Parametric Study of Hollow Core Steel-Concrete-Steel Circular Composite Column Subjected to Eccentric Loading

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***Abstract*- In modern era construction industry has experienced high growth, due to high growth material requirements are drastically increased, to cope up with these requirements we need to think about more efficient material. Composite buildings prove to be promising for multi-story building. As a result, composite columns have recently undergone increased usage throughout the world, in a composite column both the steel and concrete would resist the external loading by interacting together by bond and friction. The concrete and steel are combined in such a fashion that the advantages of both the materials are utilized effectively in composite column. The steel tube provides formwork for the concrete, steel tubes prevent excessive concrete spalling and composite columns add significant stiffness to a frame.**

This work describes a study of composite column using finite element analysis. Finite element analysis of Hollow core Steel-concrete-steel (HC-SCS) composite columns under eccentric compression is carried out using ANSYS (workbench) software. By changing the different parameters, the behavior of (HC-SCS) composite columns under eccentric compression is to be study. The column parameters examined included the thickness of inner and outer tube; Diameter of outer as well as Inner tube and conventional column is prepared in ANSYS software. Comparison is derived based on the different results derived from above analyzed models.

***Index Terms*- Composite, Steel, Concrete, ANSYS (workbench), Column, Eccentric Loading.**

I. INTRODUCTION

A composite column is a structural element composed of two or more different materials, typically metals or concrete for construction. These materials are combined to create a column that takes advantage of the strengths of each material and provides an efficient and effective load-bearing structure.

Composite columns are commonly used in construction to support buildings, bridges, high rise structure and some special structures like poles, towers, etc. They offer several advantages over traditional single-material columns, such as improved strength, stiffness, and durability. They also allow for more efficient use of materials and can reduce the overall weight of the structure.

There are several types of composite columns, each with its own advantages and disadvantages. Here are some of the most common types:

1. Concrete filled columns
- Circular concrete filled steel tube columns
- Rectangular concrete filled steel tube columns
- Square concrete filled steel tube columns

2. Totally or partially encased columns
- Totally encased concrete filled steel tube columns
- Partially encased concrete filled steel tube columns

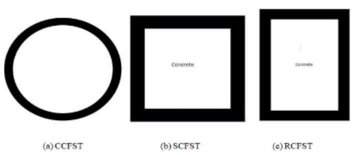


FIGURE I-1 Concrete Filled Columns

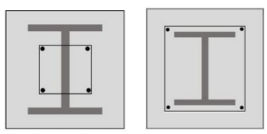


FIGURE I-2 Totally encased columnns

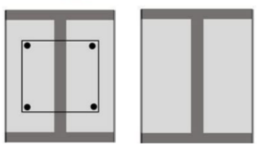


FIGURE I-3 Partially encased columns

A total 12 models are analyzed and one model [illegible]d in the ANSYS (workbench) software, with changes in the parameters mentioned below

TABLE I-1 Parameter of Column

HEIGHT	DIA. OF OUTER TUBE (D_o)	DIA. OF INNER TUBE (Di)	THICKNESS OF OUTER TUBE (T_o)	THICKNESS OF INNER TUBE (Ti)	LOADING CONDITION
500 mm	100 mm	50 mm	1 mm	1 mm	FULL
			2 mm	2 mm	HALF
	100 mm	40 mm	1 mm	1 mm	1/4TH FROM EDGE
			2 mm	2 mm	

II. FEM MODELLING OF COMPOSITE COLUMN IN ANSYS(WORKBENCH)

A. Properties of Concrete and Steel

The steel's constitutive behavior is characterized by employing an elastic-plastic model, while the properties of the concrete tube are described using bilinear attributes. In compliance with IS 456:2000, the modulus of elasticity for concrete is determined as the square root of the characteristic strength, denoted by fck. The pertinent material properties can be found in Table II-1.

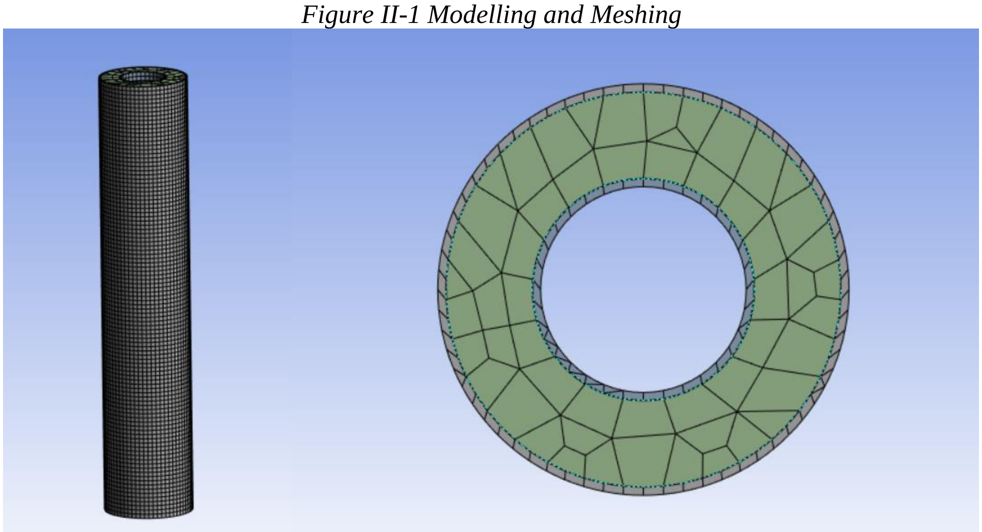
TABLE II-1 Properties of Concrete and Steel

