Comparative Study On Response Spectrum Analysis Of Building With Composite Columns And RCC Columns

Preetha V, Govindhan S, Eniyachandramouli G, Ranjith selvan K

Abstract— The indeed intention of Steel concrete composite construction has gained acceptance worldwide as an alternative to pure steel and Reinforced concrete construction. The practice of composite elements in construction sector is very low in India compared to many developing countries. There is a great potential for increasing the volume of steel in construction, especially in the current development needs. The composite construction reduces the dead weight of the structure, in turn decreases the time of construction work. In this present study G+10 multi-storied building composed of RCC columns and two different composite columns viz. Encased column and Infill rectangular tubes are analyzed by using ETABS software. In this study comparison has been made to study the variation in storey drift, storey shear, time period and the displacement of the building with RCC and composite columns.

Index Terms — Composite construction, RCC column, Composite column, Response spectrum analysis.

1 INTRODUCTION

In India, most of the building structures fall under the category of low-rise buildings. So, far the structures are constructed using reinforced concrete members, because the construction becomes quite convenient and economical in nature. Due to rapid exponential increase of population in cities; non-availability of land space is prevailed, so need for vertical growth of buildings are essential. Based on the overall shape, size and geometry, behavior due to earthquake needs to be checked to plan a high rise building. The storey shears at different storey heights in a building need to be transferred down to the basement by the shortest path; any discontinuity in the structural members results in the change in the load path. So, for the fulfillment of this purpose a large number of composite elements are introduced for medium to high rise buildings nowadays. For the high-rise buildings it has been found out that the use of composite members in construction is more effective and economical than reinforced concrete members. There is a great potential for increasing the volume of Steel in construction, especially the current development needs in India and abroad. Comparative studies of RCC with Composite multistoried building are studied and the analysis results are compared. The parameters includes Storey shear, Displacement, storey Drifts, Time Period in composite building with respect to RCC Sections.

1.2 ELEMENTS OF COMPOSITE STRUCTURE

The Steel Concrete Composite construction involves different type of composite column. The commonly used in composite columns in practice are Concrete Encased, Concrete filled, Battered Section.

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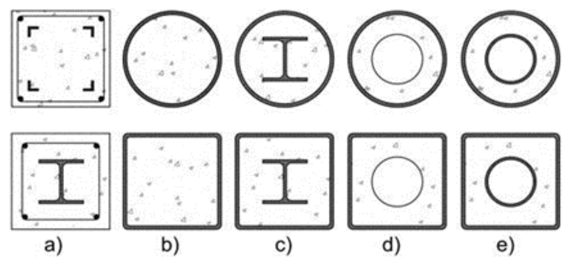


Fig. 1.1 Composite columns: (a) Concrete encased steel (CES),(b) CFST,(c) combination of CES and CFST,(d) hollow CFST sections,(e) double skin sections.

2 LITERATURE REVIEW

Sigmund A. Freeman., [1] proposed the concept of response spectra for design engineers not familiar with their significance and to summarize a variety of uses that can be applied for purposes such as rapid evaluation for a large inventory of buildings, performance verification of new construction, evaluation of existing structures for seismic vulnerability, and post-Earthquake estimates of potential damage of buildings. When earthquake ground motion data is available, the use of response spectra can be very useful in understanding how buildings perform and to identify deficiencies and damage potential. Response spectrum techniques allow engineers to visually imagine how buildings will perform during major damaging earthquakes. It is recommended that researchers and design professionals put more effort into detailed examinations of individual building response records. Luigi Di Sarno et al.,[2] proposed the fundamental structural response characteristics and technological issues of composite steel and concrete systems. It assesses the pros and cons of composite structural systems and investigates the efficacy of beam-column members. Design rules for composite constructions are presented and discussed in details in order to get deep insight into their background. Composite steel and concrete systems are a viable alternative to both bare steel and reinforced concrete structures. They exhibit enhanced stiffness, strength and ductility. Composite frames benefit of the improved performance of steel and concrete columns; beams are generally in bare steel to yield at an early stage in compliance with the capacity design rules.

