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Studies on Effect of Lateral Force on Different Types of Composite Building Frame Systems

Varghese Basil Alexander, Dominic Ashwin W, Anand N, Jayalin D

Abstract: ***Behavior of tall building depends on the performance of composite materials used for construction. Strength, stiffness and durability are the key factors to be ensured in the structural elements of the building. Building frame systems with RCC, frame systems with steel and frame systems with composite members are normally used for the construction of tall buildings. Lateral strength and stability of buildings with composite members were found to perform better under static and dynamic loads. Effect of different column profiles (steel column, composite column with square section, and composite column with circular section) on strength and deformation behavior of framing systems are investigated in this paper. A six storeyed framing system with height of 18m is considered for the investigation. It is found that composite column with circular section performs better in terms of strength and stiffness. Also comparison has been made among the three types of column to check the axial load resistance and lateral deformation.***

Index Terms**:** ***Axial load, Composite column, Lateral deformation, Steel column, ETABS***

I. INTRODUCTION

Composite materials are basically the combination of two or more materials so that the composite structural system can perform better with the inherent material properties. Steel-concrete composite building systems consist of concrete components that interact with structural steel components within the same system. By their fundamental behavior, these components give the essential attributes of strength, stiffness and stability to the overall system. They consist of composite beams or trusses, encased or filled composite columns, and steel deck reinforced composite slabs. These members are generally used in steel structures, and their progress as composite members is based on utilizing the concrete that would be required for increasing the durability of the structure or for fire - protective encasements with steel columns.

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***** Correspondence Author

Varghese Basil Alexander*, Dept of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India.

Dominic Ashwin W, Dept of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India.

Anand N, Dept of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India.

Jayalin D, Dept of Civil Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India.

II. LITERATURE REVIEW

Sharma [1] made a comparison of composite, concrete and steel structure in which composite structure has proven to be far more advantageous over steel and concrete structure in terms of strength, cost, and construction time requirements.

Kian Karimi [2] concluded that the confining pressure exerted by the FRP jacket and the composite action between composite materials enhanced the compressive behavior of the composite columns.

Fidelis Mashiri [3] investigated the post-fire behavior of shear connectors and concluded that headed studs performed well compared to Blind Bolts at ambient and target temperatures.

Anil Agarwal [4] demonstrated that shear-tab connections provided major negative moment resistance at the beam ends at high temperatures and increased the flexural capacity of the composite beam by efficiently redistributing the moment demands due to the applied gravity loads.

Silva [5] proved that the bending behavior of CFST elements is highly dependent on the steel tube properties and that the type of infill does not have a considerable influence on the flexural behavior of the member. Seismic performance assessment of steel frame and composite frame with circular CFSTs showed evidence of an increased seismic performance of composite moment resisting frames using CFST columns.

III. METHODOLOGY

Multi storeyed building comprising of three different composite framing systems was considered for the investigation. All building frames were modeled and analyzed using the software ETABS. Based on the results obtained, the performance of the three systems described below was compared in terms of axial load resistance and lateral deflection.

System 1: Composite Deck Slab, Composite Beam, and Steel Column.

System 2: Composite Deck Slab, Composite Beam, and Concrete Filled Steel Encased Circular Column.

System 3: Composite Deck Slab, Composite Beam, and Concrete Encased Square Steel Column.

Input Data:

Size of the building: 64m x 64m, Height of the building: 18m, Storey height: 3m, Number of floors: 6, Size of slab: 8m x 8m, Materials: Grade of concrete: M30, Structural steel: fy 250, Reinforcement steel: fy 500, Unit weight of concrete: 25kN/m^3, Young's modulus of steel = 2 x 10^5 MPa, Depth of slab: 160mm, Beam section: ISMB 250

The following Fig. 1 shows the plan view of the building.

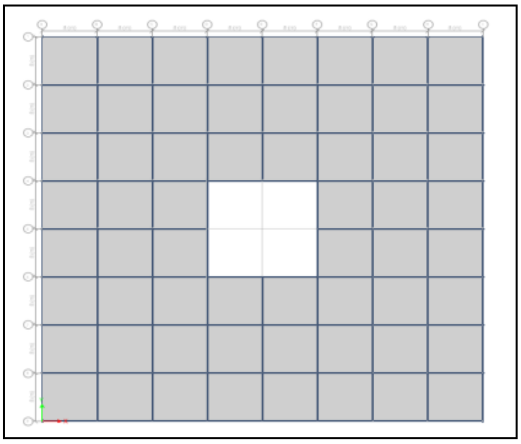

Figure 1: Plan View of the building

The following figures (Fig. 2, 3, 4, 5, 6, 7) show the 3D modeling of the building frames with steel column, composite column with circular section and square section.

