COMPARISON OF SEISMIC BEHAVIOR OF A TYPICAL MULTI-STOREY STRUCTURE WITH COMPOSITE COLUMNS AND STEEL COLUMNS

NARESH KUMAR REDDY LOMADA
[1]PG Student, Dept of Civil Engineering, AITS, Kadapa, AP, India.

GUVVALA BHAGYAMMA
Assistant Professor, Dept of Civil Engineering, AITS, Kadapa, AP, India.

Abstract- In India most of the building structures fall under the category of low rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical in nature. But since the population in cities is growing exponentially and the land is limited, there is a need of vertical growth of buildings in these cities. So, for the fulfilment of this purpose a large number of medium to high rise buildings are coming up these days. For these high-rise buildings, it has been found out that use of composite members in construction is more effective and economic than using reinforced concrete members. Reinforced concretes frames are used in low rise buildings because loading is nominal. But in medium and high-rise buildings, the conventional reinforced concrete construction cannot be adopted as there is increased dead load along with span restrictions, less stiffness and framework which is quite vulnerable to hazards. In construction industry in India use of steel is very less as compared to other developing nations like China, Brazil etc.

However, the lateral load resistance of composite columns especially against seismic loads has not been investigated so extensively. The present study makes an attempt to bring out the advantages of composite columns against conventional Steel columns in multi-storey structures. For this purpose, a typical (G+12) framed multi-storey building with two alternative column schemes. Steel and Concrete Filled Steel Tube (CFST) located in seismically active moderate zones III is taken up for evaluation and equivalent static lateral load analysis is carried out using Etabs software. The seismic performance of the selected multi-storey structure is assessed through various structural response parameters such as base shear, storey overturning moment, storey drift and roof displacement. Base shear and storey overturning moment induced by the seismic forces are reduced by **22 to 28%** for composite columns. These variations indicate that the composite columns have reduced mass/weight thus reducing the entire mass of structure in respect of reduction in base shear and the composite columns have higher global stability and resistance to buckling in respect reduction in overturning moments. Roof displacement has been reduced by **26.6%** in case of in filled column when compared with the steel. These variations show that the frame with composite columns have higher lateral stiffness than the steel columns.

I. INTRODUCTION

In India most of the building structures fall under the category of low rise buildings. So, for these structures reinforced concrete members are used widely because the construction becomes quite convenient and economical in nature. But since the population in cities is growing exponentially and the land is limited, there is a need of vertical growth of buildings in these cities. So, for the fulfillment of this purpose a large number of medium to high rise buildings are coming up these days. For these high-rise buildings, it has been found out that use of composite members in construction is more effective and economic than using reinforced concrete members. The popularity of steel-concrete composite construction in cities can be owed to its advantage over the conventional reinforced concrete construction. Reinforced concretes frames are used in low rise buildings because loading is nominal. But in medium and high-rise buildings, the conventional reinforced concrete construction cannot be adopted as there is increased dead load along with span restrictions, less stiffness and framework which is quite vulnerable to hazards. In construction industry in India use of steel is very less as compared to other developing nations like China, Brazil etc. Seeing the development in India, there is a dire need to explore more in the field of construction and devise new improved techniques to use Steel as a construction material wherever it is economical to use it. Steel concrete composite frames use more steel and prove to be an economic approach to solving the problems faced in medium to high rise building structures. A Composite Structures When a steel component, like an I-section beam, is attached to a concrete component such that there is a transfer of forces and moments between them, such as a bridge or a floor slab, then a composite member is formed. In such a composite T-beam, as shown in Figure 1, the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. Here it is very important to note that both the materials are used to fullest of their capabilities and give an efficient and economical construction which is an added advantage.

