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Response of Composite Buildings Subjected to Seismic Loads

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Abstract

Composite structures are constructed with a combination of different materials with different material properties. Steel and concrete are the most commonly used composite members in a composite building. Composite structures are durable and exhibit comparatively better structural performance and stability. The present work is a case study, that focuses on the response of a composite structure subjected to seismic loads. The storey response of the composite building is compared with that of the Reinforced Concrete (RC) framed structure. Response spectrum method of analysis is carried out to assess the internal forces (such as bending moment, axial force, shear force and torsion), storey displacement and base shear developed in the composite structure that is subjected to seismic loads. Based on the results the stability composite structure is assessed.

Keywords: *Composite Structure, Response Spectrum Method, Seismic Loads, Stability*

1.0 Introduction

Composite structures are constructed from two or more distinct materials that impart enhanced strength and resilience towards seismic loads[1-5]. Steel has a high strength, speeds up erection and is ductile. The deck slab is a fabricated composite floor slab[6,7] in which reinforced concrete is cast on a steel deck. Shear studs can be used to create a composite action between the concrete and the deck sheet. The decking serves as formwork, a work platform, and external tension reinforcement throughout the construction phases as well as during the service phase. Kim *et al.*,[8] conducted an eccentric axial compression test on high-strength concrete-encased steel columns. The grades of steel and concrete used were 800MPa Steel and 100MPa respectively The test results showed that there was a delamination of the cover and ductile behaviour of the column was observed. The failure of the section was caused by the compressive crushing of the concrete. Kim *et al.*,[9] conducted an eccentric axial compression test on the columns of various sectional shapes and the results found that the section which has L-shaped steel sections at the corner performed better than the H-shaped steel encased composite column.

Siddh *et al.*,[6] conducted an experiment on the behaviour of composite slabs with profile steel sheeting and results found that the thickness of profiled steel plays an important role in composite action. Ductile failure of the slab was observed.

The use of steel-concrete composite structural elements has increased as high-rise building constructions have become more prevalent. In this study, the stability of the composite structure when subjected to seismic loads has been assessed.

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2.0 Methodology

2.1 Details of RC Structure

The structure under consideration here is a commercial building with G+10 storeys. Figure 1 shows the building plan and Figure 2 shows the isometric view of the building. The height of each storey is 3m, and each bay span along two mutually perpendicular directions in the plan is 5m. The grade of concrete considered for beams, slabs and columns is 40MPa. The grade of steel considered is Fe 500. Columns having a cross-section of 450mmx550mm are considered. Figure 5 shows the details of the column cross-section. The cross-section dimension of all the beams considered is 300mmx450mm and the thickness of the slab is 150mm.

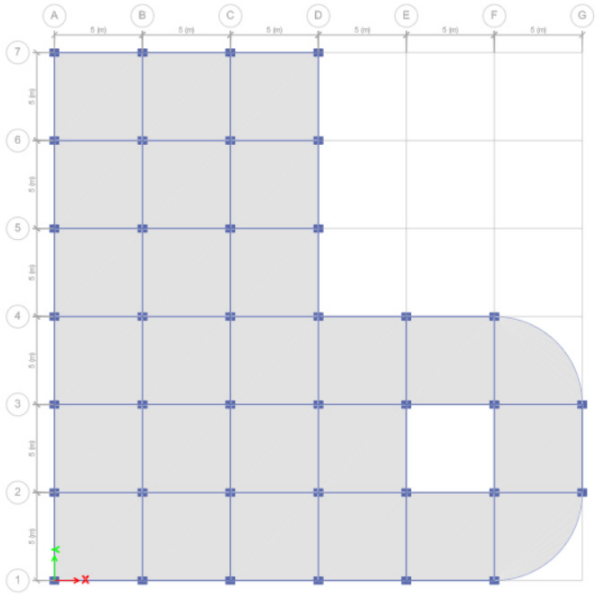


Figure 1. Building plan.

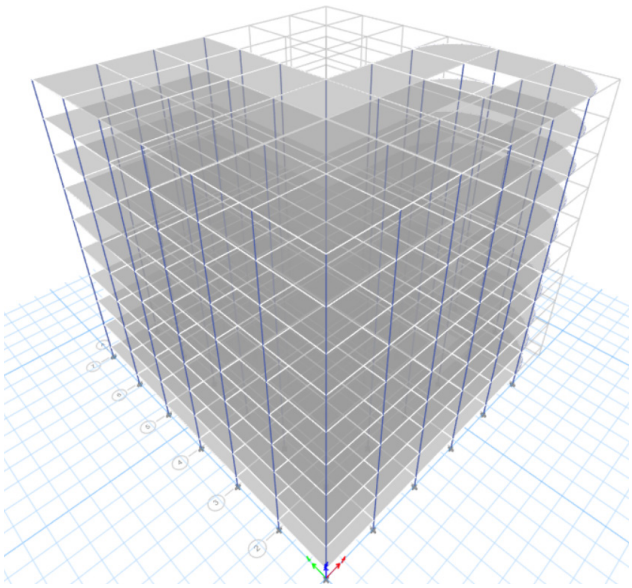


Figure 2. Isometric View of building.