Ajay Singh Gulshan et al.,[3] Proposed a special case of vertical irregularity i.e. setback is discussed. Seven types of buildings are taken for analysis, out of which one is regular building and rest are buildings with setbacks at different storey height. All six irregular structures are compared with the regular structure on the basis of shear force, axial force and bending moment at setbacks. The value of shear force and bending moment however decreases from regular to irregular structure which is due to the reduction in mass of the structure. The building with setbacks results in poor performance and the chances of failure of beams and columns in these buildings become more due to increased stresses in columns as well as in beams at setbacks.
D. Datta.,[4] proposed the high-rise buildings Steel-Concrete composite construction is cost-effective. Further, cost is a concept, which varies according to its purpose and Direct Construction Cost is an investment only. The durability, resistance to wind / earthquake tremors, Life Expectancy, better functionality are considered in assessing the Net Construction Cost and Life Cycle Cost of the structures. The use of Steel-Concrete Composite construction methodologies will help the developers to make more profit and the customers could also get more carpet area and durable structure at their affordable price. Hence, in the upcoming decades, steel could be optimally utilized by the Engineers to make the growth of Indian society more user- friendly matching with the National Housing and Habitat Policy and Housing needs of citizens.
Mr.C.Neeladharan et al.,[5] proposed a simplified method of composite slab, beam and composite column design is used and software is developed with pre and post processing facilities in Sap2000. The screenshots are included in the paper to illustrate the method employed for designing composite slab, beam and column. Sap 2000 is a standalone finite element based structural program for analysis and design of civil structures. It offers an intuitive yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques to do the most complex projects. Composite column, beam and composite slab is designed by using section designer in sap2000 and analysed.
Dr. D. R. Panchal.,[6] proposed a simplified method of composite slabs, beams and columns design is used and software is developed with pre- and post- processing facilities in VB.NET. All principal design checks are incorporated in the software. The full and partial shear connection and the requirement for transverse reinforcement are also considered. To facilitate direct selection of steel section, a database is prepared and is available at the back end with the properties of all standard steel sections. Composite steel-concrete section is relatively a new design concept in the Indian context and no appropriate updated codes are available for the design of the same A simplified approach discussed in the present work, not only eliminates costly experimentation required for design purpose but also facilitates design with multiple options for the steel sections and shear connectors with adequacy checks.
Abhishek Sanjay Mahajan et al.,[7] proposed the effect of FEC (Fully Encased Composite) on a G+ 20 storey special moment frame. In this paper two different structures are considered for the comparison under seismic analysis. The linear static analysis and nonlinear static analysis i.e. “Pushover analysis” are done for G+20 storey structure. The building is analysed and design for seismic loading by using ETAB software. Results are compared for the Base shear, Modal time period, Storey displacement and storey drift for both structures. As the composite is having more lateral stiffness, the results of time period and storey displacement shows the significant variation. While analyzing for “Non-linear static analysis the performance point for the FEC is significantly much more as compared to the RCC model.
Ahmed Yousef Alghuff et al.,[8] proposed the static and dynamic analysis methods and compare their results in order to determine the optimal conditions for application of each method. In this research, two structural models are created using the ETABS (V16.1.2) program for regular R.C buildings with typical plans, the first model with a total height of 75 m while the second model with a total height of 24 m. The buildings are analyzed using the static and dynamic methods under ASCE7-10 and IBC 2015 provisions. The results of displacements in the X directions obtained using the response spectrum analysis are less than those obtained by using the equivalent static analysis by 70 and by 80% in the Y direction for the high-rise building, while for the low-rise building is less by 35% in X direction and 38% in Y direction.
Gummireddy Aswini et al.,[9] proposed the multi-storied building of G+10 stories analysed by using ETABS software. In this study comparison has been made to compare the drift, shear force, bending moment, building with and with steel column and composite column. The values of story Drift in X and Y directions are increases from story 11 to the bottom story in both buildings (Steel Building and Composite column Building). And the maximum values are obtained from steel building than general building and composite column buildings. The beam forces are maximum for building twist and are approximately equal values for both buildings (Steel Building and Composite column Building). RCC frame has the lowest values of storey drift because of its high stiffness.
Linda Ann Mathew et al.,[10] proposed the comparison of seismic evaluation of G+15 storey building of R.C.C column and composite column with and without GFRG infill located in seismic zone V. composite column of two types have been chosen fully and partially concrete encased composite column used for analysis. The seismic behavior of the study frames is evaluated by Response Spectrum analysis by ETABS software. ETABS software is used to carry out the analysis. Comparison of conventional and composite design has done. And the following conclusion has been drawn from it. Storey drifts are higher that is 40% in the case of composite building. And drift for all building is within the limits as per IS code.
Shilpa Kewate et al.,[11] proposed the evaluation of seismic performance of concrete filled steel tubular column building by combined use of CFST columns along with RC columns. A G+30 storey residential building is analyzed by response spectrum method using software package ETABS 2015. Seismic response of building with peripheral CFST columns along with interior RC columns has been observed in this study. Results for building with conventional RC columns, building with circular CFST columns and building with peripheral CFST columns were compared in this study. It was concluded that, combined use of CFST columns and RC columns gives the midway results than that of conventional RC column building and CFST column buildings. The building with peripheral CFST columns and interior RC columns is the most suitable building model which provides the high resistance against seismic loading as well as economy due to combined

