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Structural Performance and Cost Optimization of Hollow RCC Columns Compared with Solid Members Using ANSYS Workbench

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Abstract—**The present study focuses on the structural performance and cost optimization of hollow reinforced cement concrete (RCC) columns compared with conventional solid members using ANSYS Workbench. The primary objective of this research is to evaluate how introducing hollow sections within columns affects their load-carrying capacity, deformation behavior, and overall material efficiency. In this work, hollow rectangular and square cross-sections with varying hollow core areas of 2500 mm², 5625 mm², and 10000 mm² will analyz separately for columns. The finite element analysis (FEA) is performed to determine parameters such as stress distribution, deflection, and ultimate load capacity under different loading conditions. The results from hollow and solid members are compared to assess structural efficiency and material savings. This study aims to identify the optimal hollow configuration that maintains adequate structural strength while reducing the self-weight and material cost of RCC members. The findings will expect to provide practical insights for the design of lightweight and cost-effective structural systems without compromising safety and performance**

I. INTRODUCTION

In conventional RCC structures, solid columns are commonly used because of their simplicity in design and construction. However, in many cases, the concrete present near the central core of a solid column contributes less to the load-resisting mechanism when compared to the outer regions of the section. The stress distribution in a column indicates that the outer portion of the cross-section plays a more significant role in resisting loads and moments, while a portion of the inner concrete remains comparatively underutilized. This results in excessive use of concrete, increased self-weight, and higher construction costs. Hence, the concept of hollow RCC columns has gained considerable attention in recent years as an efficient alternative to conventional solid columns.

Hollow RCC columns are structural members in which a portion of the inner concrete is removed, creating a hollow core within the section. This modification helps in reducing the dead load of the structure while maintaining sufficient strength and stiffness. The reduction in self-weight directly decreases the load transferred to the foundation, thereby reducing foundation size and overall construction cost. Hollow columns are particularly beneficial in high-rise buildings, bridges, industrial structures, and seismic-resistant structures where reduction in dead load is highly advantageous. In addition, hollow sections improve material utilization efficiency and contribute toward sustainable construction by reducing the consumption of concrete.

The structural performance of hollow RCC columns depends on several parameters such as shape of the section, size of the hollow core, thickness of concrete around the hollow region, reinforcement detailing, and loading conditions. The selection of an appropriate hollow configuration is essential to ensure that the reduction in concrete does not adversely affect the load-carrying capacity, stiffness, or stability of the column. Therefore, a detailed analysis is necessary to understand the behavior of hollow columns and compare their performance with conventional solid columns.

With the advancement of computer-aided engineering and numerical simulation techniques, finite element analysis (FEA) has become an effective tool for studying the structural behavior of RCC members. Software such as ANSYS Workbench enables accurate modeling and analysis of complex structural components under different loading conditions. Using finite element analysis, parameters such as total deformation, equivalent stress, strain distribution, and load-carrying behavior can be evaluated with high accuracy. This helps in understanding the effectiveness of different hollow configurations and identifying the most efficient section for structural applications.

In the present study, RCC columns with solid and hollow sections are analyzed using ANSYS Workbench. The hollow columns are provided with rectangular and square hollow cores having hollow areas of 2500 mm², 5625 mm², and 10000 mm². The structural behavior of these hollow columns is compared with conventional solid RCC columns under similar loading conditions. The study focuses on evaluating important parameters such as deformation, stress distribution, and structural efficiency. The main objective is to identify an optimum hollow section that achieves significant reduction in self-weight and material usage while maintaining adequate structural strength and stability.

A. Structural Behavior of Hollow Columns

The structural behavior of hollow members differs from that of solid members due to the redistribution of material and stiffness around the hollow core. Key aspects include:

- Stress Distribution:

The removal of concrete from the neutral axis region (in beams) or from the core (in columns) leads to a more efficient stress distribution. The outer layers of the member, where stresses are maximum, are retained to provide strength.

- Load-Carrying Capacity:

Properly designed hollow members can achieve load-carrying capacities comparable to solid sections while using less material. The shape and size of the hollow portion influence the stiffness and ultimate strength.

- Deflection and Deformation:

Due to reduced self-weight, hollow members often show lower deflection under service loads. However, if the hollow core area is excessively large, stiffness may reduce, leading to higher deformation.