2.2 Details of Composite Structure

Two composite structures have been considered in the present study, to assess their performance in comparison with the RC structure when subjected to seismic forces. In Composite structure-1 concrete composite column with ISHB-350 encased steel section is considered. In Composite structure-2 two numbers of ISMC-300 toe to toe are connected and encased in concrete in the composite column. The cross-section of the composite column in composite structure-1 and composite

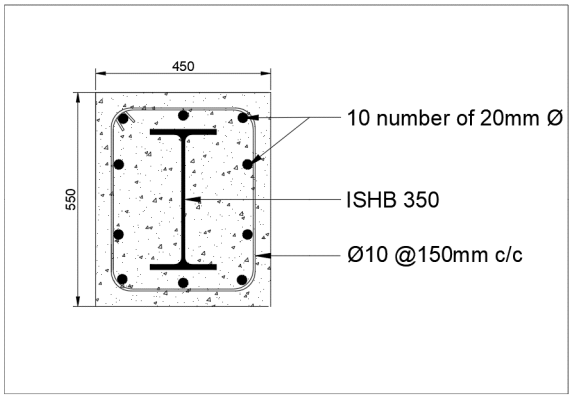


Figure 3. Composite column cross section of structure-1.

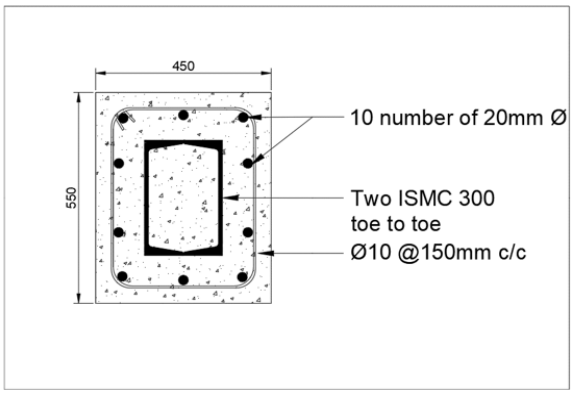


Figure 4. Composite column cross section of structure-2.

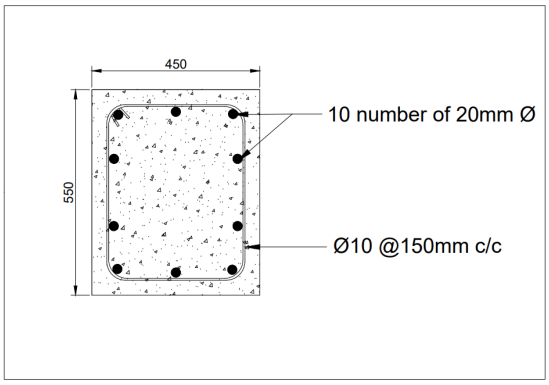


Figure 5. Column cross section of RC structure.

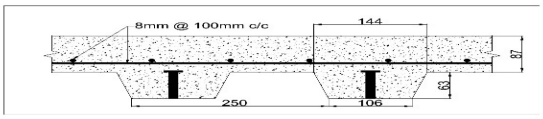


Figure 6. Cross section of the deck slab.

structure-2 are shown in Figures 3 and 4 respectively. The thickness of the deck sheet is 8mm. The diameter of the shear stud is 12mm. The cross-section details of the deck slab are shown in Figure 6.

2.3 Modelling and Analysis

Modelling and analysis of the RC structure[11] and composite structures 1 and 2 are carried out in Extended Three-Dimensional Analysis of Building System (ETABS). A live load of 4kN/m^2 and a dead load of 1kN/m^2 is considered on the slab. The seismic response of composite structures 1 and 2 and RC-framed structures is studied in ETABS using the response spectrum method of analysis. The seismic parameters taken into consideration for the response spectrum method of analysis are given in Table 1. The load combinations considered for seismic analysis are as per clause 6.3 of IS 1893 (part 1): 2016[10].

Table 1. Seismic parameters

Response Reduction Factor	3
Importance Factor	1.2
Soil Type	1
Seismic zone factor for Zone II	0.1
Seismic zone factor for Zone III	0.16
Seismic zone factor for zone IV	0.24
Seismic zone factor for zone V	0.36

3.0 Results and Discussions

The maximum storey response of the RC structure, composite structure1 and composite structure 2 that were analysed for seismic loads corresponding to different seismic zones (II, III, IV and V) the storey displacements

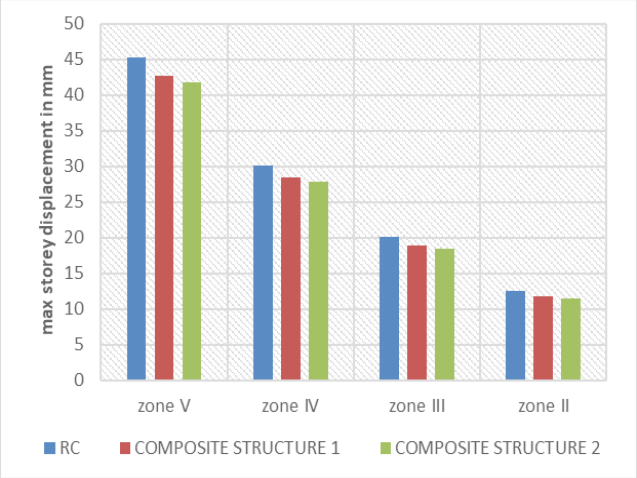


Figure 7. Maximum storey response.

