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Seismic Behavior Analysis of Composite Buildings with Respect to RCC Buildings

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Abstract: Steel concrete composite construction has gained wide acceptance worldwide as an alternative to pure steel and pure concrete construction. The use of steel in construction industry is very low in Nepal compared to many developing countries. There is a great potential for increasing the volume of steel in construction, especially in the current development needs. Not using steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. Use of composite material is of particular interest, due to its significant potential in improving the overall performance through rather modest changes in manufacturing and constructional technologies. Steel concrete composite construction means the concrete slab is connected to the composite beam with the help of shear connectors so that they act as a single unit. In the present work, steel concrete composite (both full and half composite) with RCC options are considered for comparative study of seismic behavior of 10 multistoried commercial buildings (4-storied, 5-storied, 6-storied, 7-storied, 8-storied, 9-storied, 10-storied, 12-storied, 16-storied and 20-storied which is situated in earthquake zone V and for earthquake loading, the provisions of IS:1893(Part1)-2002 is considered. For modeling of composite and RCC structures, SAP2000 software is used. Steel-concrete composite construction system is an efficient, economical and innovative method for seismic resistance of multi storied buildings. Equivalent static method of seismic analysis is used in the analysis of models. Comparison of parameters like time period, axial force, shear force, bending moment, deflection, storey drifts, base shear, storey stiffness is done for full composite(beam-column both composite), half composite(column composite) and RCC structures. The results are compared and found that composite structure is better in several aspects.

Key words: Seismic Behavior, Composite Building, Comparison of Parameters

1. Introduction

Modern civilization relies upon the continuing performance of civil engineering infrastructure ranging from industrial building to power station and bridges. For the satisfactory performance of the existing structural system, the need for strengthening is inevitable. Commonly encountered engineering challenges such as increase in service loads, changes in use of the structure, design and/or construction errors, degradation problems, changes in design code regulation and seismic retrofits are some of the causes that lead to the need for new techniques to upgrade the performance of the structures. Though concrete a versatile construction material has several advantages due to its compressive strength and mouldable shape, it has its own tensional limitation and poor ductility. Ductility is an important characteristic of a structure to resist earthquake, impact and blast loading. Steel has excellent ductile property. Hence a judicious combination of structural steel and concrete utilizing the strength possessed by them and suppressing their weakness resulted in the composite construction. The present day demands in construction on parameters such as strength, safety, serviceability, satisfactory and reliable performance expected of a structure apart from economical solutions has also made it imperative to use steel concrete composite construction techniques. Apart from economical solutions has also made it imperative to use steel concrete composite construction techniques.

2. Objectives

Major objectives of the study are as follows:

- To investigate the seismic behavior of steel-concrete composite frames over traditional reinforced concrete frames for building structures.
- To check whether steel-concrete composite sections are best alternative to RCC sections used in buildings.

3. Composite Construction

In order to design the structural member with maximum efficiency and minimum cost, steel-concrete composite construction is adopted. It is a powerful construction concept in which compressive strength of concrete and the tensile strength of steel are almost effectively used. Steel and the concrete have almost the same thermal expansion apart from an ideal combination of strength. Hence, these essential different materials are completely compatible and complementary to each other. Steel-concrete composite beams are today widely used for bridges and industrial buildings. The concrete lends the composite mass, stiffness and compressive strength and reduces deflection and vibration in the slab. The steel members give the beam its tensile strength with excellent strength to weight ratios and rapid construction times. The main advantages in utilizing steel-concrete composite construction are saving in the weight of steel. The other advantages in using steel-concrete composite section are:

- Most effective utilization of materials like concrete in compression and steel in tension.
- High ductility of steel leads to better seismic resistance of the composite section.
- Steel component has the ability to absorb the energy released due to seismic forces.
- Ability to cover large column free area.
- Faster construction by utilizing rolled and/or prefabricated components.
- Keeping span and loading unaltered, smaller sections are required compared to non-composite construction.

4. Components of Composite Construction

Composite Beam: In conventional composite construction, concrete slabs rest over steel beams and are supported by them. Under load these two components act independently and a relative slip occurs at the interface if there is no connection between them. With the help of a deliberate and appropriate connection provided between them can be eliminated. In this case the steel beam and the slab act as a “composite beam" and their action is similar to that of a monolithic Tee beam. Also we can use concrete encased steel section as composite beam.