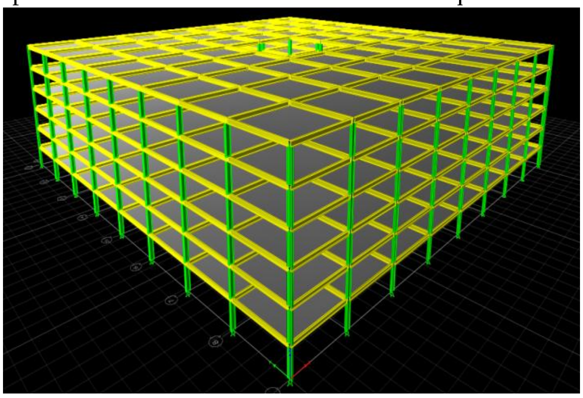

Figure 2: Structure Model in ETABS (Steel Column)

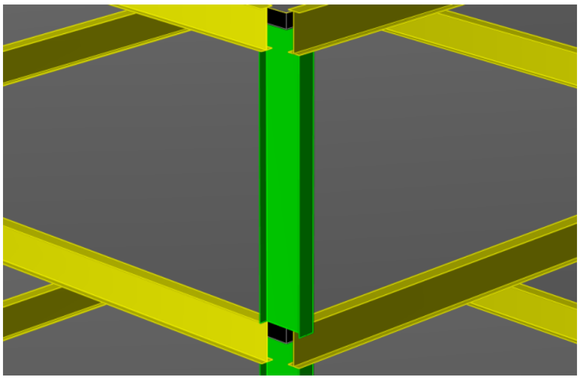

Figure 3: View of Steel Column

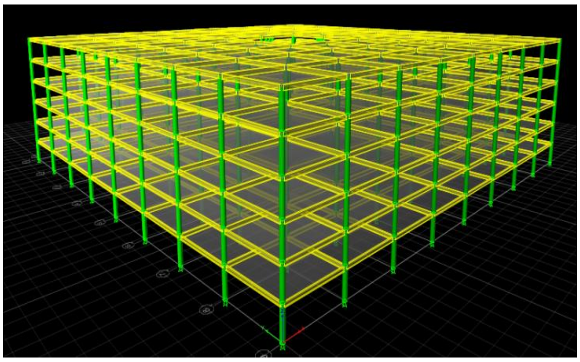

Figure 4: Structure Model in ETABS (Circular Column)

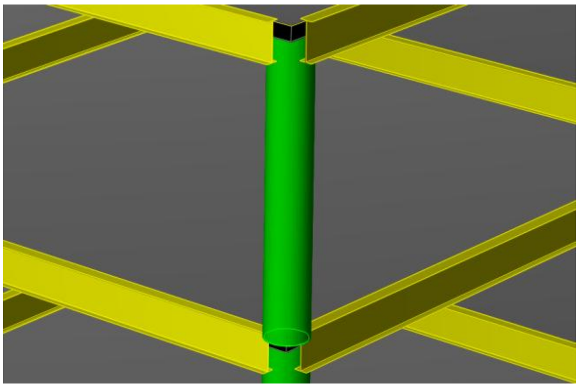

Figure 5: View of Steel Tube Circular Column

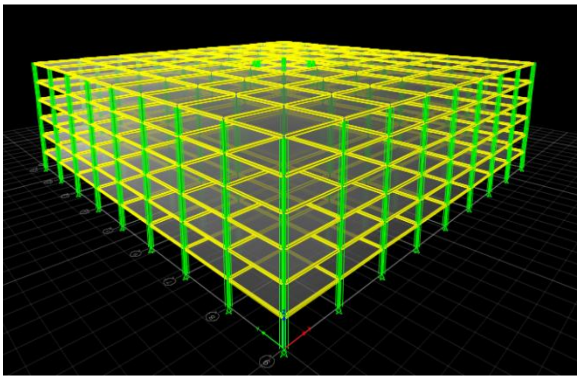

Figure 6: Structure Model in ETABS (Square Column)