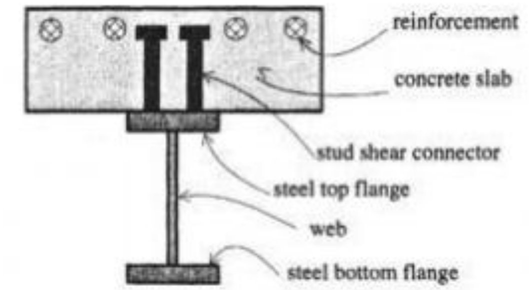


Figure.1. Cross Section of a Typical Composite Member

A. COMPOSITE STEEL-CONCRETE BEAM

A concrete beam is formed when a concrete slab which is casted in-situ conditions is placed over an I-section or steel beam. Under the influence of loading both these elements tend to behave in an independent way and there is a relative slippage between them. If there is a proper connection such that there is no relative slip between them, then an I-section steel beam with a concrete slab will behave like a monolithic beam. The figure is shown in the figure 2. In our present study, the beam is composite of concrete and steel and behaves like a monolithic beam. Concrete is very weak in tension and relatively stronger in tension whereas steel is prone to buckling under the influence of compression. Hence, both of them are provided in a composite such they use their attributes to their maximum advantage. A composite beam can also be made by making connections between a steel I-section with a precast reinforced concrete slab. Keeping the load and the span of the beam constant, we get a more economic cross section for the composite beam than for the non-composite tradition beam. Composite beams have lesser values of deflection than the steel beams owing to its larger value of stiffness. Moreover, steel beam sections are also used in buildings prone to fire as they increase resistance to fire and corrosion.

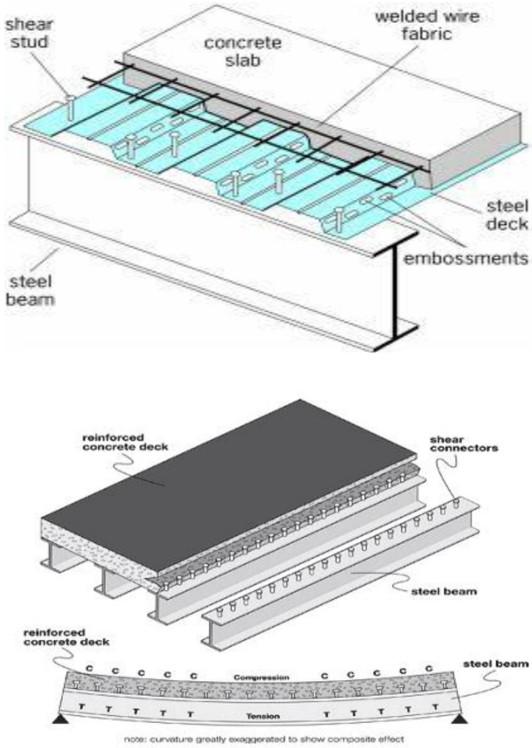


Figure.2. Composite Column-Concrete Beam

B. STEEL-CONCRETE COMPOSITE COLUMNS

A steel-concrete composite column is a compression member comprising of a concrete filled tubular section of hot-rolled steel or a concrete encased hot-rolled steel section. Figure 3(a) and figure 3(b) show concrete filled and concrete encased column sections respectively. In a composite column, both the concrete and the steel interact together by friction and bond. Therefore, they resist external loading. Generally, in the composite construction, the initial construction loads are beared and supported by bare steel columns. Concrete is filled on later inside the tubular steel sections or is later casted around the I section. The combination of both steel and concrete is in such a way that both of the materials use their attributes in the most effective way. Due to the lighter weight and higher strength of steel, smaller and lighter foundations can be used. The concrete which is casted around the steel sections at later stages in construction helps in limiting away the lateral deflections, sway and bucking of the column. It is very convenient and efficient to erect very high rise buildings if we use steel-concrete composite frames along with composite decks and beams. The time taken for erection is also less due to which speedy construction is achieved along better results.

