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Parametric Seismic Study of Steel-Concrete Composite Frames

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ABSTRACT

In India mostly multi story buildings are constructed with reinforced concrete,steel and recently the trend of construction is going toward composite structure which has beenstarted is in growing stage.Therefore the main aim of this research is to the parametric study on reinforced concrete, steel and steel- concrete composite frames.A 3D (G+9) stories building is situated in seismic zone IV and designed for same gravity loads. The reinforced beam and column were design according to the IS: 456-2000 and the composite fill sections were design according American standard AISC: 360-10.Further the beam and column sections were made by reinforced concrete, steel and steel-concrete composite. The reinforced concrete slab of uniform thickness was considering for all type of frames. Load combination is assigned according to IS: 1893-2002. The entire frame were modeled and analyzed by response spectrum method using E-tabs software 2015.Finally the results were obtained and compared in a parametric study .This study concludes that composite frame show better performance compared to reinforced concrete and steel frames.

Key words:*Steel-concrete composite, Seismic behavior, ETABS Software, Storey drift, Overturning moment etc.*

INTRODUCTION

The most significant and most unusually experienced bring together of enlargement materials is the steel and concrete. Reinforced concrete has been the most popular construction material worldwide due to its extremely good properties. However the seismic performance of reinforced concrete systems during past earthquakes,forced the researchers to find an alternative materials of construction. The steel is being a ductile material, enough strength and warning earlier than failure through way of immoderate deformations. These properties of steel are of very plenty important in case of the seismic resistant design. Thus, a comparative have a look at is essential to be done from the factor of view of seismic performance.Composite steel concrete structures are used widely in modern bridge and building construction and this system of construction is gaining popularity as multifaceted design and construction technique. Therefore in multistory structure, structural steelwork is regularly utilized together with concrete; for instance, steel beams with concrete floor slabs. Further concrete filled tube sections are one of the best composite sections that have many benefits over conventional steel and reinforced concrete sections .These sections are formed by filling concrete into a hollow steel tube section and offers resistance to carry out load through the composite action of steel and concrete. Concrete filled tube section possesses high ductility, energy, and strength absorption potential that are very vital for a shape placed in earthquake susceptible areas. In composite column construction steel and concrete are united in such a manner that the advantages of the materials are employed in a efficient manner and Concrete filled tube column is most popular in the steel-concrete composite frame. Based at the form of cross-phase, Concrete filled tube sections are labeled into numerous sorts' namely ordinary concrete filled tube section, concrete filled tube phase with reinforcement, concrete filled double pores and skin tubes, and concrete encased concrete filled tube section. inthis study, focus on the performance of the reinforced concrete, steel and steel-concrete composite and the concrete filled tube frame structure during earth quake which is building is situated in seismic zone v and also compares the seismic parameters results and analysis was done using E-tabs software 2015. An overview of previous research on reinforced concrete structure, steel structure and steel-concrete composite structure and their seismic parameters such as story drift, base shear, story stiffness, overturning moment, story displacement etc. D. R. Panchal , P. M. Marathe (2011) explained the comparative study of reinforced cement concrete, steel and composite building. They analyzed the (G+30) storey commercial building which is situated in earthquake zone IV and building plan is selected with area covering 24m x 42m. For modeling of composite, steel and reinforced cement concrete structure, use the ETABS software and found that composite structure was to beeconomical. A N. Shah, P.S. Pajgade (2013) explain the comparison of R.C.C and composite multi-storied buildings. G+15 storied building located in seismic zone IV and wind velocity 39 m/s. The plan dimension of the building is 25.61mx15.92m and height of each storey is kept same as 3.35m and the total height of the building is 56.5m. Equivalent Static Method of Analysis is used. For modeling of composite & R.C.C. structures, STAAD-pro software is used. The comparison of results of composite column building and R.C.C. column building shows that the deflection and storey drift in composite structure is nearly double than that of R.C.C. structures but the