- Buckling and Stability:

Hollow columns, being lighter, may exhibit different buckling behavior compared to solid columns. However, with adequate reinforcement and concrete cover, their stability can be maintained efficiently.

- Dynamic and Seismic Response:

The reduction in mass improves the dynamic characteristics of structures, leading to better seismic performance and reduced earthquake-induced forces.

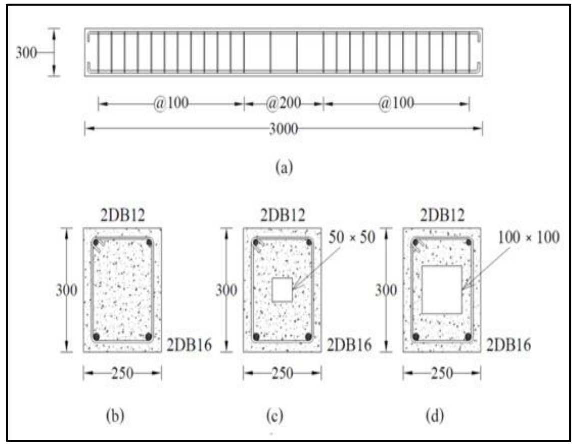


Fig 1 Hollow Beams and Columns.

II. METHODOLOGY

The research methodology defines the systematic approach adopted to achieve the study objectives and ensure reliable, reproducible, and valid results. This chapter presents the detailed steps and procedures used in analyzing the structural performance and cost optimization of hollow reinforced cement concrete (RCC) beams and columns compared with conventional solid members using ANSYS Workbench.

The methodology involves three major phases:

1. Model Development and Simulation – Creating solid and hollow RCC beam and column models with varying hollow ratios using ANSYS Workbench.
2. Structural Analysis – Conducting finite element analysis (FEA) to determine stresses, deformations, and load capacities.
3. Cost Optimization – Evaluating the reduction in material quantity and estimating corresponding cost savings.

A. Problem Statement

In conventional reinforced cement concrete (RCC) structures, columns are designed as solid members to ensure adequate strength and stiffness. However, a significant portion of the concrete especially in the core region remains underutilized in resisting applied loads, leading to unnecessary material use and increased self-weight. With rising construction costs and the demand for sustainable structural design, it becomes essential to explore alternatives that can reduce material usage and cost while maintaining adequate strength and serviceability

Column Specifications

- Overall dimensions: 300 mm × 300 mm × 3770 mm (square section)
- Reinforcement: 8 longitudinal bars of 16 mm diameter with 8 mm ties @ 150 mm c/c
- Concrete cover: 30 mm
- Hollow core configurations (same as beams):
  - Hollow Area 1: 2500 mm²
  - Hollow Area 2: 5625 mm²
  - Hollow Area 3: 10000 mm²
  - One solid column for comparison

