

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

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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 analyze 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

Reinforced Cement Concrete (RCC) is one of the most widely used construction materials due to its strength, durability, and adaptability to various structural forms. However, with the continuous growth in infrastructure demands, there is a strong need to develop economical and efficient structural members that reduce material consumption without compromising performance. One of the promising approaches to achieve this is the use of hollow sections in beams and columns, which can significantly reduce self-weight and cost while maintaining sufficient load-carrying capacity.

In traditional RCC structures, solid beams and columns are designed to resist both bending and axial loads. Although these solid members provide high strength, a considerable portion of the concrete, particularly in the core regions, remains underutilized in terms of stress distribution. Replacing these low-stressed regions with hollow sections can result in a more efficient use of materials, leading to lighter structures and reduced construction costs.

The development of advanced computational tools such as ANSYS Workbench allows for detailed finite element analysis (FEA) of complex structural models, making it possible to accurately simulate and study the behavior of hollow and solid RCC members under various loading conditions. Through such analysis, critical parameters such as deflection, stress distribution, and ultimate load capacity can be evaluated to determine the most effective hollow configuration.

A. Hollow Columns

Hollow structural members are concrete or composite elements that contain a void or hollow core within their cross-section. Unlike conventional solid reinforced concrete (RCC) members, hollow beams and columns are designed to eliminate unnecessary concrete from regions that contribute little to structural strength. This concept is inspired by the natural efficiency of hollow forms found in nature (such as bones or bamboo), which combine strength and lightness effectively.

In structural engineering, hollow sections are primarily used to reduce self-weight, minimize material consumption, and enhance the performance of structural systems under various loading conditions.

The hollow portion can be circular, square, or rectangular depending on the design requirements and formwork constraints. In RCC construction, hollow members can be created using plastic, steel, or foam inserts placed during casting, or by using pre-cast segments with voids.

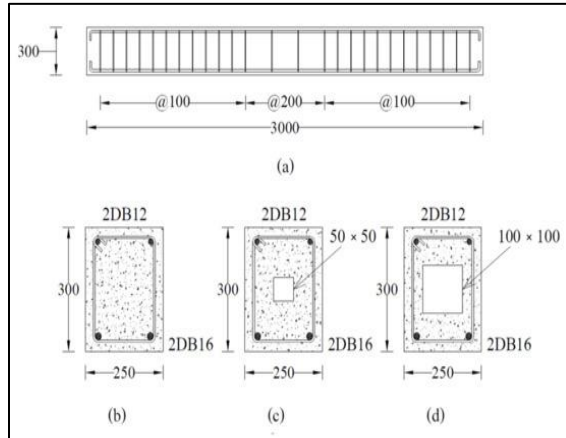


Fig 1 Hollow Columns.

II. STATE OF DEVELOPMENT

A literature review forms the foundation of any research work, as it helps to identify existing knowledge, research gaps, and the direction for further study. The development of hollow reinforced cement concrete (RCC) structural members has been an evolving topic of interest among researchers aiming to achieve lightweight, economical, and sustainable construction systems.

Several studies have been carried out to analyze the structural performance of hollow beams and columns, the effect of voids on stiffness and strength, and the cost optimization achieved by reducing material usage. With advancements in finite element analysis (FEA) tools such as ANSYS Workbench, it has become possible to simulate realistic behavior and optimize hollow structural designs effectively. This chapter presents a comprehensive review of previous research relevant to hollow RCC members, their behavior, applications, and numerical analysis methods

[1] Haider M. Abdulhusain et al. (2020)

This study reviews experimental and numerical investigations on hollow reinforced concrete beams (HRCB). It highlights that removing concrete from

low-stress zones reduces weight, material usage, and seismic forces without significantly affecting load capacity. The study also emphasizes sustainability benefits such as reduced CO₂ emissions. Additionally, hollow sections allow easy passage of utilities. Overall, HRCBs are efficient and economical structural elements.

[2] Hadi Naser Ghadhban Al-Maliki et al. (2021)

This research investigates the structural behavior of hollow RC beams under partial uniformly distributed loads using ANSYS software. The results show that hollow beams maintain adequate strength while reducing weight. Failure modes were primarily diagonal shear failures. The numerical results closely matched experimental findings. The study confirms the reliability of FEM analysis.

[3] Ibrahim A. Sharaky et al. (2021)

This study analyzes the flexural response of RC beams with openings at different locations and sizes. It was found that openings near the center significantly reduce load capacity compared to those near supports. Longitudinal holes had the least impact on strength. Beam length and opening position strongly influence failure modes. Predictive equations were also proposed.

[4] M. Longshithung Patton et al. (2023)

This paper compares HST, RCC, and CFST columns under axial compression. Results show CFST columns significantly improve load-carrying capacity compared to RCC and HST. Finite element analysis closely matched experimental results. Strength enhancement was observed up to 2–2.9 times. The study highlights CFST as an efficient structural system.

[5] Ali Said Alnuaimi et al.