Composite Column: A steel concrete composite column is a compression member, comprising either of a concrete encased hot rolled steel section or a concrete filled hollow section of hot rolled steel. It is generally used as a load bearing member in a composite framed structure. Composite members are mainly subjected to compression and bending. In a composite column both the steel and concrete would resist the external loading by interacting together by bond and friction. Supplementary reinforcement in the concrete encasement prevents excessive spalling of concrete both under normal load and fire conditions.

5. Building Details

The buildings considered here are commercial building. Altogether 10 buildings of heights 12m,1 5m,18m,21m,24m,27m,30m,36m,48m,60m with storey height 3m. The plan dimensions taken ar e16m*16m,32m*28m,32m*24m,32m*20m, 32m*16m, 32m*32m. The study is carried out on the same building plan for R.C.C, Steel and Composite construction. The floor plans were divided into no of bays in such a way that center to center distance between two grids is 4 meter by 4 meters respectively. Columns and beams used for different models are as follows.

Composite buildings (column composite): Beams- ISWB450, ISHB250, Columns -800mmx600mm (ISHB450), 400mmx400mm (ISHB250)

Composite buildings (column and beam composite): Beams- 350*300(ISHB150), 300*200(ISHB100), Columns-800mmx600mm (ISH50), 400mmx400mm (ISHB250)

RCC buildings: Beams - 600mmx230mm, 250mmx250mm, Columns - 1200mmx400mm, 400mmx400mm.

Table 1: Data for analysis of all buildings

Seismic zone	V
Wind speed	50 m/s
Soil condition	Medium soil
Importance factor	1.0
Zone factor	0.36
Floor finish	1.5 kN/m^2
Live load at all floors	4.0 kN/m^2
Grade of concrete	M25
Grade of steel	Fe250
Density of concrete	25kN/m^3

6. Modeling and Analysis

3D building models are analyzed using Equivalent Static Method and non linear static method. The buildings models are analyzed by using SAP2000 V18 software. In composite beam (column composite) structure the beams are modeled as steel beam element and columns are modeled as composite column element with concrete encased steel section. In RCC structure the beam and column are modeled as RCC beam and column element. In composite (beam and column composite) both beams and columns are modeled as concrete encased steel section as composite section. The different parameters such as node displacement, maximum shear force, axial force and maximum bending moment, time period and few more parameters were studied for the models. The dead load and live load are considered as per IS-875 (part 1 & 2). For earthquake loading IS: 1893 (Part1)-2002 is used.

7. Results

Analysis of all three type buildings is done and the results are as follows:

Results from linear static analysis

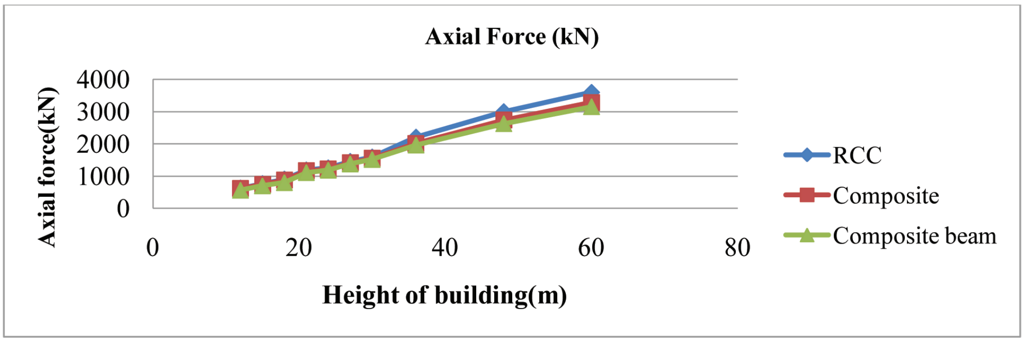

Fig. 1: Comparison of Axial Force

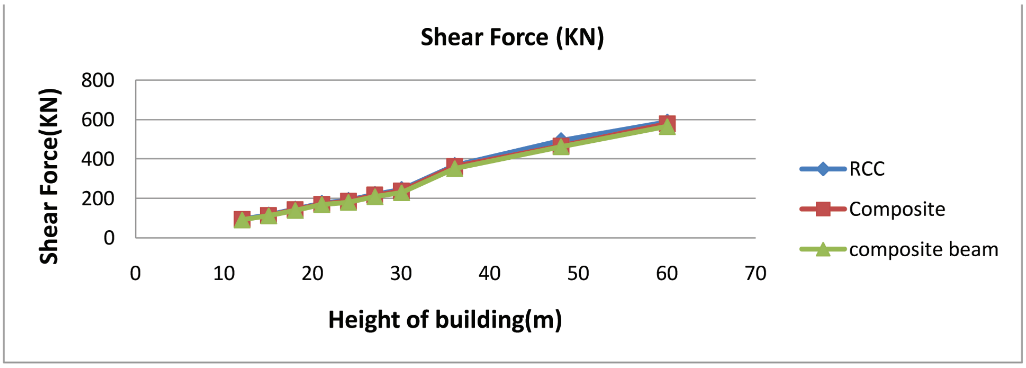

Fig. 2: Comparison of Shear Force

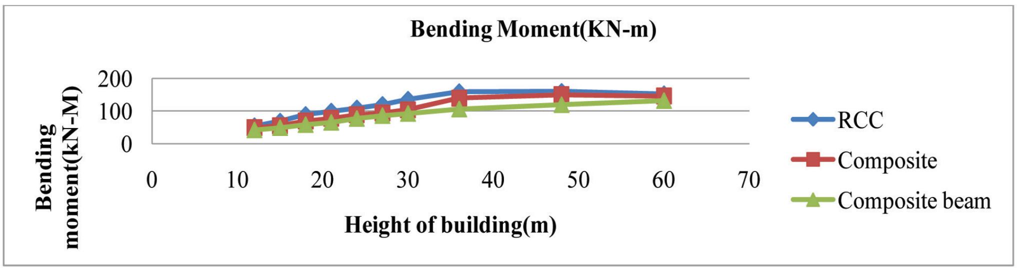

Fig. 3: Comparison of Bending Moment

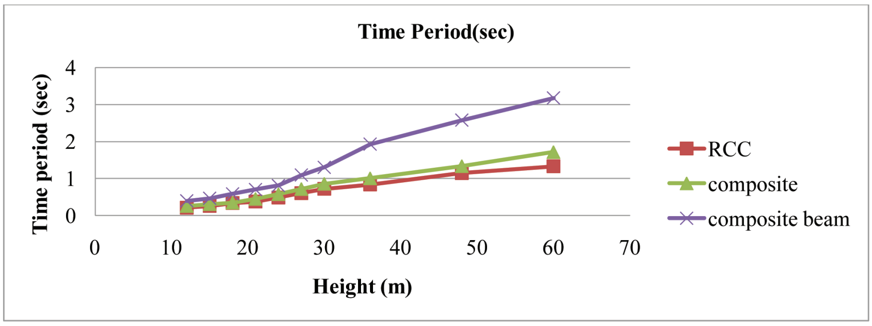

Fig. 4: Comparison of Time Period

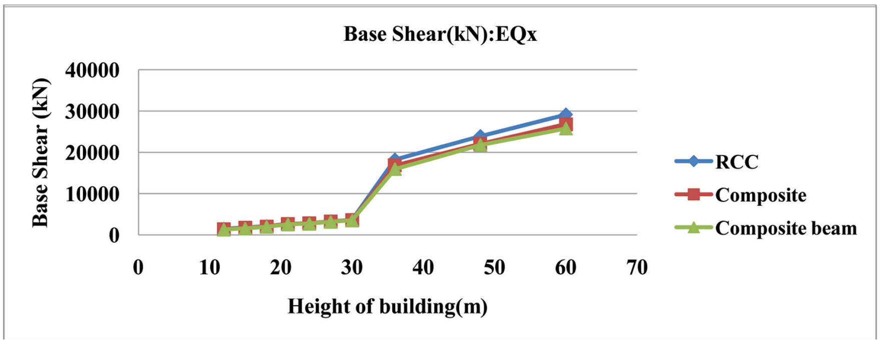

Fig. 5: Comparison of Base Shear (EQx)

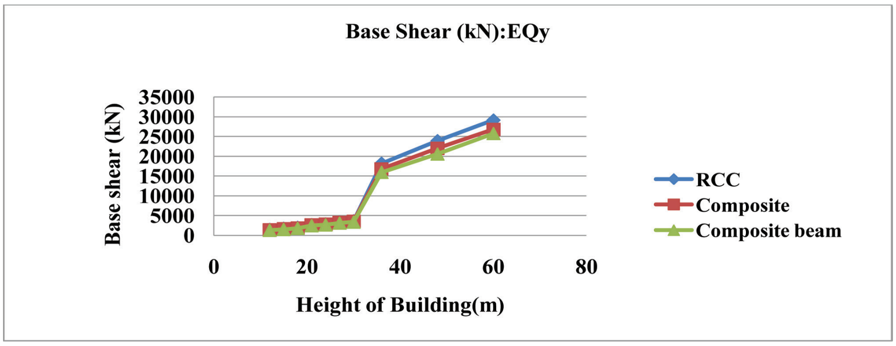

Fig. 6: Comparison of Base Shear (EQy)