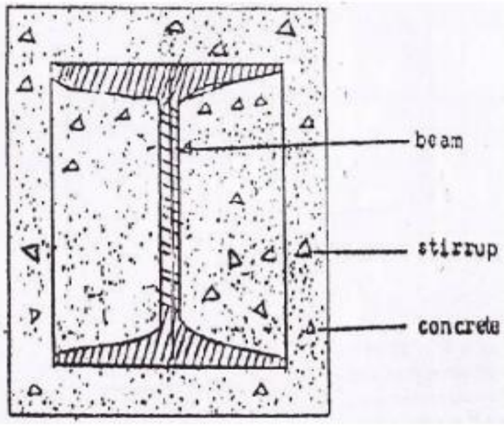


Figure.3a. Concrete Encased Steel Column

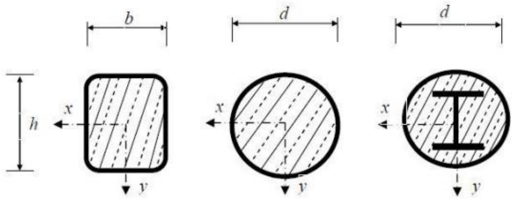


Figure.3b. Steel Encased Concrete Column Sections

II. OBJECTIVES OF THE STUDY

- A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure.
- Typical cross-sections of composite columns with fully and partially concrete encased steel sections
- The buildings in India are constructed with RCC and the adoption of steel structures is generally confined to industrial buildings and of late multi-storey buildings, which have acquired prominence by adopting composite structural elements.
- However, in recent times, the composite columns are gaining popularity for use in multi-storey buildings by virtue of their excellent static and earthquake resistant properties such as lower mass, high strength, rigidity and stiffness, significantly high toughness and ductility, large energy dissipation capacity.
- Besides these advantages, easy site erection and installation capability can lead to reduction in labour and foundation costs compared to RCC columns and have excellent buckling resistance, reduced maintenance and fireproofing cost compared to steel columns.
- Also, the composite systems are lighter in weight (about 20 to 40% lighter than concrete construction). Thus, the composite system is a more complete structural system than simple reinforced concrete or steel elements.
- When adopting a composite section, the amount of structural steel, reinforcing steel and concrete area, and the geometry as well as the position of the three materials represent relevant design parameters.
- Indeed, a number of different combinations are possible thus leading to a flexible design. Due to these reasons composite members are gaining importance for the making of sky-scrapers, infrastructure growth and especially for high rise structures of seismic regions in the world.

- A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure.
- The load carrying capacity of composite columns is more than that of the bare reinforced column and the structural steel column included in the system.

The main objectives of the present study are:

Comparison of seismic behaviour of two types of multi-storey framed structures consisting of:

a) Steel frame with RC slab

b) Steel beam, RC slab and Concrete Filled Steel Tube (CFST) Composite columns.

Economic Analysis of the two alternative structures.

III. SCOPE OF THE STUDY

The scope of the present study is envisaged to the following criteria:

(1) Type of structure - (G +20) framed multi-storey structure

(2) Hot rolled steel beams of grade Fe 250 are to be used

(3) Reinforcing steel of grade Fe 500 is to be used

(4) Concrete of grade M 30 is to be used

(5) The structure is assumed (for software purpose) to be located on hard soil/rock strata the area of the building is hard soil.

(6) The building frame is assumed to be Ordinary Moment Resisting Frame (OMRF)

(7) The connections at the joints are assumed to be simple moment resisting

(8) Only seismic analysis by equivalent lateral force method as per IS 1893:2002 codal provisions

(9) Analysis is to be carried out for the one possible location of the structure in: zone III

(10) For the design of composite columns, the design provisions of Eurocode (EC4) are adopted in the absence of specific recommendations and guidelines for composite columns in the Indian Standards

(11) Steel columns are designed as per IS 800:2007 codal provisions

(12) The Two alternative structures are compared with the following structural performance parameters: Base shear, storey drifts, storey overturning moments and roof displacements.

