Seismic Analysis of Steel Concrete Composite System and its Contrast with RCC Structures

K. Mukesh Kumar[1], H. Sudarsana Rao[2]

[1]PG Scholar, Dept. of Civil Engineering JNTUA, Anantapur, India

[2]Professor & Director ICS, JNT University, Anantapur, India

Abstract: ***Composite structures made of steel and concrete are very 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 low to high rise (5, 10 and 15 storied) RCC and composite structures are considered in seismic zone V. The seismic behavior of the study frames designed by the proposed methodology is evaluated by Response spectrum and nonlinear time-history analysis by .ETABS software.***

Keywords: ETABS, column, beam, slab

1. Introduction

RCC structures are more popular due to ease in construction .but in developing countries there is a need for large number of medium and high rise structures to take care of growing urban population. The area available in urban areas is very less which is insufficient to provide accommodation for the growing population. So the available area should be properly utilized which can be possible by employing a large number of medium to high rise structures. For such high rise structures it was found that steel concrete composite structures are more beneficial than traditional RCC structures. The reason behind the reputation of composite structures is its benefits it possesses when compared with RCC and steel constructions. In case of low rise structures RCC construction is sufficient due to less dead load. But in medium and high rise structures where there are more dead loads and increased spans which are prone to serious hazards composite structures are required.

Most of the developed European and American countries use steel as a construction material more frequently which may not be seen in India. Development of techniques to achieve economy should be devised in developing countries like India. Use of composite structures is one of such methods with which we can accomplish safety and economy.

2. Objective

The objectives of the study is to explain the concept of composite construction and to describe the elements comprised in steel concrete composite structures and to evaluate the performance of composite structures under earthquake loading and comparing it with conventional RCC structures. The parameters considered for comparisons are displacements, story drifts, column axial forces, column bending moments and shear forces, beam shear forces and bending moments, time period of the structure and dead weight of the structure.

3. Composite Construction

A composite member is constructed by combining concrete member and steel member so that they act as a single unit. As we know that concrete is strong in compression and weak in tension on the other side steel is strong in tension and weak in compression. The strength of concrete in compression is complemented by strength of steel in tension which results in an efficient section. By the concept of this composite member the concrete and steel are utilized in a well-organized manner.

The structural elements which are comprised in a composite construction are given below
1) Composite deck slab
2) Composite beam
3) Composite column
4) Shear connector

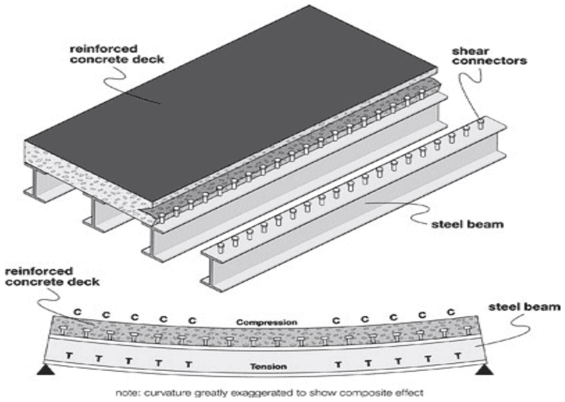

Figure 3.1: composite deck slab and beams

3.1 Composite Deck Slab

Composite floor system comprises of steel beams, metal deck and concrete slab. In general a steel beam for example I section is coupled with steel deck over which a concrete slab is laid.

The metal deck rests between two steel sections which also serve as operational stand for concrete work. This composite floor system acts as a diaphragm due to which the composite floor system produces a rigid horizontal diaphragm, providing solidity to the structure in addition to that it distributes wind loads and earthquake loads to the composite frame system.

3.2 Composite Beam

A composite beam is produced by placing a concrete slab over steel beams mostly I section. When loads are applied on this member these rudiments have a tendency to perform in a self-regulating way which results in occurrence of slip among them. This relative slip can be eliminated when we provide an appropriate connection between steel beam and concrete slab, by providing connections the steel beam and concrete slab is made to act as a single unit. The steel which is weak in compression buckles under compression loads and concrete which is weak in tension develops cracks due to tensile loads. By providing above mentioned arrangement concrete and steel elements act together in order to resist both tensile and compression loads in an efficient way. Due to higher stiffness than steel members composite members deflect less than them. For same loading, employing composite beam results in thin, effective and economic cross sections than RCC structures.