Concrete		Structural steel	
Density [kg/mm3]	2.30E-06	Density [kg/mm3]	7.85E-06
poisson's ratio	0.18	poisson's ratio	0.3
Grade of concrete	Modulus of Elasticity [N/mm2] 5000√fck	Young modulus [Mpa]	2.00E+05
fck 30	27386.13	Yield Strength	345

B. Modelling and Meshing

An appropriate mesh for the simulation of the end plates and core concrete involves utilizing an eight-node 3-D solid element. Additionally, to accurately represent the steel tube, a four-node conventional shell element is employed. Various grid sizes are tested to ascertain the most suitable mesh configuration. Refer to Fig II-1 for a visual representation of the selected element mesh.

Figure II-1 Modelling and Meshing

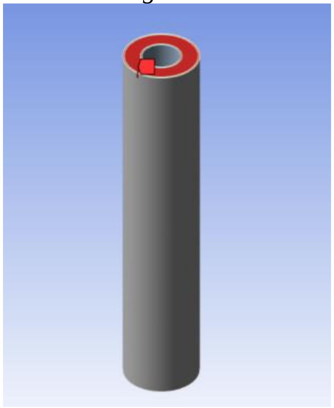


C. Application of Gradual loading

The column was designed with careful consideration, taking into account the load distribution and support conditions. As illustrated in the accompanying figure, the load was applied at the top portion of the column, while the bottom portion was supported in a hinged manner.

With precision and meticulousness, I gradually applied the load, monitoring the column's response until the critical point of buckling initiation. This method allowed for a comprehensive understanding of the column's performance and its ability to withstand various loads.

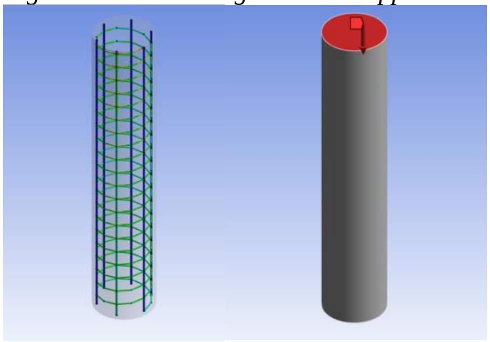
Figure II-2 Loading Condition on Column



III. FEM Modelling of Conventional Column in ANSYS(workbench)

In order to ensure compliance with the guidelines outlined in the IS 456 (2000) CODE specifications for the construction of conventional reinforced cement concrete columns, meticulous preparation was undertaken in ANSYS (workbench) software. The column was modelled using a selection of carefully chosen materials and dimensions. The reinforcement consisted of a total of six of 3 mm thick longitudinal bars, strategically placed throughout the column to enhance its strength. Additionally, to further augment the structural integrity, spiral bars with a thickness of 2 mm were incorporated in accordance with the Indian standard code, as shown in the fig III-1. The distance between the two longitudinal bars was maintained at approximately 52.35 mm, ensuring adequate spacing for effective reinforcement. Furthermore, a clear cover of 6.25 mm was applied to the column, serving as a protective layer and safeguarding the embedded reinforcement from potential damage. To complete the model, spiral reinforcement was incorporated at a distance of 25 mm apart from each other, effectively enclosing the longitudinal bars and contributing to the overall stability of the column. Lastly, the concrete used in this model was of M30 grade as we used in the previous model.

Figure III-1 Modelling and Load Application



IV. Analysis and Discussion

In these research study, total of 13 models were prepared and analyzed using the ANSYS (Workbench) software. Out of these 13 models, 12 were hollow core circular composite columns, while 1 model represented a conventional column. The aim of the analysis was to assess the behavior and performance of these different column types under various loading conditions.

To simulate realistic scenarios, different loading configurations were applied to the column models. The loading was distributed over the entire area, as well as on half and one-fourth of the top surface of the columns. These loading configurations are depicted in Figure IV-1, providing a visual representation of how the forces were distributed across the column models.