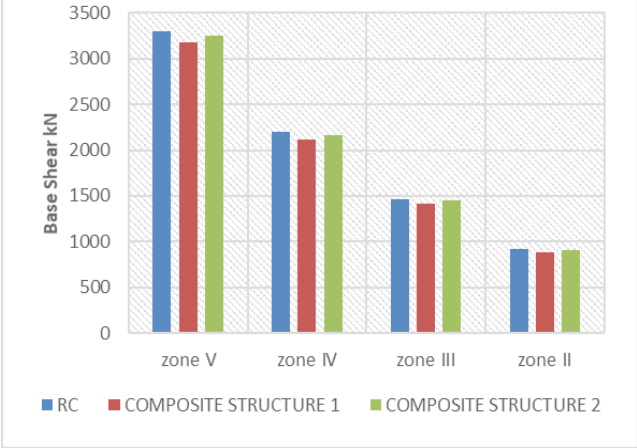


Figure 8. Base shear.

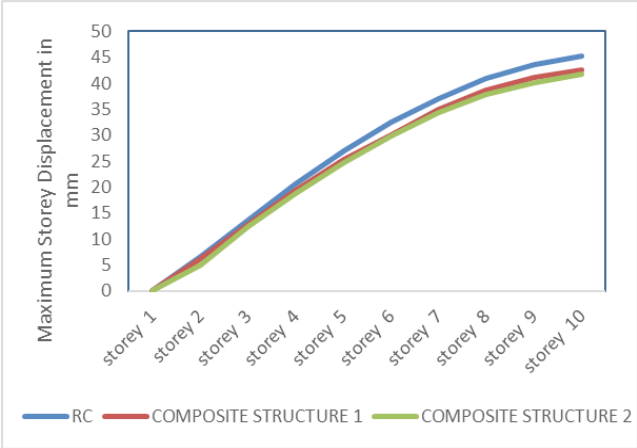


Figure 9. Storey displacements for zone 5.

and the corresponding base shear developed due to the seismic loads considered in this study are shown in Figures 7 and 8 respectively. Figure 9 shows the storey response of all floors in the RC structure and composite structures 1 and 2 in seismic zone V.

The maximum storey displacement of RC structure, composite structure-1 and composite structure-2 was observed to be 45.27mm, 42.65mm and 41.82mm respectively. The maximum base shear in the RC structure, composite Structure-1 and composite Structure-2 was found to be 3304kN, 3179kN and 3253kN respectively.

In the case of the RC structure analysed for seismic forces corresponding to zones IV and zone V, thirty-five frames failed as per the design check and when the RC structure was analysed for zones II and III all the frames in the RC structure were found to be safe as per the design.

In the case of composite structures 1 and 2, all the frames that were designed passed the design check and were safe when subjected to seismic loads that corresponded to all four seismic zones (II, III, IV and V).

The understanding gained from the present study on the response of composite buildings subjected to seismic loads can improve the design and construction towards better earthquake resistance of mining infrastructure. This knowledge would further help to enhance the safety and seismic resilience of the mining facilities and minimise the risk of damage during earthquakes.

4.0 Conclusions

- The lateral loads that act at different floor levels due to earthquakes are efficiently resisted by the composite columns present in the composite structures when compared to the RC structure, the reason being that the composite columns have higher axial and lateral stiffness when compared to RC columns that have the same gross cross-sectional dimensions.
- In the case of the RC structure analysed for seismic forces corresponding to zones IV and zone V, thirty-five frames failed as per the design check and when the RC structure was analysed for zones II and III all the frames in the RC structure were found to be safe as per the design. In the case of composite structures 1 and 2, all the frames that were designed passed the design check and were safe when subjected to seismic loads that corresponded to all four seismic zones (II, III, IV and V).
- Therefore, it is understood from the present work that, the RC structure designed in the present work is structurally stable to resist earthquake forces corresponding to zone II and zone III.
- The composite structure designed in the present work is very safe and stable enough to resist earthquake forces in Zone II and Zone III and the same structure is also structurally stable enough to resist earthquake forces corresponding to Zone IV and Zone V for the same design configuration.
- Therefore, it is understood from the study that, composite structures are more efficient to resist earthquake forces in seismically active zones (zone IV and zone V).
- Comprehending the behaviour of composite structures subjected to seismic loads from this study, the risk assessment of mining infrastructure can be carried out. Where the mining infrastructure comprises structures such as overhead walkway bridges, conveyor/ supporting structures and transportation facilities that are built up of composite constructions. The risk assessment study helps the mining companies located in seismically active zones to mitigate the risk of structural failure and associated financial losses due to earthquakes.

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