The composite deck slab and composite beams are shown in fig 3.1

3.3 Composite Columns

A compression member consisting of both steel and concrete elements can be termed as steel concrete composite columns. There are two types of composite columns

1. Concrete section with embedded steel section
2. A hallow steel section with concrete infill

The types of composite columns are shown in fig 3.2

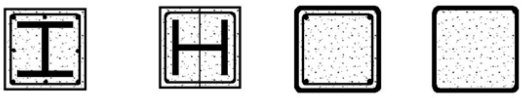

Figure 3.2: Types of composite columns

Friction and bond are the two parameters which makes both steel and concrete elements to act as a single unit in composite columns. The general process of construction of composite column includes erection of hallow steel section or I section which takes the initial construction loads then it is filled with concrete or concrete is casted around I beam. Lateral deflections and buckling of steel members are prevented by concrete member. In addition to that composite columns have less cross sectional area and light weight when compared with RCC columns. Due to this the usable floor area increases in composite structures and foundation cost is also decreased

3.4 Shear Connectors

This is the main component which is responsible for the development of composite action between concrete slab and steel beam by shear transfer. This helps the composite system to take up large amounts of flexural stresses and to transfer horizontal loads to the lateral load resisting system.

The purpose of shear connectors is to avoid partition of concrete slab and steel beam and to transmit the lateral shear at the concrete and steel interface. There are many types of shear connectors which can be employed based on their suitability.

4. Literature Review

D.R. Panchal & **Dr. S. C. Patodi** performed Equivalent static method to find the response of composite system of structures and RCC structures under dead load, live loads, wind loads and earthquake loads. The fallouts of RCC and composite systems are equaled

Shashikala. Koppad, Dr.S.V.Itti worked on a 15 storied building which is situated in zone III of earthquake zones in India with RCC and composite systems. They calculated the cost analysis for composite and RCC and decided that material cost is decreased for composite system in comparison with RCC system

D.R. Panchal and P.M. Marathe modeled a 30 storied building with composite and RCC options. The structure was placed in earthquake zone IV of India. As the load varies for different story levels they have considered different cross sections at different story level. They matched different parameters and finally concluded that composite structures are better than RCC structures for high rise structures.

Shwetha A. Wagh and U.P. Waghe considered 25 storied structure with composite system and RCC systems which was situated in Nagpur belonging to earthquake zone II of India. In STAAD PRO they performed equivalent static method and they calculated material cost of both the systems and they decided that for high rise structures usage of composite system will result in economy of the structure.

Sattainathan.A and Nagarajan.N demonstrated a 20 storied building one with Composite sections and another with RCC sections in seismic zone IV of earthquake zones in India and equivalent static method of analysis was performed on the modeled structures and they gave a conclusion that due to flexibility of composite structures they deflect more than RCC structures by which they can face earthquake loads in a better way than RCC structures.

5. Modelling & Analysis

The Layout of plan having 4X4 bays of equal length of 5m. The buildings considered are composite and RCC structures of 5 story, 10 storey and 15 storey. The storey height is kept uniform of 3m for building models. The analysis illustrates the step-by-step procedure for determination of forces.

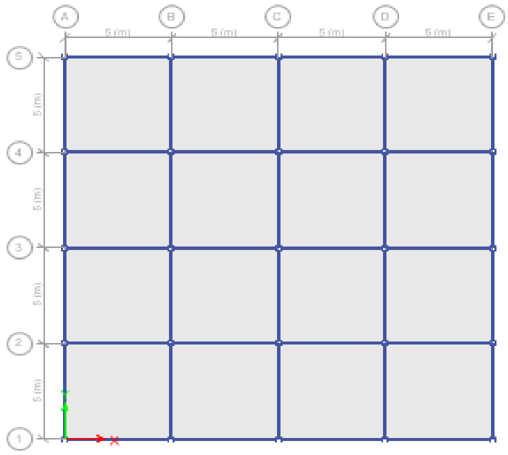

Figure 5.1: Plan view of models

The sections considered for different models are given below:

	Section	Composite	RCC
Low Rise(5 Storey) Structure	Column	300mmX300mm with embedded ISHB 200	350mmX350mm
	Beams	ISMB200 with shear connectors	250mmX350mm
	Slab	125 mm thick concrete slab	125 mm thick concrete slab
Medium Rise(10 Storey) Structure	Column	350mmX350mm with embedded ISHB 250	400mmX500mm
	Beams	ISMB250 with shear connectors	300mmX400mm
	Slab	125 mm thick concrete slab	125 mm thick concrete slab
High Rise (15 Storey) Structure	Column	400mmX400mm with embedded ISHB 300	450mmX550mm
	Beams	ISMB300 with shear connectors	350mmX450mm
	Slab	125 mm thick concrete slab	125 mm thick concrete slab

The basic parameters considered for the design are
Live load: 2 KN/sq.m
Floor finishes load: 1.25 KN/sq.m
Wall load: 10 KN/m (230 mm wall)
Earthquake parameters considered are
Zone: V
Soil type: Hard soil
Importance factor: 1
Response reduction factor: 3
Earthquake loading as per IS 1893

Codes for analysis
RCC design: IS 456:2000
Composite design: IS 11384

The above mentioned building models are analyzed using Response spectrum method. The building models are analyzed using ETABS software. The different parameters such as displacements, story drifts, column axial forces, column bending moments and shear forces, beam shear forces and bending moments, time period of the structure and dead weight of the structure are compared for composite and RCC structures.