IV. RESULTS

A. ANALYSIS OF RESULTS AND DISCUSSION

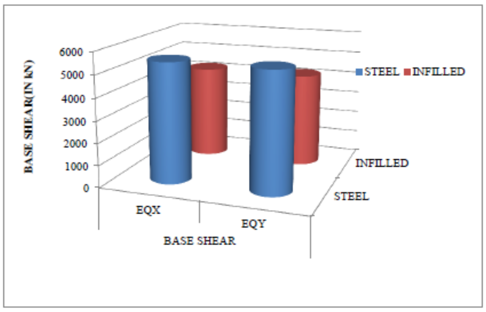
After analyzing the two alternative structures located in seismic zone III by equivalent static lateral force method conforming to IS 1893:2002 using Etabs, the results are extracted and compared in terms of critical earthquake response parameters such as base shear, maximum storey drifts, roof displacements, storey overturning moments.

a) Design Seismic Base Shear:

Seismic forces accumulate downward in a building. Seismic forces in the building are greatest at the base of the building. The seismic force at base of the building is called the *base shear*. Earthquakes often damage buildings at this level. In a multi-storey building all vibration modes of the building contribute to the base shear as shown below.

TABLE.1 Variations of Base Shear in Seismic Zone III

Column Types	Base Shear	
	EQX	EQY
Steel	5460	5460
Infilled	4260	4260

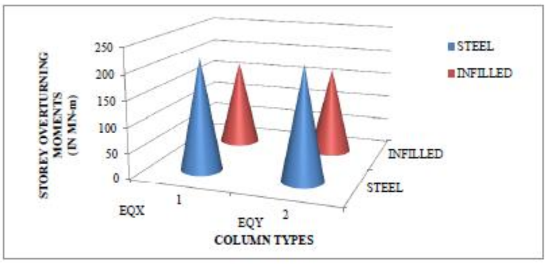


Graph.1: Base Shear Variation in Zone Iii.

From figure above it is evident that, when compared to steel (5.5 MN) columns, the composite columns are found to experience the least magnitude of base shear (4.3 MN) and 22% reduction in base shear can be attributed to the reduction in mass of the composite columns, which in turn reduces the mass of the structure.

B) STOREY OVERTURNING MOMENT:

Storey overturning moments are calculated by multiplying seismic lateral forces with the storey height. In the present case, a considerable reduction of overturning moments is noticed for composite columns, where the columns are short.

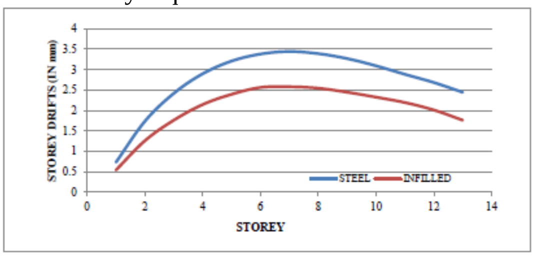


Graph.2: Variations Of Storey Overturning Moment In Seismic Zone Iii

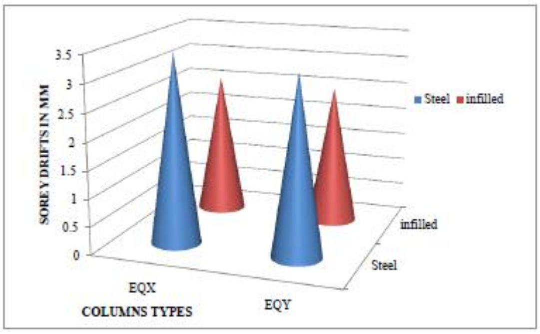
From figure above, it is evident that, when compared to steel (220 MN-m) columns, the composite columns, especially the infilled columns are found to experience the least magnitude of overturning moment (171 MN-m). The 22% reduction in overturning moment is observed with respect to steel columns. This variation apparently shows that the structure with composite short columns has greater stability against buckling as well as overturning at base level and thus providing continuous load path for the upcoming forces to the foundation.

