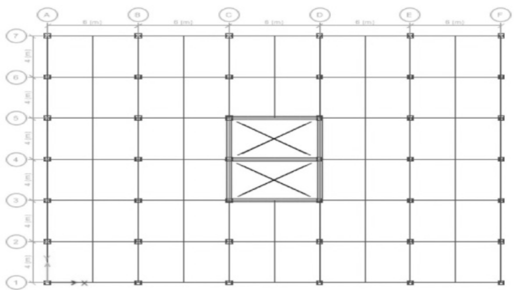


Fig. 8 - Typical Plan of Composite Structure

Table 1 - Data for Analysis of RCC and Composite Structure

Plan dimension		**30 m x 24 m**
Total Height of building	10 storey	33 m
	20 storey	65 m
	30 storey	97 m
Height of each storey		3.2 m
Height of parapet		1 m
Thickness of slab		0.125 m
Thickness of wall		0.15 m
Seismic zone		III
Wind speed		39 m/s
Importance factor		1.5
Zone factor		0.16
Floor finish		1 kN/m^2
Live load		4 kN/m^2
Grade of concrete for slabs		M 30
Grade of concrete for beams and columns		M 30
Grade of reinforcing steel		Fe415
Density of concrete		25 kN/m^3
Density of brick		18.5 kN/m^3
Damping ratio		5%

Table 2 - Beam Size for RCC building

RCC building	**Model-1 10 storey**	**Model -2 20 storey**	**Model -3 30 storey**
GF to 10th floor	0.23 m x 0.5 m	0.23 m x 0.5 m	0.3 m x 0.6 m
10th floor to 20th floor	-	0.23 m x 0.5 m	0.3 m x 0.6 m
20th floor to 30th floor	-	-	0.3 m x 0.6 m

Table 3 - Column Size for RCC building

RCC building	**Model-1 10 storey**	**Model -2 20 storey**	**Model -3 30 storey**
GF to 10th floor	0.4 m x 0.4 m	0.6 m x 0.6 m	0.8 m x 0.8 m
10th floor to 20th floor	-	0.4 m x 0.4 m	0.6 m x 0.6 m
20th floor to 30th floor	-	-	0.5 m x 0.5 m

The model of composite frame for 10 storey, 20 storey and 30 storey building was conceived considering RCC shear wall. The shear wall is modeled as reinforced concrete structure. In case of some typical composite option the floor to floor height of the building has been considered as 3.2m. The composite structure analysis plan is shown in fig.8.

Table 4 - Beam Size for Composite building

Composite building	Model-1 10 storey	Model -2 20 storey	Model -3 30 storey
GF to 10th floor	Main Beam –ISWB 400	Main Beam –ISWB 400	Main Beam –ISWB 400
	Secondary Beam- ISWB 200	Secondary Beam- ISWB 200	Secondary Beam- ISWB 200
10th floor to 20th floor	-	Main Beam –ISWB 400	Main Beam –ISWB 400
	-	Secondary Beam- ISWB 200	Secondary Beam- ISWB 200
20th floor to 30th floor	-	-	Main Beam –ISWB 400
			Secondary Beam- ISWB 200

Table 5 - Loads on RCC and Composite Structure

Loads		
1.	Wall Load	7.2 kN/m
2.	Slab Load	3.125 kN/m^2
3.	Floor Finish	1 kN/m^2
4.	Parapet Load	3 kN/m
5.	Stair Case	12 kN/m
6.	Live Load	4 kN/m^2

The examples of buildings are considered in the present study are modeled in ETABS 2013 by giving all the required input data. The building models are analyzed separately for equivalent static analysis (ESA) and response spectrum analysis (RSA) with respective load combinations. The observations and discussions on the results obtained are discussed below.

Results

In this study different types of analysis carried out namely Equivalent Static Analysis (ESA) and Response Spectrum Analysis (RSA) are presented. The different types of analysis are carried out in ETABS 2013 software. For comparative study the results obtained for composite and RCC structure model is considered. An effort has been made to calculate all the structural parameter of composite and RCC structure elements.