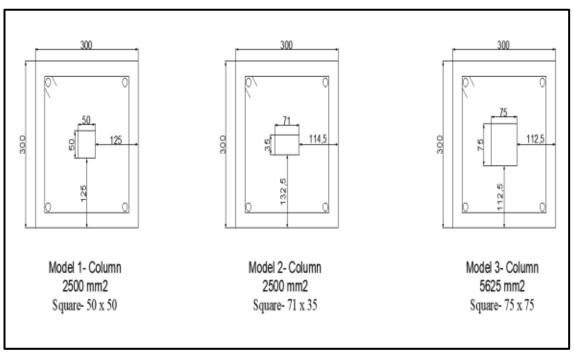


Fig 2 Plan of Model 1, 2, 3

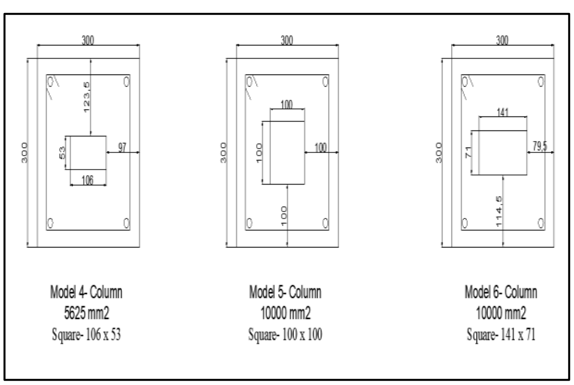


Fig 3 Plan of Model 4, 5, 6

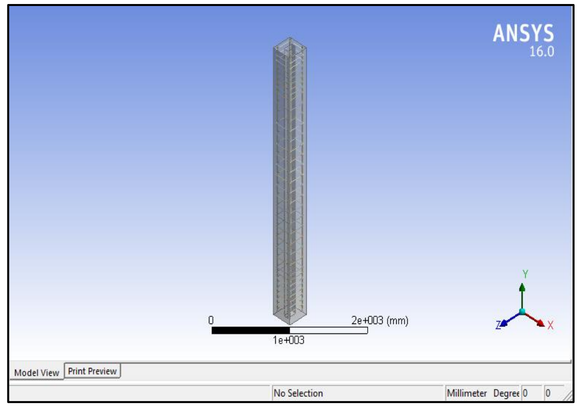


Fig 4 Column 3D model in ANSYS

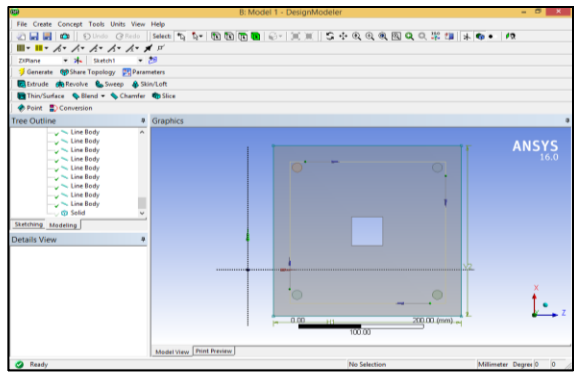
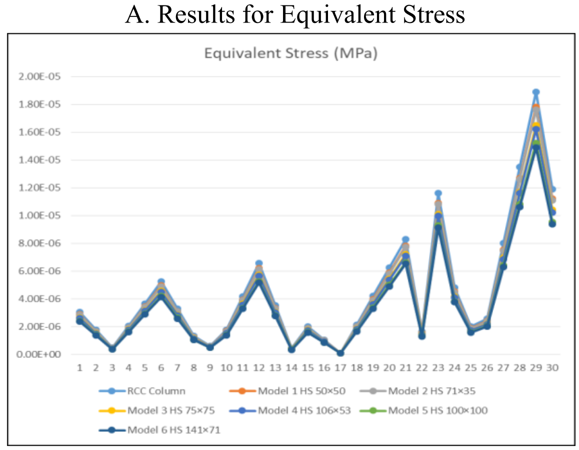


Fig 5 ANSYS Model 1 -HS50 × 50

III. RESULTS FOR TIME HISTORY ANALYSIS

A. Results for Equivalent Stress

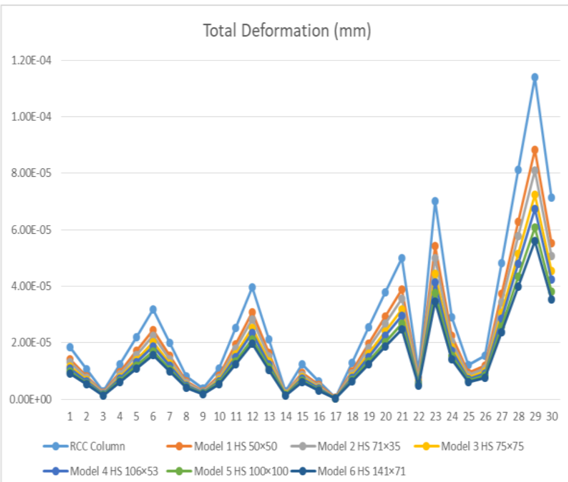


Graph 1 Results for Equivalent Stress

The equivalent stress variation of RCC and hollow RCC columns under time history loading. The RCC column exhibited the highest stress values throughout the analysis, while hollow columns showed comparatively reduced stresses. The stress values fluctuated with time due to dynamic loading effects.

Among all models, square hollow sections performed better than rectangular sections because of their uniform stress distribution. Model 1 (HS 50×50) and Model 3 (HS 75×75) showed better structural performance with controlled equivalent stress and stable behavior. Larger hollow sections such as Model 5 and Model 6 exhibited lower stiffness, which may affect overall stability. Model 1 (HS 50×50) and Model 3 (HS 75×75) were identified as the optimum hollow column configurations.