deflection is within the permissible limit. Composite structure is more economical than R.C.C. structure. S. A.Wagh, U.P Waghe(2014) ,present the comparative study of R.C.C. with steel, concrete composite were considered for the different (G+12, G+16, G+20, G+24) stories buildings situated in Nagpur earthquake zone II and wind speed 44m/s was analyzed by using the STAAD-Pro software. Compare the cost analysis between the R.C.C and steel structure for four commercial building. It is found that composite structure is more economical than R.C.C structure and gives the speed in construction.Z. Mujawar, P.Sangave (2015) explained comparative evaluation of reinforced concrete, steel and composite structures under the effect of static and dynamic loads. In this paper, the behavior of reinforced concrete, steel and composite structures under the effect of seismic loading. The result parameters are base shear, displacement and inter-storey drift. After the result they see that base shear for composite structure has reduced by 31% and for steel structure 29% compared to that of reinforced concrete structure. Displacement for composite structure has increased by 48% and for steel structure by 49% comparedto that of R.C.C structure. Storey drift was also more compared to R.C.C and steel structure. Time required for composite structure was less than the other structuresH. Nausheen, H.Eramma(2015)An extensive study has been carried out on the behavior of composite column and conventional column and keeping all other structural members same for both the structures. The composite column design were carried out according to Euro code 4 and conventional column design by IS 456-2000. The Modeling of buildings was considered in III seismic zoneand analysis has been carried in ETABS software. Results were obtained of various parameters in terms of base shear, storey overturning, storey drift and concluded that low rise conventional building is more suitable than low rise composite building.N .V. Ganwani, S. S. Jamkar(2016) in this paper acomparative study of seismic performance of a 3D (G+8) storey RCC and steel concrete composite building frame situated in earthquake zone IV considering the equivalent static method and response spectrum method were used for seismic analysis. ETAB 2015 software was used and results were compared and conclude that the composite construction is more economical than the conventional RCC construction.A.S. Boke, K. R. Suryawanshi(2017)the behavior of reinforced concrete, steel and composite structures under the effect of seismic loading and a comparative study of RCC and steel-concrete composite (G+10) residential building were studied.Response spectrum method was used for comparison of three structures with the help of ETABS software. The parameters were studied as base shear, displacement and inter-storey drift. Itisfoundthecompositestructuregivebetterresulttha n R.C.C structures. P. S. Sanjay, S. R. Parekar(2019) , Present the compare study on seismic performance of a 3D (G+8) storey RCC, Steel and Composite building frame situated in earthquake zone V. All frames are designed for same gravity loadings. The RCC slab is used in all three cases. Beam and column sections are made of RCC, Steel or Steel-concrete composite sections. Equivalent static method and response spectrum method are used for seismic analysis. ETABS 2015 software was used for analysis and results were reported based on fundamental time period, displacements, base shear and storey drift. Comparative study concludes that, RCC construction is best suited for low rise buildings among all the three types of constructions.T.G.N.C.Vamsi Krishna, S.V.Surendhar, M.S.R. Krishna.(2019) In this study a geometrically irregular residential building (G+18 storey) was designed and analyzed for both cases of RCC and composite structures (considering earthquake zone III) using ETABS software. The structure wasanalyzed using linear static, linear and non-linear dynamic methods, such as equivalent static method, response spectrum method and time history method. From the observed results, it may be clearly inferred that a steel composite, performs well in-terms of structural integrity when compared with an RCC structure. M. AkifUddin, M. A. Azeem(2020)Discus the composite structure with concrete filled steel tubular columns, a composite structure with concrete encased I section columns and a RCC structure. All the models considered are G+15 storey and are irregular in plan and the irregularity condition as per IS 1893-2002 is satisfied resulting in T shape and Plus Shape models. It was observed after performing response spectrum analysis on the models that the stiffness is less in composite structures when compared to RCC structures. The displacements and drifts are less in RCC structures owing to larger value of stiffness but are within the permissible limits. The base shear and base moments are found to be less in composite structures due to the fact that the dead weight of composite structures is less compared to RCC structures. There is no significant difference in the response parameters of the two composite structures.