C. STOREY DRIFT*:*

Storey drift is generally defined as the lateral displacement of one floor relative to the floor below. The inter-storey drift criterion is the global collapse parameter that is utilized to evaluate the force reduction factors reflecting the average margin of safety exhibited by each frame under the effect of ground motions. Total building drift is the absolute displacement of any point relative to the base. Building separations or joints must be provided to permit adjoining buildings to respond independently to earthquake ground motion. For seismic loads, the maximum story drift is found from ETABS and is compared to the allowable story drift given in IS 1893:2002. It was determined that all floor levels met the serviceability requirements for seismic forces.



Graph.3: Drift Variation At Various Storey Levels Of Two Alternative Structures With Different Column Types Located In Seismic Zone Iii



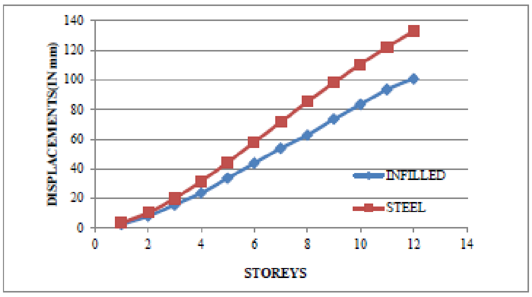
Graph.4: Shows Storey Drift Variations In Zone Iii

From figure above, it is observed that, when compared steel (3.44 mm) columns, the composite columns, especially the infilled columns are found to experience the least magnitude of storey drifts (2.58 mm). The storey drift of 25 % reduction in case of infilled column is observed when compared with the steel columns, which has highest magnitude of storey drift (3.23 to 3.44 mm). The reduction in storey drift is due to reduction in base shear and increase in stiffness of the composite columns.

D. ROOF DISPLACEMENTS:

Earthquake-induced motions, even when they are more violent than those induced by wind (as cited by Taranath (2005). evoke a totally different human response—first, because earthquakes occur much less frequently than windstorms, and second, because the duration of motion caused by an earthquake is generally short. Displacements, the extent to which a structural element moves or bends under pressure is the main serviceability concern in the structures. Lateral displacements that occur during earthquakes should be limited to prevent distress in structural members and architectural components.

The value of maximum roof displacement is a direct and efficient measure used to quantify the overall displacement response of a building. However, the value of roof displacement provides no direct information about localized deformation within a structure. If the value of the inter-story displacement for each story is the same as the value of the roof displacement divided by the number of stories, the structure is said to deform uniformly



Graph.5: Displacement Variation At Various Storey Levels Of Four Alternative Structures Located In Seismic Zone Iii.

From figure above it can be seen that, the least roof displacement occurs in case of infilled columns (98 to 105 mm) compared to steel (143 mm) columns. Roof displacement has been reduced by **26.6%** in case of infilled column when compared with the steel. These variations show that the frame with composite columns have higher lateral stiffness than the steel columns.

CONCLUSION

The advantage of superior performance of composite columns under gravity loads have been brought out in several studies. However, the lateral load resistance of composite columns especially against seismic loads has not been investigated so extensively. The present study makes an attempt to bring out the advantages of composite columns against conventional Steel columns in multistorey structures. For this purpose, a typical (G+12) framed multi-storey building with two alternative column schemes vis a vis. Steel and Concrete Filled Steel Tube (CFST) located in seismically active moderate zones III is taken up for evaluation and equivalent static lateral load analysis is carried out using Etabs software. The following conclusions are drawn in respect of various performance parameters.