In the present study, the composite and RCC multistorey residential building is considered. The parameter considered are natural period, lateral load, base shear,nodal displacement, maximum shear force, axial force and maximum bending moment and total building weight is considered and their variation in the form of graph is shown.

5.1 Base Shear for RCC and composite

Table 6 - Comparison of Base shear Vs. Storey No. For X- Direction[10 storey model]

STOREY NO	RCC		COMPOSITE	
	EQX - RCC	RSPX - RCC	EQX- Composite	RSPX-Composite
10	1347.179	1183.114	899.5761	782.4221
9	2981.418	2595.603	2135.950	1855.441
8	4283.523	3692.825	3121.050	2702.123
7	5291.185	4555.558	3883.391	3372.340
6	6042.091	5263.640	4451.485	3918.012
5	6573.931	5862.786	4853.845	4371.699
4	6924.393	6370.026	5118.985	4747.260
3	7131.167	6785.974	5275.418	5046.544
2	7231.940	7092.488	5351.658	5259.940
1	7265.292	7265.496	5376.863	5376.425
0	7265.292	7265.496	5376.863	5376.425

The base shears are shown for equivalent static analysis (ESA) and response spectrum analysis (RSA) for the building.

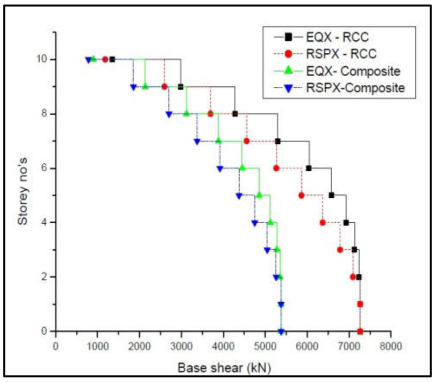


Fig. 9 - Comparison of Base shear Vs. Storey No. For X- Direction [10 storey model]

5.2 Nodal Displacement For RCC And Composite Building

Table 7 - Comparison of Base shear Vs. Storey No. For X- Direction[10 storey model]

Storey no	RCC		Composite	
	Disp-RCC (Eqx)	**Disp-RCC (rspx)**	**Disp-Composite (Eqx)**	**Disp-Composite (rspx)**
10	26.6	23.1	21.8	19.2
9	23.5	20.5	19.2	16.9
8	20.3	17.7	16.5	14.6
7	17	14.9	13.8	12.3
6	13.8	12.1	11.1	10
5	10.6	9.4	8.6	7.7
4	7.7	6.9	6.2	5.6
3	5.1	4.6	4.1	3.7
2	2.9	2.6	2.3	2.1
1	1.2	1.1	0.9	0.9
0	0	0	0	0

(Note : disp – Displacement)

Fig. 10 - Comparison of Storey no Vs. Displacement (mm) For X- Direction [10 storey model]

5.3 Time period for RCC and composite

Approximate fundamental natural period of vibration (Ta) , in seconds, of RCC and composite model with brick infill panels is estimated by IS 1893 (Part 1) : 2002 empirical expression :

$$Ta = 0.09h/\sqrt{d}$$

Table 8 - Comparison of Time period (sec) Vs. Storey no For X-Direction

storey	Time period		
	Aprox.-X	**RCC-X**	**Composite - X**
10	0.542	0.691	0.612
20	1.068	1.902	1.825
30	1.593	2.757	3.146

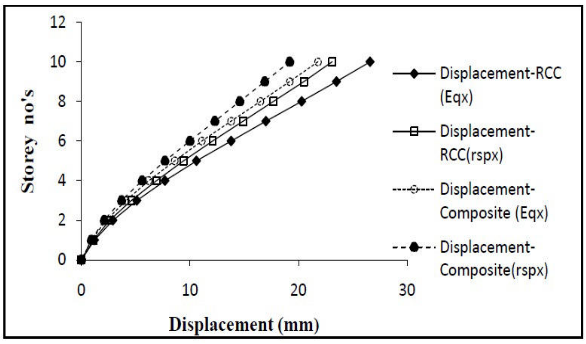
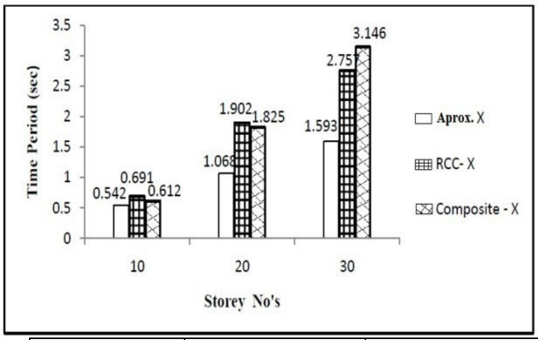