Figure IV-1 Different Loading Conditions

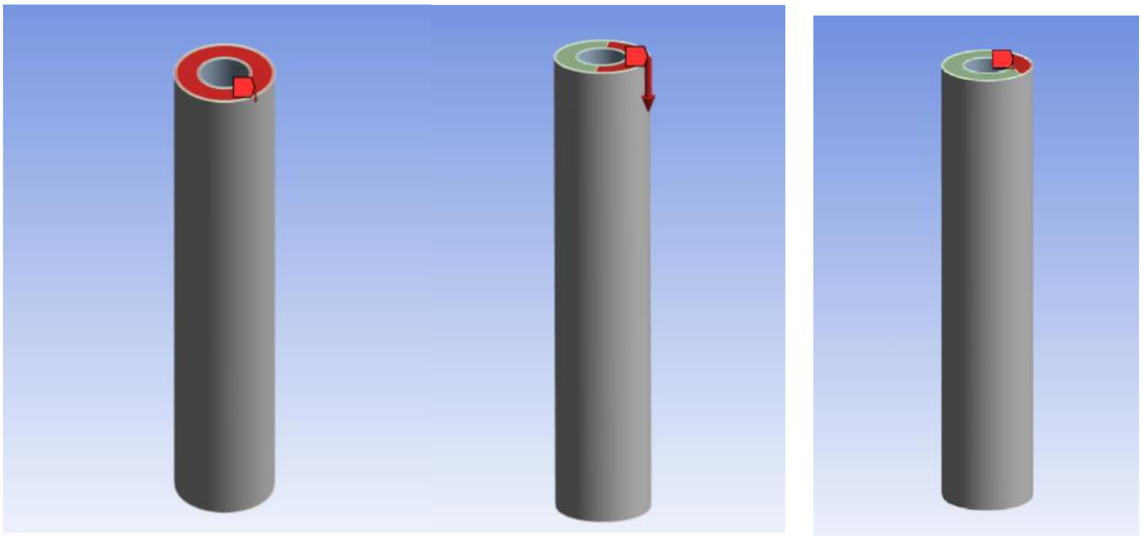


Table IV-1 Comparison of Different Model

COLUMN SIZE		THICKNESS OF TUBE	AREA OF APPLICATION OF LOAD	STATIC LOAD (N)	LOAD MULTIPLIER	BUCKLING LOAD (KN)
OUTER DIAMETER	INNER DIAMETER					
100	50	1	FULL	170000	10.478	1781.26
100	50	1	HALF	65000	29.47	1915.55
100	50	1	1/4TH	42000	36.709	1541.778
100	50	2	FULL	220000	14.506	3191.32
100	50	2	HALF	90000	38.043	3423.87
100	50	2	1/4TH	45000	56.642	2548.89
100	40	1	FULL	190000	9.47	1799.3
100	40	1	HALF	90000	23.67	2130.3
100	40	1	1/4TH	40000	37.199	1487.96
100	40	2	FULL	190000	18.77	3566.3
100	40	2	HALF	95000	39.87	3787.65
100	40	2	1/4TH	45000	70.57	3175.65
CONVENTIONAL COLUMN						
100	6NOS @ 3 mm bars spiral reinforcement @2		FULL	210000	6.469	1358.49

The table IV-1 presents the results obtained from various models, which were analyzed using the ANSYS Workbench software. The analysis of the table clearly demonstrates that the buckling load carrying capacity is lower in the conventional design of RCC column compared to the hollow core steel concrete steel circular (HC-SCS) composite column. The RCC column has a buckling load carrying capacity of 1358.49 KN, whereas the HC-SCS composite column, with dimensions of 100 mm outer diameter, 50 mm inner diameter, and a steel tube thickness of 1 mm on both sides, has a buckling load carrying capacity of approximately 1781.26 KN.

On the other hand, the static load carrying capacity is slightly higher in the case of the conventional RCC column. However, by increasing the steel tube thickness in the HC-SCS composite column to 1 mm, the static load carrying capacity surpasses that of the conventional RCC column. The reduced inner diameter of the HC-SCS column leads to an increased load resisting area, resulting in an ultimate static load carrying capacity increase of approximately 1% for a 1 mm thickness and 11-12% for a 2 mm thickness.

V. CONCLUSION

- Increasing the thickness of the steel tube enhances the buckling load carrying capacity. With a 1 mm thick steel tube, the capacity is approximately 1781.26 KN, while a 2 mm thick steel tube increases it to 3191.32 KN. This represents a significant percentage increment of 79.2%.
- Decreasing the diameter of the inside tube leads to an increase in load carrying capacity, although the difference is not substantial. Increasing the thickness of the concrete inside the column by 10 mm does not significantly affect the buckling load carrying capacity.
- Table IV-1 demonstrates that when the load is applied to half the area of the column, the buckling load carrying capacity is higher. The outer and inner tube provide significant support, allowing the column to withstand higher loads. Full area loading results in concrete crushing at an early stage. However, in terms of static load carrying capacity, full area loading can sustain more load than half area loading.
- When load is applied to only 1/4th area of the column, the column can only withstand a small portion of the load, leading to local buckling and failure at an initial level of load.
- Decreasing the diameter of the inside tube increases the concrete volume and overall area to bear the load, thus increasing the load carrying capacity.
- Comparing the conventional RCC column, which has a static load carrying capacity of approximately 210 KN, with the hollow core steel-concrete-steel circular composite (HC-SCS) column, it is evident that the HC-SCS column is much more efficient. The buckling load carrying capacity of the HC-SCS column is significantly higher than that of the RCC column.

- Overall, the research demonstrates that the HC-SCS circular composite column exhibits enhanced load carrying capacity and is a more efficient alternative to conventional RCC columns.

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