use of RC columns with smaller section sizes.

Prateek Jaiswal et al.,[12] proposed the composite shear wall consists of a steel boundary frame attached to one side of the concrete shear wall. For seismic analysis response spectrum method has been used in STAAD.Pro software. In this work, it has been shows after comparing all types of structure where considered composite shear wall in different locations, all are under design consideration by giving efficient results like base shear wall and lateral deflection, but the less and minimum value is found in composite shear wall at location 4 (composite shear wall at the corners). In this work, it has been concluded that the consideration of plain or composite shear wall in different locations, all are under design consideration by giving efficient results like base shear wall and lateral deflection, but the less and minimum value is found in composite shear wall at location 4 (composite shear wall at the corners). The application of composite shear wall provides lesser footmark; hence it is very beneficial from architectural argument by providing more useable floor space mainly in high rise structures. The slighter weight of composite shear wall will result in minor foundations as well as lesser seismic forces.

Ramesh B M et al.,[13] proposed the comparison of seismic performance of plan irregular configurations of RC, and Composite building frame which is situated in earthquake zone IV. Total number of 12 models been modelled (6 RC & 6 Composite) all models are of G+10 storey buildings. All frames are designed for same gravity loadings. Beam and column sections are made of Either RCC and Structural Steel-concrete composite sections. Response Spectrum method are used for seismic analysis. Effect of each building is studied with respect to time period, base shear, storey shear, displacements, drift & axial force. ETABS-2015 Software is used for analysis and results are compared. There are slight changes in time period of both RC & composite buildings, RC buildings has more frequency when compared with composite buildings. Base shear values are more for composite buildings when compared with RC buildings. Because seismic weight of Composite materials, when compared with RC buildings. Base shear and storey shear of composite buildings is high, due to more seismic weight of the building. Drift variations are observed for both RC and composite buildings which may be due to differential size of columns. It is observed that the RC buildings have more axial force than the composite buildings.

Shivani et al.,[14] proposed the high rise composite buildings, Composite Encased Columns (CEC) or Composite Infilled Columns (CIC) are used. To determine the optimal column from CEC and CIC based on the seismic response and quantity of the material when used in a G+14 composite building is the objective of study. Models of composite building with infilled and encased columns are analyzed and designed using ETABs. Seismic analysis is done by Response spectrum method based on Indian code. Wind analysis is also carried out as per Indian Codes. The software results are analyzed for seismic behavior and the quantity of the material used for CEC and CIC are compared. Base shear and lateral displacement of a building with encased column is higher than that of same building with infilled column. So with respect to lateral loads composite building with infilled columns will have a better behavior. The stiffness of composite building with infilled column is higher. Composite buildings with infilled columns are rigid compared to buildings with encased column.

3 STRUCTURAL CONFIGURATION

The building considered for the analysis is commercial building. The response spectrum analysis is carried out to predict the behavior of structural elements. The study is carried out with same building plan and storey height for both RCC and Composite building with Encased Column (CES) and rectangular concrete Filled Tubes (CFS) under Seismic Zone 3. The loads and load combination adopted for the analysis are shown in table 3.1. The types of column taken for study of response spectrum analysis are shown in fig: 3.1.