Fig. 11 - Comparison of Time period (sec) Vs. Storey no For X-Direction

5.4 Weight Of RCC and composite Structure

Table 9 - Comparison of Total weight (kN) Vs. Model For RCC and Composite



Model	RCC(kN)	Composite(kN)
10	87435.15	67633.16
20	183524.4	139125
30	309387.15	219813.8

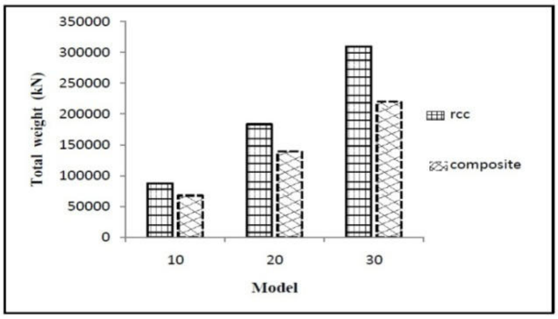


Fig. 12 - Comparison of Total weight (kN) Vs. RCC and Composite.

5.5 Axial force for RCC and Composite

Table 10 - Comparison of Axial Force (kN) Vs. Model For Corner column

Model	RCC	COMPOSITE
	Corner column (C1) - RCC	**Corner column (C1)- Composite**
10 storey	1644.889	1241.012
20 storey	4045.45	2941.7463
30 storey	8470.09	5029.76

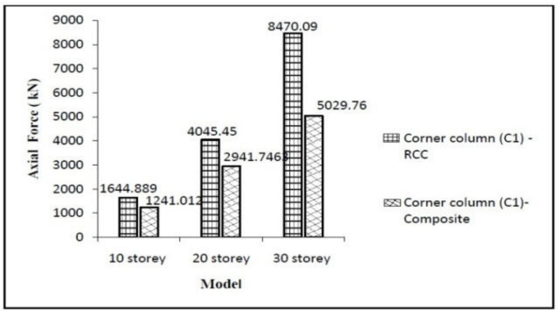


Fig. 13 - Comparison of Axial Force (kN) Vs. Model For Corner column

5. Discussion

Table 6 shows comparison between equivalent static analysis (ESA) method, the design base shear (EQX-composite) are decreased by 26% in composite structure as compared to (EQX-RCC) R.C.C framed structure.

Table 7 represent comparison between the nodal displacement vs No. of storey. Displacements in X direction for composite buildings are lower than that of RCC buildings by 18.04%, 16.88% in X direction respectively.

Table 8 represent comparison between time period for RCC and composite building. Natural period in X direction for 10 storey , 20 storey composite buildings are lower than that of RCC buildings by 11.43%, 4.04% and for 30 storey 14.10% higher than RCC in X direction. similarly 12.31% , 3.01% lower than RCC and for 30 storey 10.86% higher than RCC in Y direction respectively.

The total weight for composite and RCC structure is referred in a table 9 The Bar graph as shown in fig. 12 shows the total weight for Composite and RCC structures.Total weight of building for 10 storey , 20 storey and 30 storey composite buildings are lower than that of RCC buildings by 22.64%, 24.19% and for 30 storey 28.95% respectively.

From table 10 it is clear that for 10 storey , 20 storey and 30 storey building the axial forces on corner composite column is reduced by 24.55%, 27.28% and for 30 storey 40.61% than that of RCC corner column respectively.

6. 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 10 storey, 20 storey and 30 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.
- As the sizes of the column members from R.C.C option to the composite option reduces about 43.75%,

55.55% and 43.75% for 10 storey, 20 storey and 30 storey.

- 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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