Modeling: Modeling of reinforced concrete, steel and steel-concrete composite structure are referring here to the design of slab, beam, column, material properties and loading conditions as taken in this study. Modeling and analysis of the structure is done using E-tabs software 2015 and analyzed by using response spectrummethod. In the study, six different type of building frame models having different materials properties were considered. The plan dimension of the building is 18 x 27 m and the height of each storey for RC; steel and steel-concrete composite frame is 3m. The building having 3D (G + 9) storied located in seismic zone IV and for earthquake loading, the provisions of the Indian standard IS: 1893(Part1) 2002, the provisions of the IS: 456- 2000, provisions of the IS: 800-2007, and guide lines according to American standard AISC: 360-10 were considered for the analysis respectively. The floor plans were divided into four by six bays in such a way that centre to centre distance between two grids is 4.5 meters by 4.5 meters respectively. This study is modeled to compared the seismic behavior of eight types of framed structure consisting of (i) Reinforced concrete slab, beam and column(ii) steel beam , steel column andreinforced concrete slab(iii) Steel column , reinforced concrete slab and beam(iv) steel beam , reinforced concrete slab and column(v) Concrete filled tube (CFT)rectangular beam and column and reinforced concrete slab(iv) (CFT)rectangular beam with I section encased both in beam and column and reinforced concrete slab(vii) (CFT)circular beam and column , reinforced concrete slab(viii) (CFT) circular beam with I section encased both in beam and column and reinforced concrete slab. The plan and 3D view of building is shown in figure 1. Different sections and types of frames are listed in table 1 ,and material propertiesand seismic data is given in table2.

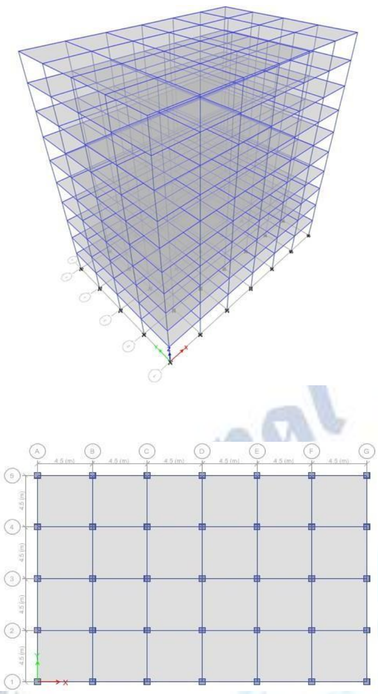

Figure 1. Plan and 3D view of the building

Table 1. Section used in the design of frames

Types of frames	Beam dimension	Column dimension	Slab
RC Frame	250 X 400 mm Cross section	500 X 500 mm Cross section	120 mm thick RC slab
Steel Frame	ISMB 200	ISHB 450-2 with 40 mm cover plate	120 mm thick RC slab
Composite 1 frame	ISMB 250	500 X 500 mm Cross section	120 mm thick RC slab
Composite 2 frame	250 X 400 mm Cross section	ISMB 500 with 40 mm cover plate	120 mm thick RC slab
CFT 1 frame	250 X 400 mm CFT With 12 mm thick	500 X 500 mm CFT With 12 mm thick	120 mm thick RC slab
CFT 2 frame	250 X 400 mm CFT With ISMB 150 steel section	500 X 500 mm CFT With ISMB 300 steel section	120 mm thick RC slab
CFT 3 frame	250 X 400 mm CFT With 12 mm Thick	500 mm diameter CFT column with 12 mm thick	120 mm thick RC slab
CFT 4 frame	250 X 400 mm CFT With ISMB 150 steel section	500 mm diameter CFT column with ISMB 300 steel section	120 mm thick RC slab

Table 2 : Material propertiesand seismic data

Unit weight of concrete	25 kN/m³	Seismic zone	IV
Unit weight of steel	78 kN/m³	Importance factor (I)	1
Grade of concrete	M30	Response reduction factor (R)	5 (SMRF)
Grade of steel sections	Fe250	Soil type	Medium soil
Grade of reinforcing steel	Fe415	Response spectrum function	IS 1893:2002 Spectrum
Modulus of elasticity for concrete	25 kN/m²	Function damping ratio	5 %
Modulus of elasticity for steel	210 kN/m²	Zone factor (Z)	0.24

Results and discussion: In the present study,Response spectrum analysishas been performed using E-tabs software 2015and results of eight different types of models has been studied and compared with their parameters such as story drift, base shear, overturning moment, story stiffness, shear force etc. The objective of this study is to see the variation in the parameters value for different types of framesstructure.