6. Results

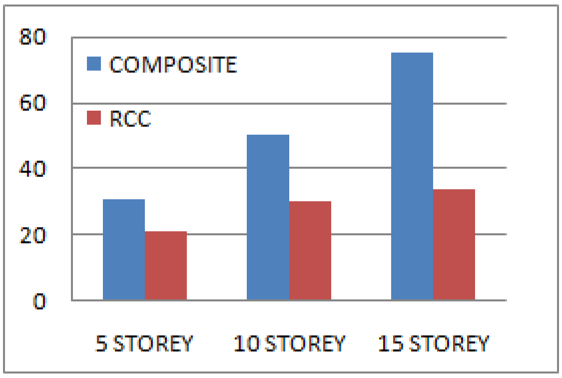

Figure 6.1: Maximum displacements (mm) in x direction

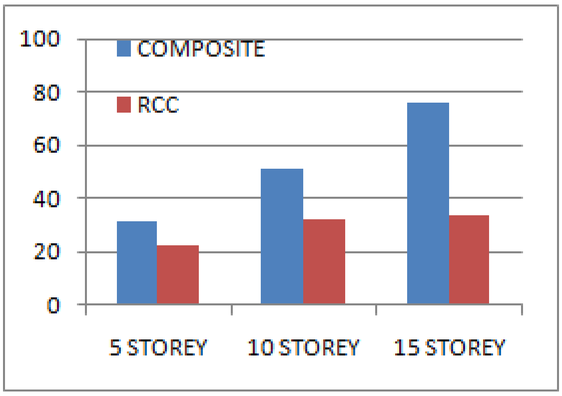

Figure 6.2: Maximium displacements (mm) in y direction

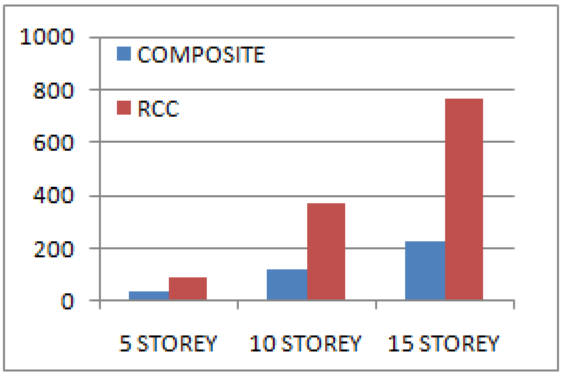

Figure 6.3: Column axial force (KN)