Table: 3.1 Load combinations and values

S.No	Load Combination	Loads	Values
1	1.5(DL+LL)	Live Load	2kN/m^2
2	1.0(DL+LL)	Roof Live Load	1.5 kN/m^2
3	1.2(DL+LL+EQX)	Floor finish load	2kN/m^2
4	1.2(DL+LL+EQY)	As per IS456-2000 and IS1893-2002 codal provisions	
5	1.5(DL+EQX)		
6	1.5(DL-EQX)		
7	1.5(DL+EQY)		
8	1.5(DL-EQY)		

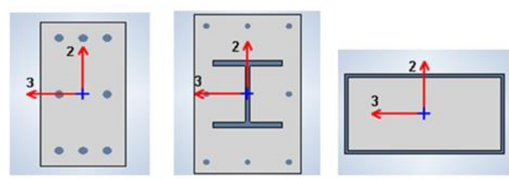


Fig. 3.1 Types of Columns analysed

Table: 3.2 Structural Parameters

Parameters	RCC Column	Encased Composite Columns	In-Filled Tubular Columns
No. of. Storey	G+10	G+10	G+10
Typical Floor height	3.5m	3.5m	3.5m
Ground Floor height	4.5m	4.5m	4.5m
Plan dimension	30m	30m	30m
Beam size	300mm x 300mm	300mm x 300mm	300mm x 300mm
Column size	300 x 600 mm	600 x 900 mm	300 x 600 mm
Thickness of slab	150mm	150mm	150mm
Concrete grade	M30	M30	M30
Seismic Zone	ZONE 3	ZONE 3	ZONE 3
Type of Soil	Site class D	Site class D	Site class D
Response Reduction Factor (R)	5	5	5
Importance Factor (I)	1.5	1.5	1.5