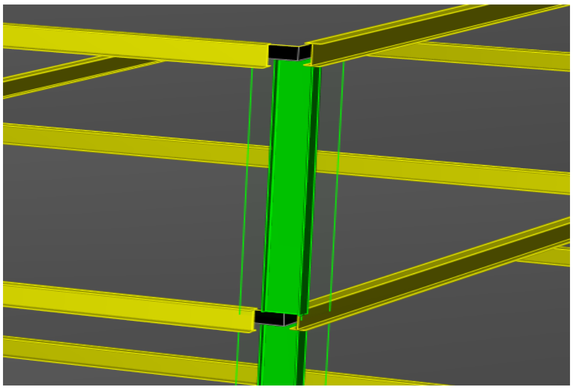

Figure 7: View of Concrete Encased Square Column

IV. ANALYSIS OF RESULTS

A. Profiled Deck Slab:

Composite slabs comprise of reinforced concrete cast on top of profiled steel decking. This decking acts as a formwork and a working platform during the construction stage, whereas acts as an external reinforcement at the composite stage.

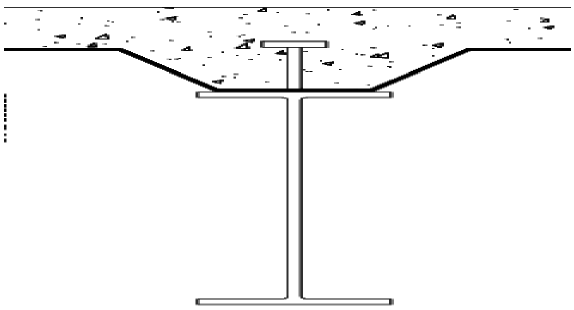

Figure 8: Profiled deck slab

Fig. 8 shows the view of profiled deck slab.

Design Details: The following loads and checks were considered while designing the deck slab,

Dead Loads- Self wt. of slab: 3.75kN/m^2, Finishes: 1kN/m^2, Ceilings and Services: 0.5kN/m^2, Partition Loads: 1.5kN/m^2

Live Load: 4kN/m^2

Checks- Shear resistance bond, bending resistance, fire resistance, and deflection.

Details of Profiled Deck Slab and Connector:

Thickness of Sheet = 0.9mm, Depth of rib = 46mm, Trough width = 105mm, Crest width = 33.5mm, Neutral axis depth of the deck = 20.38mm, Deck weight = 0.09kN/m^2, Diameter of shear stud = 19mm, Overall nominal height of stud = 100mm, Ultimate strength of stud = 450N/mm^2, Partial safety factor of shear stud = 1.25, Number of shear studs per rib = 2

B. Composite Beam:

A beam that is made by combining two or more material is generally called as composite beam. In the present work a steel beam connected with a deck slab with the help of shear studs are considered as composite beam.

Design Details: The following checks were considered while designing the composite beam,

Checks- Deflection, web buckling, web bearing, moment of resistance, shear resistance, shear connection resistance, degree of shear connection.

C. Load Combinations:

The structure is analyzed by providing proper load factors to the applied dead load, live load and wind load.

Table 1: Load Combinations

S. No.	Primary Loads	Load Combination	Limit State of Collapse	Limit State of Serviceability
1	Dead Load (DL)	DL+LL	1.5	1.0
2	Live Load (LL)			
3	Wind Load (WL)	DL+LL +WL	1.2	

D. Bending Moment, Shear and Deflection Diagrams:

Based on the load combinations provided for each load as shown in Table 1, the following Fig. 9 shows the bending moment, shear force and deflection diagram obtained for Beam 89.

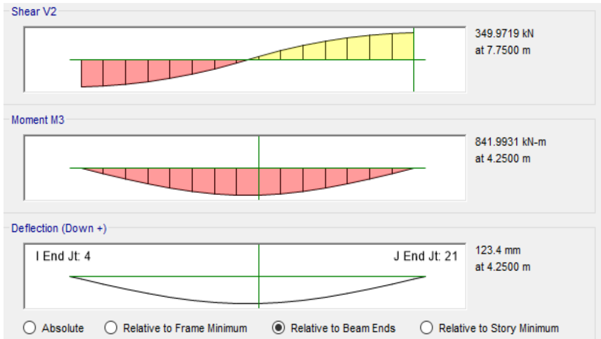

Figure 9: Bending Moment, Shear Force and Deflection diagrams (System 1)