B. Total Deformation (mm)

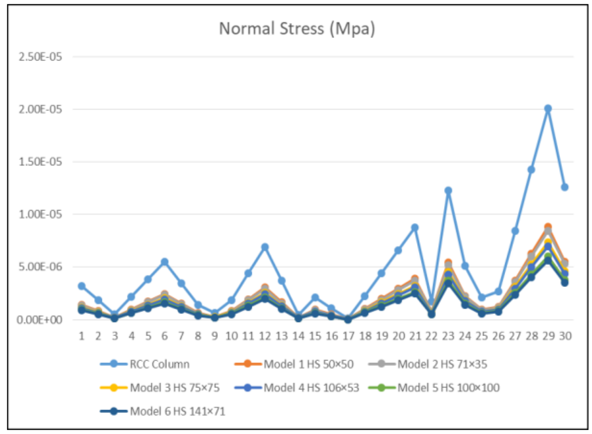


Graph 2 Results for Total Deformation (mm)

The total deformation values of RCC and hollow RCC columns under time history loading. The deformation values increased and decreased with time due to the dynamic response of the structure. The RCC column showed the highest deformation throughout the analysis, whereas all hollow column models exhibited comparatively lower deformation values.

Among the hollow sections, square hollow models showed better performance than rectangular hollow sections due to their balanced stiffness and uniform load distribution. Model 1 (HS 50×50) and Model 3 (HS 75×75) demonstrated stable deformation behavior with adequate structural stiffness. Larger hollow sections such as Model 5 and Model 6 showed lower stiffness because of higher hollow core dimensions. The maximum deformation was observed at 29 sec for all models. Therefore, Model 1 (HS 50×50) and Model 3 (HS 75×75) were identified as the optimum hollow column configurations based on deformation performance and structural stability.

C. Normal Stress



Graph 3 Results for Normal Stress

The normal stress values obtained from the time history analysis of RCC and hollow RCC columns. The RCC column showed the highest normal stress values during the entire loading duration, while all hollow section models exhibited comparatively lower stresses.

The stress values fluctuated with time due to dynamic loading effects. Square hollow sections showed more uniform and stable stress distribution compared to rectangular hollow sections. Model 1 (HS 50×50) and Model 3 (HS 75×75) demonstrated better structural performance with controlled normal stress values and improved stiffness characteristics.

The maximum normal stress was observed at 29 sec for all models. Larger hollow sections such as Model 5 and Model 6 showed lower stiffness and reduced stress resistance due to larger void areas. Therefore, Model 1 (HS 50×50) and Model 3 (HS 75×75) were identified as the optimum hollow column models.

VI. CONCLUSION

- The present study investigated the structural behavior of hollow reinforced cement concrete (RCC) columns using finite element analysis in ANSYS Workbench. Different hollow core configurations with square and rectangular sections were analyzed and compared with a conventional solid RCC column under time history loading conditions. The study mainly focused on evaluating equivalent stress, total deformation, normal stress, and maximum principal elastic strain.

- From the analysis results, it was observed that the hollow RCC columns exhibited satisfactory structural performance while reducing the quantity of concrete used. The equivalent stress and normal stress values of hollow columns were comparatively lower than those of the conventional RCC column, indicating efficient stress distribution within the structural member. The deformation and strain values increased slightly with increase in hollow core size due to reduction in stiffness; however, the behavior remained within acceptable limits.
- Among all the hollow configurations considered, the square hollow sections performed better than the rectangular hollow sections because of their uniform geometry and balanced stiffness characteristics. Model 1 (HS 50×50) and Model 3 (HS 75×75) demonstrated better overall structural performance with controlled stresses, moderate deformation, and stable strain behavior throughout the time history analysis.
- The cost analysis also indicated that hollow RCC columns can reduce concrete consumption and overall construction cost. Model 3 (HS 75×75) provided the maximum material saving and better cost efficiency, while Model 1 (HS 50×50) showed balanced structural stability with economic performance. Even after considering thermocol filler cost, the hollow columns remained more economical than the conventional RCC column.
- The study concludes that hollow RCC columns can be effectively used as an alternative to solid RCC columns for achieving structural efficiency, reduction in self-weight, and economical construction. Among the analyzed models, Model 1 (HS 50×50) and Model 3 (HS 75×75) were identified as the optimum hollow column configurations based on structural performance and cost effectiveness.

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