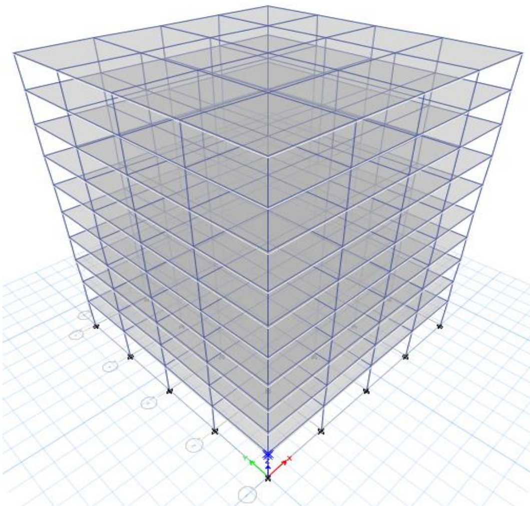


Fig. 3.2 G+10 3D model View

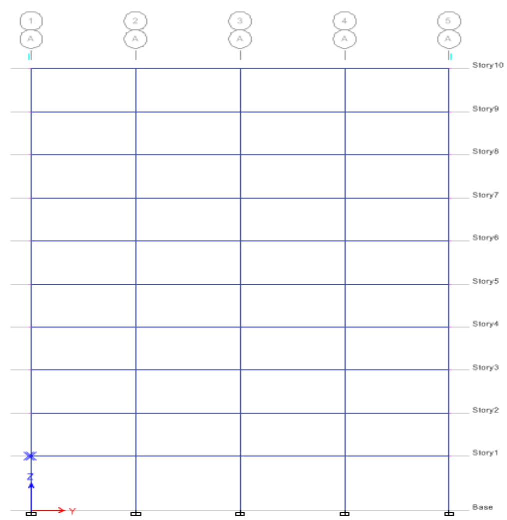


Fig. 3.3 Building Elevation

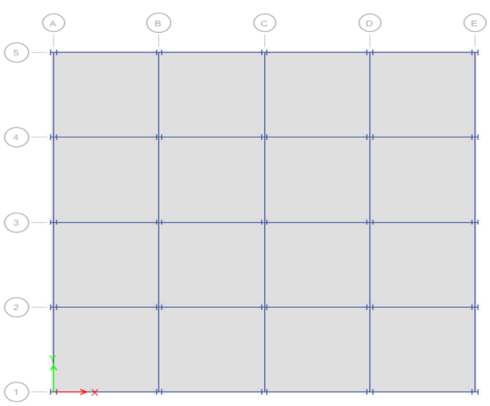


Fig. 3.4 RCC Building Plan

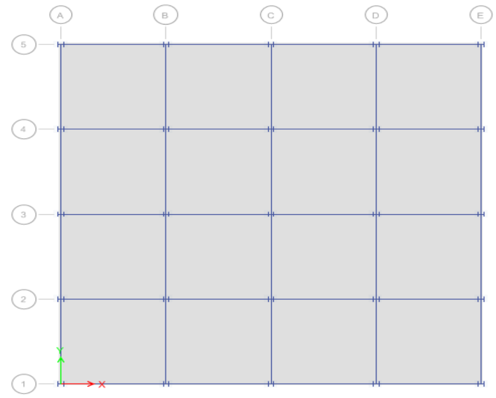


Fig. 3.5 Encased sections- Building plan

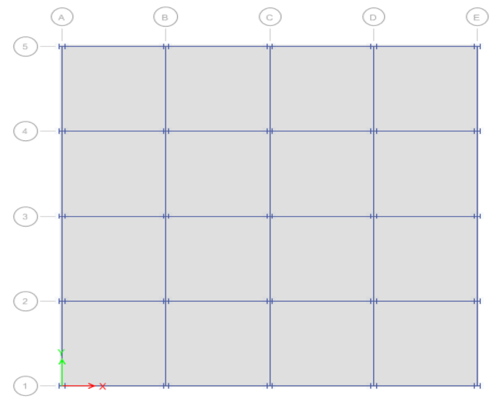


Fig. 3.6 Infilled section- Building plan

4 ANALYSIS OF BUILDING

Linear static and response spectrum analysis methods are used for the analysis of RCC and composite structures. In equivalent static analysis single mode of vibrations are considered. Base shear can be determined by multiplying total seismic weight of building to coefficient of acceleration spectrum value. In response spectrum method, dynamic characteristics are considered for analysis. In this method multiple modes of vibrations are considered where base shear of each mode can be calculated separately. It can be calculated by determining the modal mass and modal mass participation factor (CQC method) for each mode. EQX- Equivalent static in X direction EQY- Equivalent static in Y direction RSX- Response spectrum in X direction RSY- Response spectrum in Y direction.

5 RESULTS AND DISCUSSION

The linear static and response spectrum analysis are carried out using ETABS 17 software. The results for different types of buildings are compared. The Storey Shear for each storey level for RCC and Steel Concrete Composite building with Encased and Concrete Filled Steel tubes (CFS) values are shown in fig: 5.1 to 5.3.The storey shear is small for composite building due to reduction in dead weight of the structure as compared to RCC.