E. Effect of Axial Force on different column profiles:

Steel Column:

Dead and live loads from slab and beams are transferred to steel column in this system. The beams are modeled with shear connections. Joints are modeled in such a way that beam shear forces are allowed to transfer on column joints. The following are the geometric and material properties of column used for modeling. The following Fig. 10 shows the profile of steel column used for modeling this frame system. The columns are designed considering the effect of static loads only. The load combination of 1.5(DL+LL) is considered as a critical load combination for the design of steel column. Columns are designed for axial forces only. Suitable optimal section is selected to resist the applied loads. Buckling resistance of column about z and y axis is checked and lateral deformation is measured at roof level of the building and compared with the allowable values.

Details of Welded Section:

Yield Strength of Steel = 250MPa, Depth of Section = 600mm, Breadth of flange = 350mm, Thickness of flange = 30mm, Thickness of web = 20mm, Sectional area = 31800mm^2, r_{zz} = 248.9mm, r_{yy} = 82.2mm, Young's modulus of steel = 200000N/mm^2

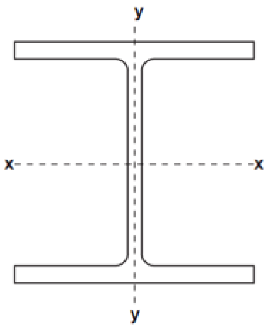

Figure 10: Profile of Steel Column

Fig. 11 shows the axial force diagram obtained for steel column.

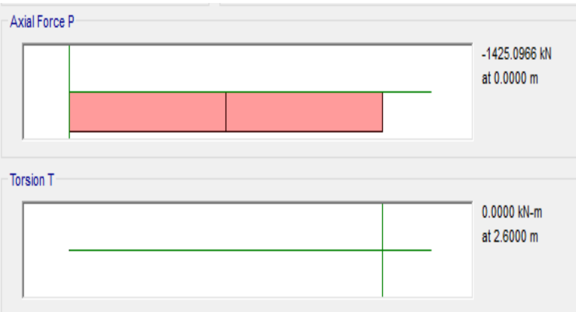

Figure 11: Axial Force Diagram (Steel Column)

Steel Encased Circular Column:

Composite steel encased circular column is used for modeling the second system. The following Fig. 12 shows the profile of composite column with circular section. The following are the details of geometric and material properties of the section used for modeling. As like the previous system, this system is also analyzed for 1.5(DL+LL) load combination to obtain the optimal column section. Lateral deformation at roof level taken from the analysis results are compared with other framing systems.

Section Details:

Diameter of Column = 350mm, Thickness = 10mm, Diameter of rod = 12mm, Grade of Concrete = M40, Yield Strength of Steel = 250MPa, Yield Strength of Reinforcement = 500MPa, Partial Safety Factor (Structural Steel) = 1.10, Partial Safety Factor (Concrete) = 1.5, Partial Safety Factor (Reinforcement) = 1.15

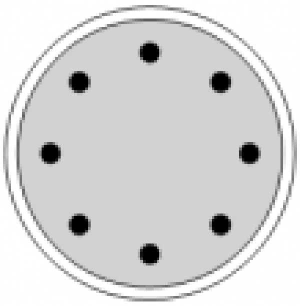

Figure 12: Profile of Steel Encased Column

Fig. 13 shows the axial force diagram obtained for steel encased circular column.

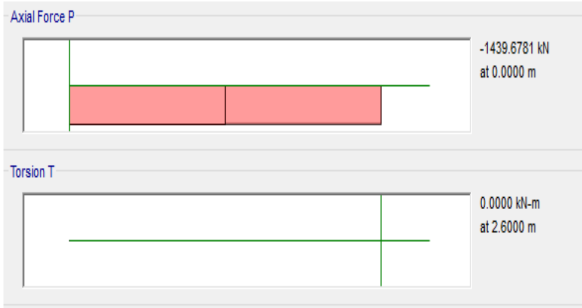

Figure 13: Axial Force Diagram (Steel Encased Column)

Concrete Encased Square Column:

The following Fig. 14 shows the profile of composite column with square section. The following are the details of geometric and material properties of the section used for modeling. Static loads are considered for selecting the optimal section of composite column subjected to axial loads. Axial load resistance of composite column is checked about z and y axis. The design procedure is followed as per Euro code. Lateral deformation at roof level taken from the analysis results are compared with other framing systems.