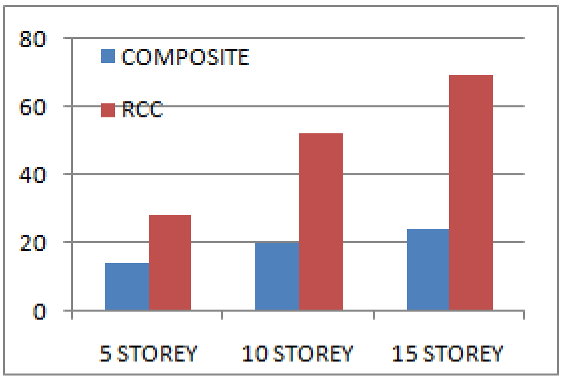

Figure 6.4: Column shear force (KN) in x direction

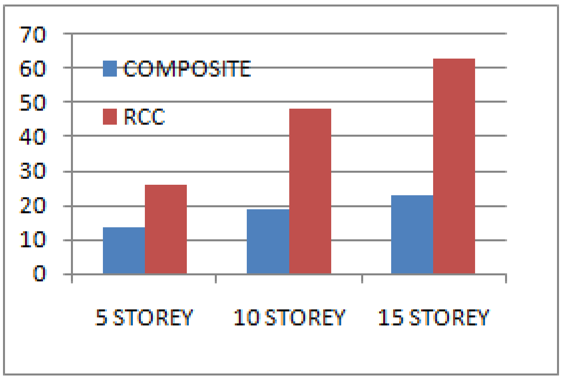

Figure 6.5: Column shear force (KN) in y direction

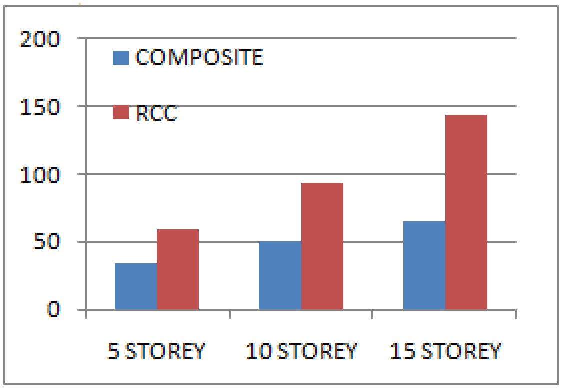

Figure 6.6: Column bending moment (KN-m) in x direction

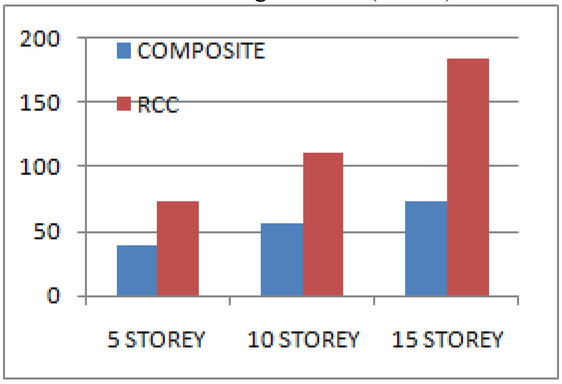

Figure 6.7: Column bending moment (KN-m) in y direction

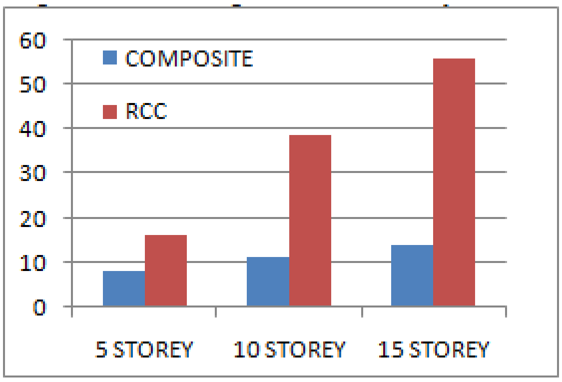

Figure 6.8: Shear forces (KN) in beams

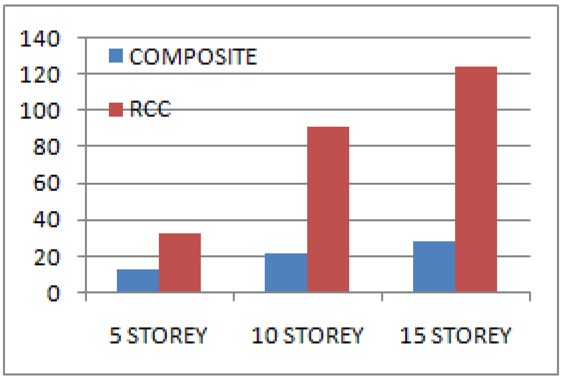

Figure 6.9: Bending moments in beams

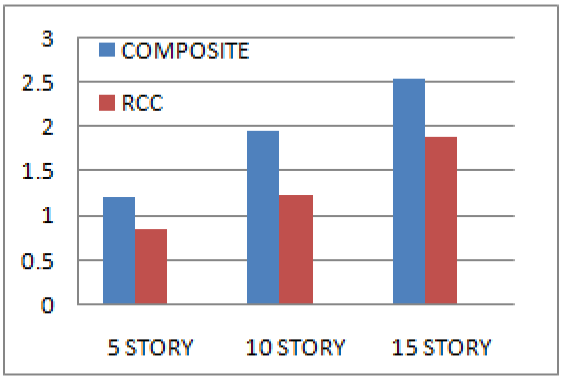

Figure 6.10: Maximum time periods

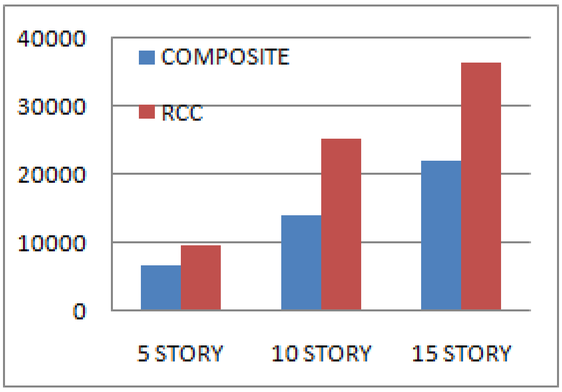

Figure 6.11: Dead weight of structure

7. Discussion of Results

1) The time period of the structure is reduced from composite to RCC as shown . The time period is reduced from 1.214 s to0.852 s in low rise(5 story) structure,1.954 s to 1.242 s in medium rise (10 story) structure, and 2.537 s to 1.882 s in high rise(15story) structure.
2) The Dead weight of the structure is reduced from RCC to composite as shown . The dead weight of the structure is reduced from 9588 KN to 6840 KN in low rise structure, 25155.06 KN to 14208.07 KN in medium rise structure and 36535.493 KN to 21921.34 KN in high rise structure.
3) The displacements of the structure are reduced from composite to RCC as shown. The displacements is reduced from 30.8 mm to 20.6 mm in low rise(5 story) structure,49.9 mm to 29.8 mm in medium rise (10 story) structure, and 75.1 mm to 33.79 mm in high rise(15story) structure in x direction and 31.8 mm to 22.4 mm in low rise(5 story) structure, 51.3 mm to 32.6 mm in medium

rise (10 story) structure, and 76.5 mm to 34.42 mm in high rise(15story) structure in y direction.

4) The column axial forces are reduced from RCC to composite as shown. The column axial forces are reduced from 92.91 KN to 41.43 KN in low rise structure, 368.75 KN to 121.55 KN in medium rise structure and 763.43 KN to 229.03 KN in high rise structure.
5) The beam shear forces are reduced from RCC to composite as shown . The beam shear forces are reduced from 16.15 KN to 7.87 KN in low rise structure, 38.57 KN to 11.19 KN in medium rise structure and 55.56 KN to 13.89 KN in high rise structure.
6) The beam bending moments are reduced from RCC to composite as shown . The beam shear forces are reduced from 32.28 KN-m to 13.18 KN-m in low rise structure, 90.35 KN-m to 21.69 KN-m in medium rise structure and 123.95 KN-m to 28.51 KN-m in high rise structure.