Lateral Load Resistance:

The seismic performance of the selected multi-storey structure is assessed through various structural response parameters such as base shear, storey overturning moment, storey drift and roof displacement.

a) Seismic Forces under Lateral Loads:

Base shear and storey overturning moment induced by the seismic forces are reduced by **22 to 28%** for composite columns. These variations indicate that the composite columns have reduced mass/weight thus reducing the entire mass of structure in respect of reduction in base shear and the composite columns have higher global stability and resistance to buckling in respect of reduction in overturning moments.

b) Displacement characteristics:

Lateral deformations such as storey drifts and roof displacements have been checked at various storey levels of all structures with two alternative columns located in zone III.

c) Storey drifts:

When Zone III is considered, the storey drifts are the highest in case of steel, which is well within the permissible limit of 0.004h = 18 mm (as per IS 1893:2002). The composite columns undergo about 25 to 28.5% reduction of lower storey drifts when compared with the steel columns.

d) Roof displacements:

In a similar passion, the roof displacement is highest in case of Steel column. Roof displacement has been reduced by **26.6%** in case of

CFST column when compared with the steel. Also, the maximum lateral displacement is the roof displacement value which indicates that the deformation of the entire structure is uniform in two alternative cases. Thus, both parameters demonstrate higher order of both global and local stability indicating that the composite columns are stiffer than conventional Steel columns.

- Based on the analysis and design of multi-storied building, the following conclusions are made:
- Building layout and design has to follow the nature especially for sunlight and wind directions. These types of principles were explained in vastu where followed at the beginning of project only.
- Geotechnical engineering cannot be neglected while building the tall buildings. The geotechnical engineer needs to be consulted to do soil sampling, analysis, ground water depth and mainly for estimation of soil bearing capacity.
- The proposed building should be in area where all the types of amenities are available.
- In design IS456, IS875 were used for calculation of all forces and loads.
- The use of light weight concrete and lightweight materials will reduce the dead load of structure, which then allows the structural designer to reduce the size of the columns, footings, and other load bearing elements.
- The occurrence and spread of fire is unpredictable and uncertain. It is therefore critical that fire proof materials and fire resistant products measure up to the highest possible standards of performance as well as reliability.
- For more than 5 storey buildings it is better to provide the connecting beams in between the flats. Limit state design is the best approach for designing the buildings.

SCOPE OF THE PROJECT:

This report is clear with the structural analysis and design of multi-storeyed building which was designed by ETABS. This software is very innovative and easier which is better than staad pro. It is better for designing the high rise buildings under the applied live load, dead load, wind load, earthquake load, and seismic load. Construction of apartments were become a needy in urban areas, mainly construction of g+5 residential buildings for living were taking place. So I suggest my project will apt for above specified buildings with measurements, so that it reduces time period for designing

REFERENCES

[1] Arivalagan .S, Kandasamy .S (2010), ―Study on concrete-filled steel member subjected to cyclic loading‖, International Journal of Civil and Structural Engineering‖, Vol. 3, pp. 458–465.

[2] IS 456: 2000, ―Code of Practice for Plain and Reinforced Concrete‖, Bureau of Indian Standards, New Delhi.

[3] IS 800: 2007, ―Code of Practice for General Construction in Steel‖, Bureau of Indian Standards, New Delhi.

[4] IS 1893: 2002, ―Criteria for Earthquake Resistant Design of Structures – general provisions for buildings (Part-1)‖, Bureau of Indian Standards, New Delhi, 2002.

[5] Eurocode 4 (1994): Part 1.1, ―Design of Composite Steel – Concrete Structures; General Rules and Rules for Buildings‖.

[6] Lin Hai Han, Wei Li (2010), ―Seismic performance of CFST column to steel beam joint with RC slab: Experiments‖, Journal of Construction Steel Research, Vol. 66, pp. 1374–1386.

[7] Lin Hai Han, Wei Li (2011), ―Seismic performance of CFST column to steel beam joint with RC slab: Analysis‖, Journal of Construction Steel Research, Vol. 67, pp. 127–139.

[8] Syed rehan. Mohure ―Study of Seismic and Wind Effect on Multi Storey RCC.Steel and Composite Building. International journal of engineering and innovative technology, volume 3, issue12, june 2014.