Section Details:

Column Size = 500mm x 500mm, Steel Section = ISHB 400, Depth of Section = 400mm, Breadth of flange = 250mm, Thickness of flange = 12.7mm, Thickness of web = 10.6mm, sectional area = 10470mm^2, r_{zz} = 166mm, r_{yy} = 51.6 mm, Diameter of rod = 12mm, Grade of Concrete = M30, Yield Strength of Steel = 250MPa, Yield Strength of Reinforcement = 500MPa, Partial Safety Factor (Structural Steel) = 1.10, Partial Safety Factor (Concrete) = 1.5, Partial Safety Factor (Reinforcement) = 1.15

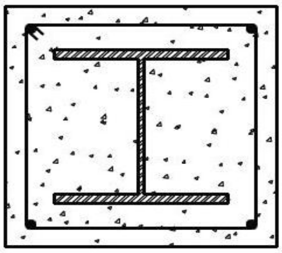

Figure 14: Profile of Concrete Encased Column

Fig. 15 shows the axial force diagram obtained for concrete encased square column.

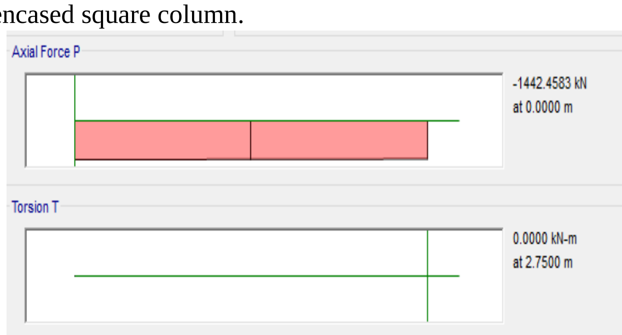

Figure 15: Axial Force Diagram (Concrete Encased Column)

F. Comparison of Analysis Results:

The following Table 2 shows the details of axial load resistance of three systems.

Table 2: Axial Load Resistance

	Actual Axial Load (kN)	Axial Load Resistance (kN)	Ratio
System 1	5801	6117	0.95
System 2	5814	6091	0.95
System 3	5900	6390	0.92

The following Table 3 shows the details of lateral deformation of three systems.

Table 3: Lateral Deformation

	Actual Deflection (mm)	Permissible Deflection (mm)	Remarks
System 1	16.20	36	Safe
System 2	11.87	36	Safe
System 3	15.36	36	Safe

V. CONCLUSION

Building frame system consists of steel column, composite concrete encased square column and composite steel encased circular column considered for the investigation. Frames were analyzed for dead, live and wind loads. Loads and combinations were considered as per relevant standards. Structural elements were designed as per IS 11384, IS 800 and Euro code. Suitable optimum column section has been adopted to resist the actual axial load on column. The axial resistance ratio for the columns with different profile ranges between 0.92 and 0.95. A reduction in lateral deformation is found to be 27% for a system with circular column and 6% for a system with square column as compared to a system with steel column. However the cost is higher for the system with composite square and circular column than a system with steel column.

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AUTHORS PROFILE

Varghese Basil Alexander, B-Tech Civil Engineering in Karunya Institute of Technology and Sciences. Area of interest and research work is in the field of Structural Engineering. Student member of Indian Geotechnical Society, Coimbatore Chapter. Filed a patent search report on Grid Formwork. Email ID: basil.d.1017@gmail.com

Dominic Aswin W., B-Tech Civil Engineering in Karunya Institute of Technology and Sciences. Area of interest and research work is in the field of Structural Engineering. Student member of Indian Geotechnical Society, Coimbatore Chapter. Email ID: dashwin5277@gmail.com

Dr.N.Anand graduated from Karunya Institute of Technology and Sciences, Coimbatore in the year 2003. He completed his Ph.D work in the area of Self Compacting Concrete Subjected to Elevated Temperature during the year 2014. Presently, he is working as Associate professor in Department of Civil Engineering, KITS, Coimbatore. He has published more than 55 research papers in International Journals and Conferences. His research areas are High performance concrete, Fire resistance of concrete and lateral load behavior of tall structures.

Ms.D.Jayalin graduated from Karunya Institute of Technology and Sciences, Coimbatore in the year 2010. She is working as Assistant professor in Department of Civil Engineering, KITS, Coimbatore. Her areas of interest are Eco friendly Buildings, Disaster Resistant Structures, and Special Concrete.