7) The column shear forces are reduced from RCC to composite as shown. The column shear forces are reduced from 28.27 KN to 14.3 KN in low rise structure, 51.93 KN to 19.58 KN in medium rise structure and 68.8 KN to 24.08 KN in high rise structure in x direction and 26.02 KN to 13.74 KN in low rise structure, 48.24 KN to 18.88 KN in medium rise structure and 62.72 KN to 23.21 KN in high rise structure in y direction.
8) The column bending moments are reduced from RCC to composite as shown. The column bending moments are reduced from 58.93 KN-m to 34.76 KN-m in low rise structure, 93.73 KN-m to 50.25 KN-m in medium rise structure and 143.93 KN-m to 64.77 KN-m in high rise structure in x direction and 72.95 KN-m to 38.51 KN-m in low rise structure, 110.27 KN-m to 56.4 KN-m in medium rise structure and 184.2 KN-m to 73.89 KN-m in high rise structure in y direction

8. Conclusions

- Through E-TABS values of time period of the structures are extracted. The maximum time period is for composite structures, it means it is more flexible to oscillate back and forth when lateral force act on the building and RCC structures has least time period which says that it is less flexible.
- The increased stiffness of RCC structures results in increased frequency and reduction in time period than composite structures
- The maximum displacements are more in composite structures but within limit. This is because composite structures are more flexible as compared to RCC structures.
- Story drifts of composite structures are comparatively more than RC structures but within permissible limits
- The axial forces are reduced in case of composite structures which results in thinner sections of columns
- The column shear forces and bending moments in x and y directions are very less in composite structures when compared to RCC structures
- Due to thinner column sections in composite structures the usable floor area increases
- The shear forces and bending moments are reduced in composite structures which results in thinner sections in beams.
- Due to the reduced dimensions of columns and beams the dead weight of composite structures is found to be less than RCC structures, this results in lowering the foundation cost.
- Due to the light weight of the structure the composite structures are less susceptible against seismic forces acting on the structure.
- The analysis of composite structures show that the axial forces, moments, and shear forces of the structure are very less for the same loading as compared to the RCC buildings. The reduced moments and axial forces results in reduced dimensions of columns and beams. Hence one can conclude that the composite construction is more economical than conventional RCC structures.

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Author Profile

K. Mukesh Kumar is P.G Student (Computer Aided Structural Engineering). JNTU Anantapuram.