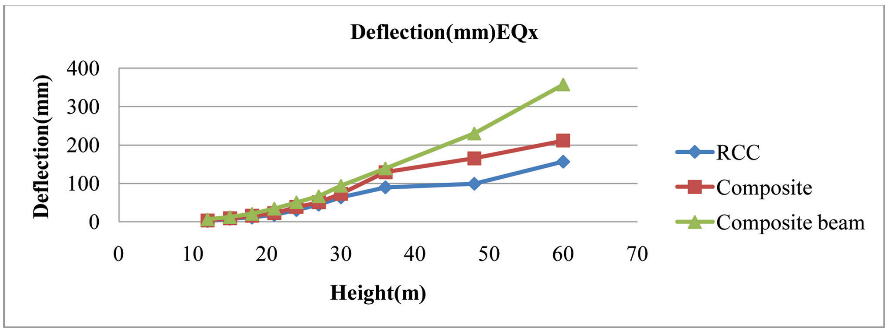

Fig. 7: Comparison of Deflection (EQx)

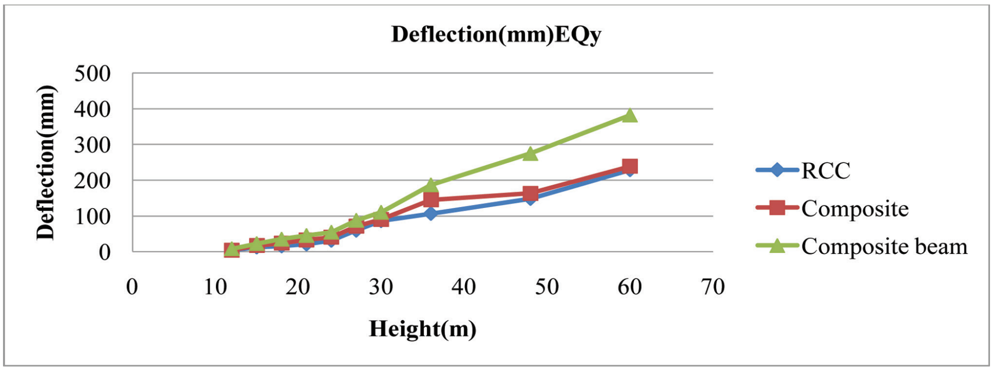

Fig. 8: Comparison of Deflection (EQy)