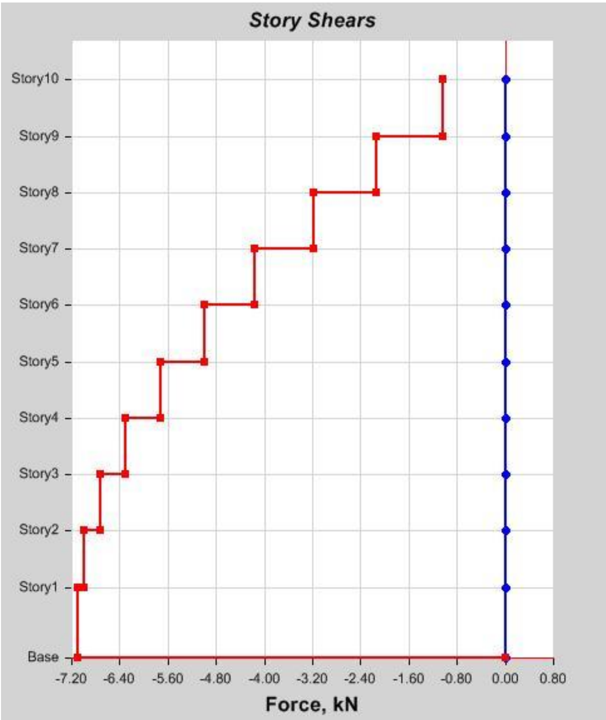


Fig. 5.1 Encased concrete sections

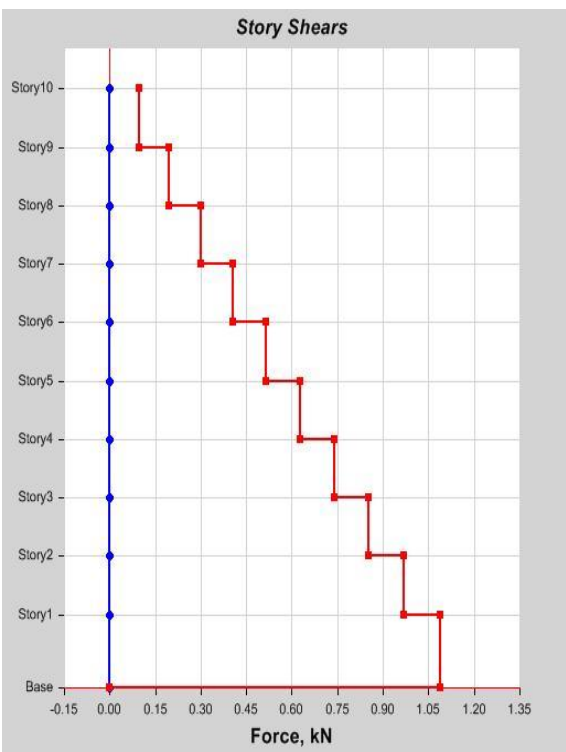


Fig. 5.2 Infilled tubular sections

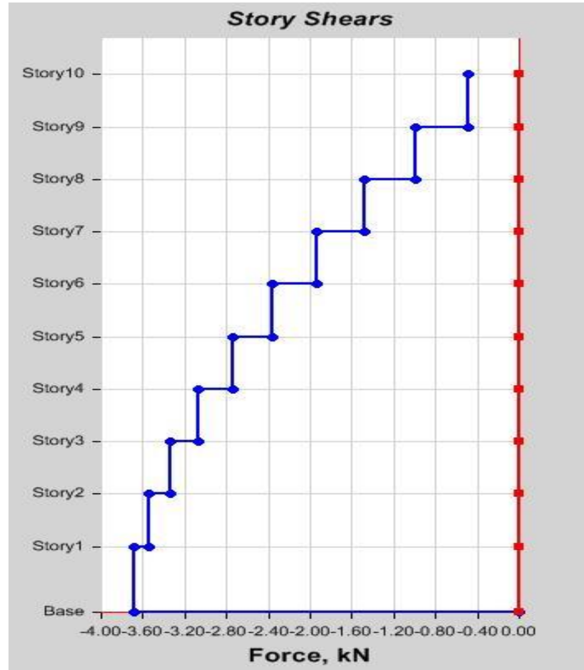


Fig. 5.3 RCC sections

The Storey Drift for each storey level for RCC and Steel Concrete Composite building with Encased and Concrete Filled Steel tubes (CFS) are shown in fig: 5.4 to 5.6.The storey drift is high for CFS building when compared to RCC and CFS.