Storydrift: The figure2 shows the storey drift valuesobtained in X and Y directions. It is observed that story drift in both the direction found more in steel frame as compared to other frame in this study. It is also seen the storey drift was more in Y direction compared to X direction. This may be due to the ductile behavior of steel and steel frame has low stiffness value. Further the lowest values are observed in CFT2 model compared to other frames. However all the values are within the permissible limit and satisfying the IS: 1893-2002.

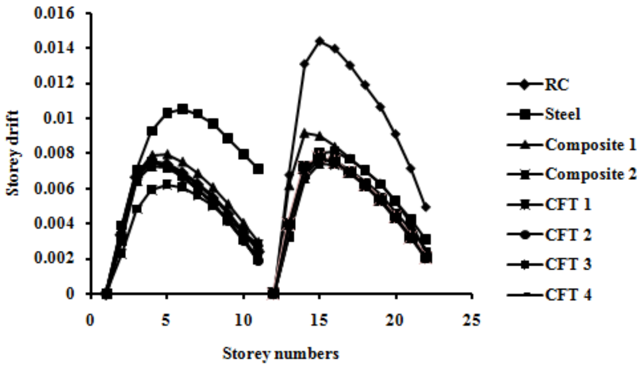

Figure 2: Story drift in X-direction and Y direction

Story baseshear: As the base shear is the horizontal reaction to the lateral forces and horizontal forces results from the storey weight. From the figure3 , it is observed that higher values were obtained in CFT1 model in the both the direction and the lowest values were in steel frame in Y direction. the base shear, that CFT 1 in X and Y-direction has more base shear than RC, steel and other composite frames because CFT 1 has more weight than other frames. Steel frame has low base shear because of its low weight. Base shear value is increase in CFT frames.

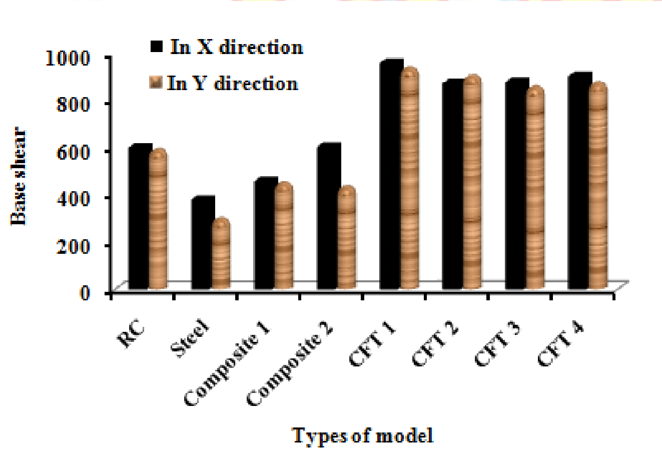

Figure3.Story base shear in X & Y-direction

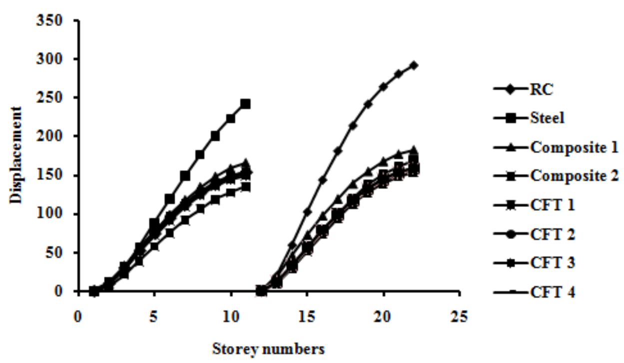

Figure 4.Story displacements in X-direction and Y direction

Storeydisplacement: The storey displacement verses storey numbers figure both in X and Y direction are shown in figure4.It is seen from the figure that steel frame model has more displacement in both direction. However composite 2 model has less displacement in X direction and CFT1 model has the less displacement in Y direction compared with other frame in this study. Further the displacement is increase with the increase in storey number of the frame and the maximum displacement at observed at 10th story.