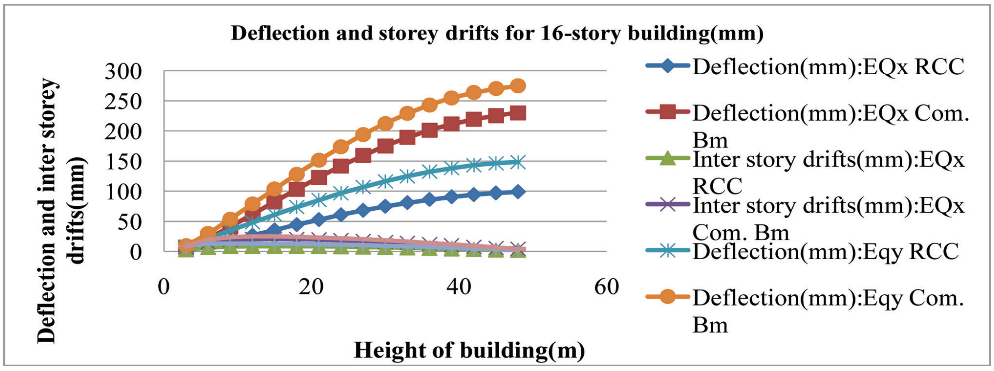

Fig. 9: Comparison of deflection and inter storey drifts

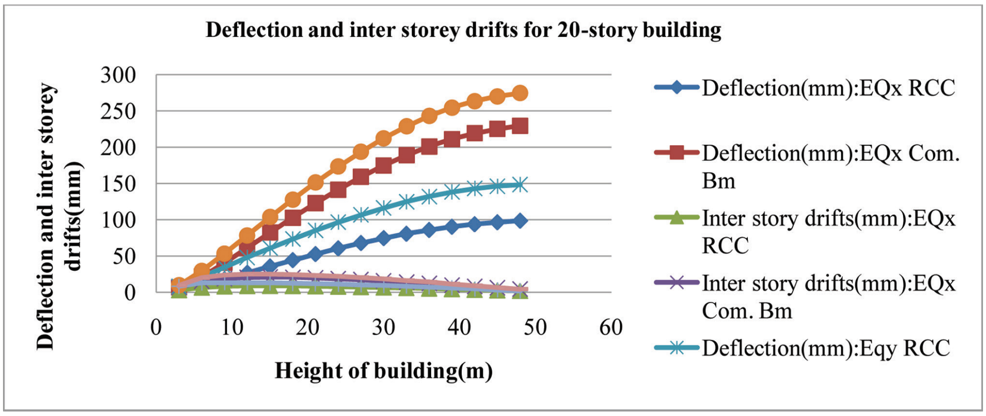

Fig. 10: Comparison of deflection and inter storey drifts

8. Results and Discussion

From linear static analysis following results were observed for three types of structures.

- For composite (column) structure the lateral displacements are increased from 4% to 36% in transverse direction and about 12% to 50% in longitudinal direction than the RCC structure and for composite (beam and column) structure it is increased by 25% to 55% and 30% to 75% in transverse and longitudinal directions respectively.

- The axial force in composite (column) columns is found to be 2.5% to 9% less than RCC columns and in composite (column and beam) it is found to be 4.5% to 12.5% less than RCC columns.
- The shear force in composite column (column) is reduced by 1.5% to 5.5% and 4.5% to 12.5% in composite (beam and column) column respectively than the RCC structure in linear static analysis.
- The bending moment in composite column (column) is found to be 4.5% to 23.5% less and 14.5% to 34.5% less in composite (beam and column) column respectively than reinforced concrete columns in linear static analysis.
- The time period of composite (column) structure is increased by 3% to 22.5% and of composite (beam and column) is increased by 40% to 60% than the RCC structure.
- The base shear in composite (column) structure is found to be reduced by 2% to 8% in both longitudinal direction and lateral direction and in composite (beam and column) structure 3.5% to 12.5% in longitudinal and 4%to 14% in lateral directions respectively than pure in RCC structure in equivalent static analysis.
- The inter storey drift for composite (beam and column) buildings is increased by about 50% than the RCC buildings.
- In composite structure due to high ductile nature of steel it leads to increased seismic resistance of the composite section.

Table 2: Results from nonlinear static analysis (Characteristic of performance points)

Storey				
Storey	**Parameters**	**RCC**	**Composite**	**Composite beam**
16	Maximum Base Shear	49805.32	39952.375	32633.638
	Maximum displacement	0.21	0.218	0.282
	Spectral acceleration	0.249	0.211	0.163
	Spectral displacement	0.159	0.189	0.244
	Effective period	1.605	1.899	2.456
	Effective damping	0.05	0.05	0.05
20	Maximum Base Shear	51249.98	39445.08	32367.82
	Maximum displacement	0.266	0.31	0.401
	Spectral acceleration	0.199	0.17	0.131
	Spectral displacement	0.199	0.234	0.303
	Effective period	2.007	2.354	3.05
	Effective damping	0.05	0.05	0.05

9. Conclusion

The maximum time period is of composite buildings, it means it is more flexible to oscillate back and forth when lateral forces act on the building. Also results show that RCC buildings have least time period which says it is very less flexible amongst all three structures. The maximum nodal displacement is double in composite buildings than RCC buildings but within the limit. This is because; composite structure is more flexible as compared to RCC structure. Steel and composite structure gives more ductility to the structure as compared to the RCC which is best suited under the effect of lateral forces. The seismic forces of composite buildings are found to be less than RCC structure which may be because of lesser seismic weight of composite buildings. As the results show performance of the Composite option for high rise buildings is best than RCC buildings. Weight of composite structure is quite low as compared to RCC structure which helps in reducing the foundation cost. Speedy construction facilitates quicker return on the invested capital & benefit in terms of rent. That is why we can say that composite buildings are more economical than RCC buildings.

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