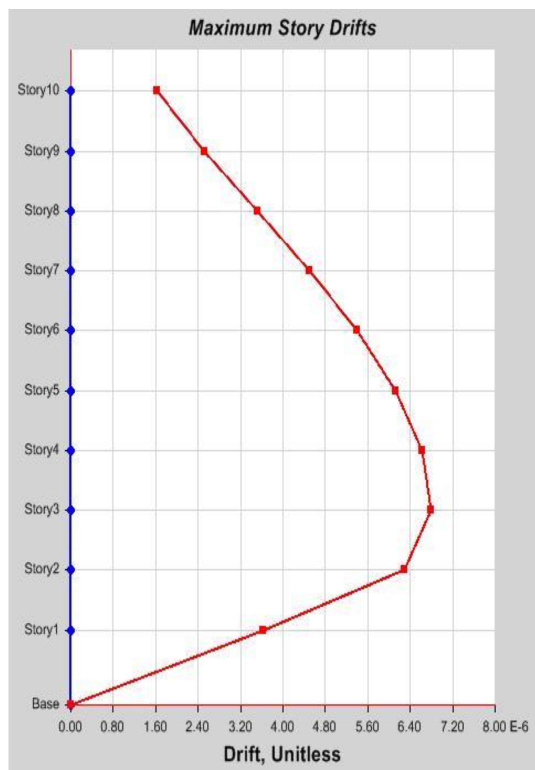


Fig. 5.4 Encased concrete sections

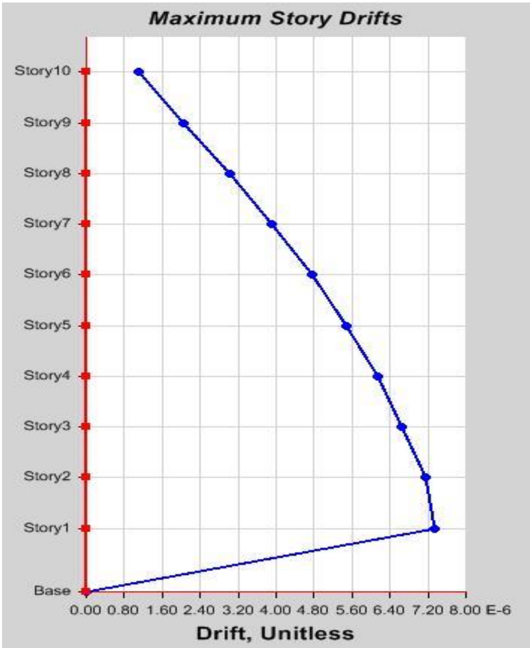


Fig. 5.5 Infilled tubular sections

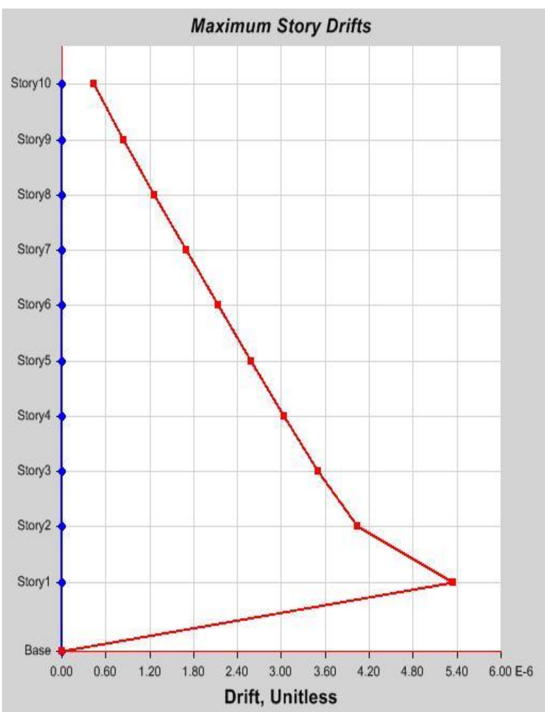


Fig. 5.6 RCC section

The Storey displacement for each storey level for RCC and Composite building with Encased and Concrete Filled Steel tubes (CFS) are shown in Fig: 5.7 to 5.9. The displacement is high for composite building than the RCC.