Axialforce .Axial force at top of building verses storey numbers of all the models is shown in the figure 5.It can be seen form figure 5,that axial force is decrease with the increase in stories. CFT 1 model has maximum axial force at each story.. Steel frame has less axial force compare to other frames. Axial force in steel frame is decrease 31% than CFT 1 frame.

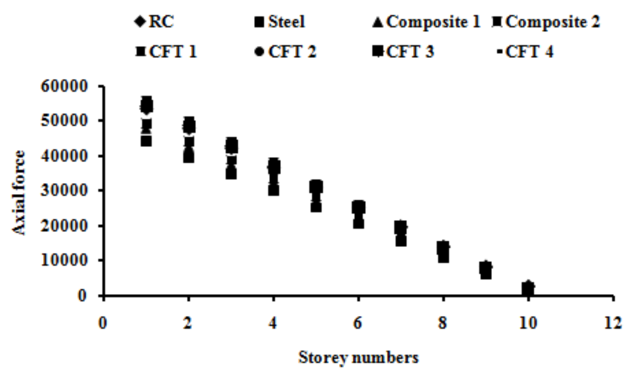

Figure 5. Axial forces at top verses stories

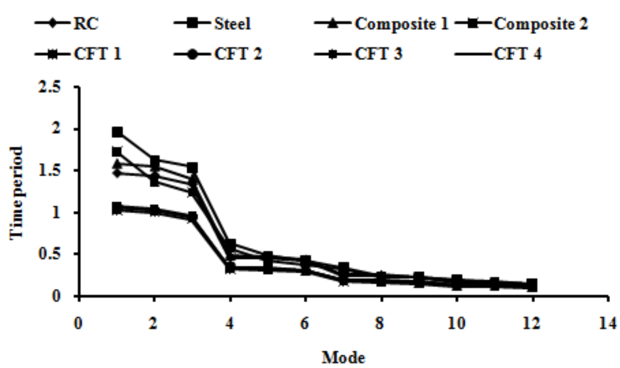

Figure 6. Time period at modes

Timeperiod: Time period verses modes for different cases are shown in figure 6.The time period is decreasing with the increase the mode in a similar fashion. The time period of the steel frame was observed much higher andCFT1 frame gets less time period. However the time period of CFT sections are less than the reinforced concrete frame structures.

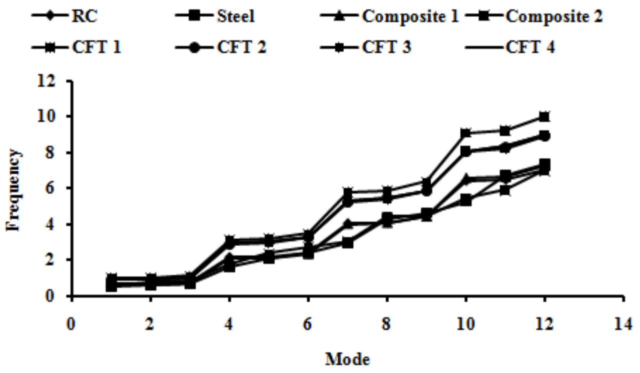

Figure 7. Frequency for different cases

Frequency: Observed frequency for different frames is shown in figure7. It is observed from the figure that CFT 1 model has more frequency as compare to other frames because CFT1 model has more stiffness than other frames further the composite 2 frames have less frequency as shown in graph.

Overturningmoment: Overturning moment for different frames both in X and Y direction are shown in figure8. It is observed that CFT 1 frame has maximum overturning moment in X- direction than other frame and composite 1 model has less overturning moment.

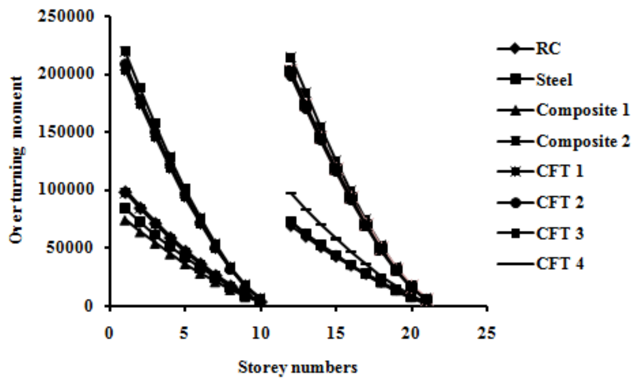

Figure 8. Overturning moment in X and Y-direction for different cases

Storey shearforce: Storey shear force in both X and Y-direction for different frames are shown in figure9.It can be seen in the figure that storey shear force in X-direction decrease with the increase in the stories and CFT 1 model has more value as compare to other frames further the composite 1model has the lowest value of story shear force. However it is also seen that CFT frame model have more storey shear force than other steel, concrete and composite frames. The 10th storey composite 1 model has lowest value than other frames in both X and Y direction.

Storystiffness: Story stiffness for different frames is shown in figure 10. It is observed that CFT 1 frame has more story stiffness in X and Y directions than other frames because CFT 1 has more weight as compare to other frames. At first and second story of composite 1 frame has low value of the story stiffness after second story steel frame has low stiffness.

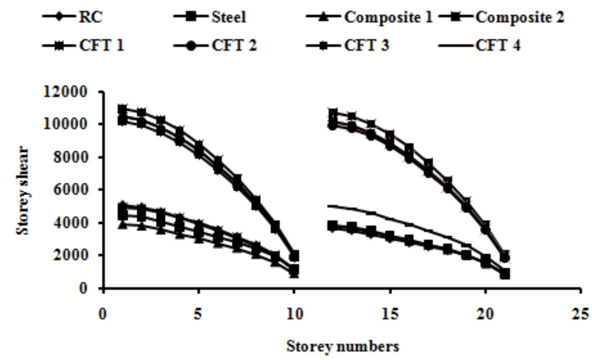

Figure 9. Story shear force X and Y-direction for different frames

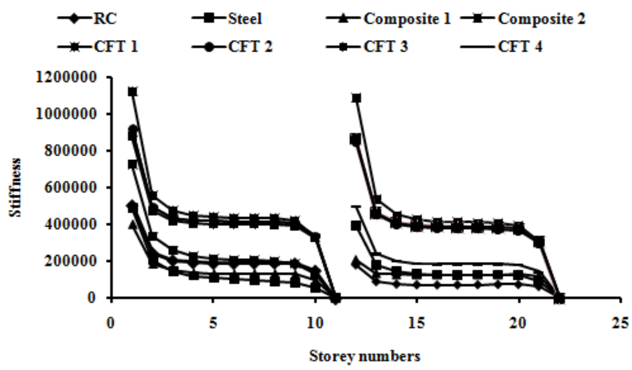

Figure 10. Story stiffness for different frames in X and direction

CONCLUSION

The main observations the analysis is summarized below. Comparing the analytical study of the entire eight models with reference to RC model it is observed that all the model behave identical for the parameters studies however the differences were pronounced in magnitude. Story drift in both X and Y-direction in steel frame model has more as compare the RC and other steel-concrete composite frames. The values of Base shear both in X and Y direction for composite model 1and 2 has reduced by % and for steel model by % compared to that of

Reinforced concrete model , however the base shear for CFT1m CFT2,CFT3and CFT4 has increased to much compared to that of reinforced concrete model . Story displacement in X & Y-direction in steel frames has maximum displacement as compare to other RC and steel-concrete composite frames because the steel frame has more ductile and have lowstiffness.Axial force in decrease as increases the stories and CFT 1 frame has maximum axial force up to 9th stories and after that RC frame has more axial force than otherframes.Time period in steel frame has maximum because of it low stiffness value. CFT 1 frame has low time period because it has highstiffness.Frequency is inversely to the time period so CFT 1frame has high frequency than otherframes.Overturning moment in X-direction CFT 1 frame has maximum value and composite 1 frame has low value. In Y-direction CFT 1 has more value and steel frame has low value of overturning moment. All the CFT frames have maximum value of overturning moment than other steel –concrete compositeframes.All CFT frames have high value of story shear force and story shear force in X & Y-direction CFT 1 frame has maximumvalue. Story stiffness in X & Y-direction in CFT 1 has more as compare to other frames up to 9th stories and after that CFT 2 has more value because of its more weight. In X-direction composite 1 frame has low value of story stiffness. The seismic behavior of CFT model gives the better performance compared to RC, steel and other steel-concrete composite frames.

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