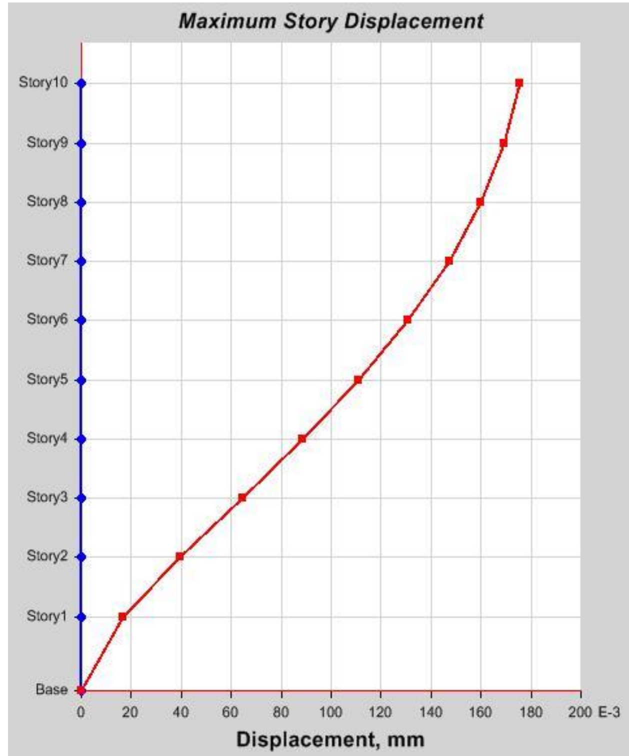


Fig. 5.7 Infilled tubular sections

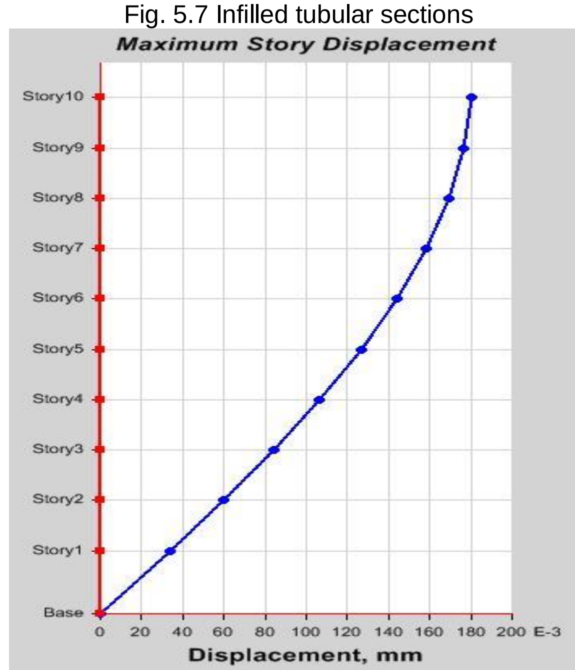


Fig. 5.8 Encased concrete sections

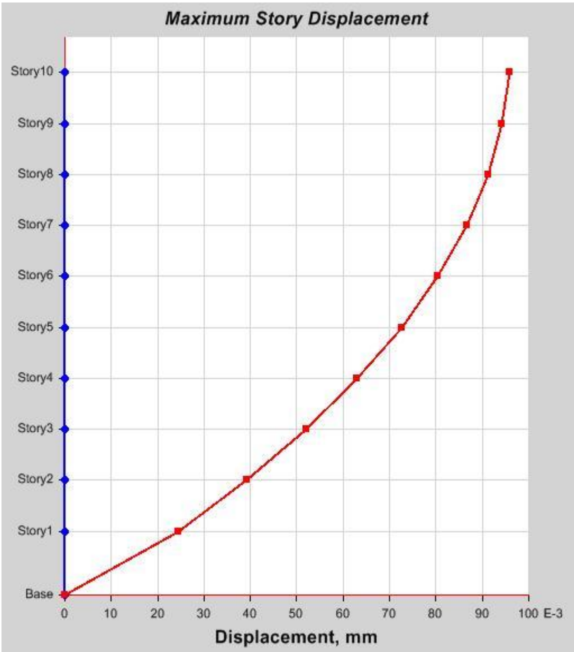
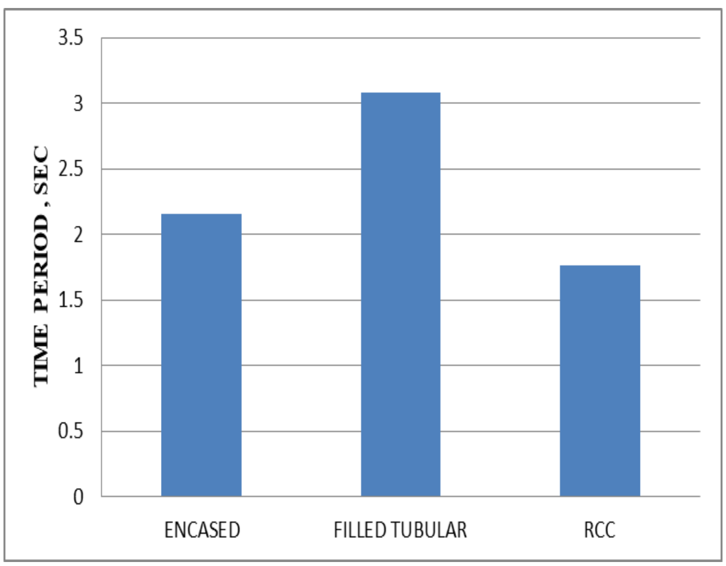


Fig. 5.9 RCC Section

The Time Period for RCC and Composite building with Encased and Concrete Filled Steel tubes (CFS) are shown in Fig: 5.10.The time period increases for composite than RCC.



5 CONCLUSION

The following conclusions are arrived based on the response spectrum analysis for the commercial building located at Zone 3.

- Storey drift reduces in composite structures as compared to RCC, because composite structures have higher stiffness and different moment of inertia for columns than that of RCC. But for both RCC and composite structures, storey drift are within permissible limit, i.e., 0.004 times the height of storey.
- Storey Shear reduces in composite than in RCC. Due to reduction in self-weight of as compared to RCC which in turn reduces the foundation cost of the structure.
- Time period is reduced for RCC than the composite structures. Besides the composites are being more ductile, resist lateral load better than RCC structures.
- Storey displacement is maximum for composite building as compared to RCC building both in X and Y direction. RCC building has the lowest storey displacement because of its high stiffness.

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