This study compares hollow and solid RC beams under combined loading. Solid beams showed higher cracking and failure loads than hollow beams. However, the concrete core in hollow beams contributes to strength. The performance depends on torsion-to-bending ratios. Hollow beams are economical but slightly weaker than solid beams.

[6] Ashraf Mohamed Mahmoud (2011)

This research presents finite element modeling of hollow RC columns strengthened with FRP laminates.

CFRP showed better performance compared to GFRP in enhancing load capacity. The developed model closely matched experimental results. Only a small reduction in strength was observed when using GFRP. The study recommends CFRP for strengthening.

[7] Suniti Suparp et al. (2023)

This study evaluates solid, hollow, prismatic, and non-prismatic RC beams experimentally and numerically. Results indicate that non-prismatic sections reduce shear demand. Hollow beams showed comparable behavior to solid beams. GFRP reinforcement performed similarly to steel. Numerical results agreed well with experimental findings.

[8] P. Gokul et al. (2024)

This research investigates RC beams with openings filled with hollow square sections. Openings reduced strength and increased deflection. However, filling the openings improved performance compared to empty ones. Finite element analysis validated the behavior. Crack patterns and load-deflection responses were studied.

[9] Nasr Z. Hassan et al.

This study examines RC beams with PVC pipe openings in the tension zone. Small diameter openings had negligible effect on strength and stiffness. Larger openings reduced capacity and caused brittle shear failure. Crack width increased in hollow beams. Numerical results showed good agreement with experiments.

[10] Murtada A. Ismael et al. (2022)

This study investigates hollow-core self-compacting concrete beams with different void sizes. Concrete volume reduction up to 14.2% was achieved with minor strength loss. An optimal void size was identified for best performance. Sustainability benefits include reduced energy and CO₂ emissions. Larger voids increased ductility.

[11] Haitham Jameel Abd et al. (2024)

This numerical study evaluates the effect of size, shape, and number of openings in RC beams. Larger openings significantly increased deformation and reduced strength. Circular openings performed better than square or rectangular ones. Increasing the number

of openings reduced load capacity. Opening geometry plays a key role.

[12] Abdul Muttalib I. Said et al. (2024)

This study investigates hollow concrete columns reinforced with GFRP bars. Increasing GFRP ratio improved load capacity significantly. However, steel reinforcement contributed more due to higher stiffness. Experimental and numerical results were in close agreement. GFRP offers a corrosion-resistant alternative.

[13] Waseem Khan et al. (2024)

This study analyzes the effect of notches and repair materials on RC beams. Increasing notch size reduced load capacity. Repair materials improved strength, especially adhesives. Bacterial mortar performed better than cement mortar. Numerical and experimental results were closely matched.

[14] Jain Jo et al. (2014)

This study proposes RC beams with hollow neutral axis using PVC pipes. Concrete near the neutral axis contributes little to strength. Removing it reduces self-weight and cost. Experimental and analytical results showed acceptable performance. The concept is economical and practical.

[15] Afra Pareed et al. (2019)

This research studies hollow core RC beams using PVC pipes at different depths. Results show reduced material usage and self-weight. Strength reduction was minimal. Beams performed well under flexural loading. The method improves sustainability and cost efficiency.

[16] Mayadah Falah et al.

This study investigates hollow RPC columns strengthened with CFRP under loading. CFRP confinement slightly improved load capacity. Performance depended on thickness and placement of CFRP. Both axial and eccentric loads were analyzed. The study confirms CFRP effectiveness.

[17] Siddharth A. Gaikwad et al. (2017)

This paper analyzes hollow RC columns in building design. Hollow columns reduce self-weight and foundation size. Software analysis showed improved efficiency. The design is economical and suitable for

seismic conditions. Hollow columns are advantageous over solid ones.

[18] Sherin G Ponnachen et al. (2017)

This study compares seismic performance of hollow and solid RC members. Hollow members reduced seismic mass and forces. Analysis showed lower storey shear and drift. Performance of hollow structures was better. The study supports their use in buildings.

[19] Gurudath C. et al. (2021)

This research evaluates seismic performance of hollow and solid RC members. Hollow members reduced displacement, shear, and overturning moments. Response spectrum analysis showed improved behavior. Hollow sections enhanced structural efficiency. They are beneficial in seismic regions.

[20] Mona Abd ELmaguid et al. (2021)

This review discusses behavior of hollow RC columns with openings. Openings reduce cross-sectional area and load capacity. However, they are required for functional needs. The study highlights design considerations. Proper design ensures balance between strength and utility.

III. SUMMARY OF LITERATURE

A review of the existing literature reveals that several studies have explored the behavior of hollow reinforced concrete members to reduce self-weight and material consumption. However, most of these investigations have focused primarily on either hollow beams or hollow columns individually, with limited research comparing both elements under similar design and loading conditions. Moreover, many previous works examined circular or irregular hollow sections, while rectangular and square hollow configurations which are more practical and commonly used in construction have not been comprehensively studied. Another significant gap is that most available studies are experimental in nature, involving small-scale specimens, and very few have utilized finite element analysis (FEA) using ANSYS Workbench to accurately simulate stress distribution, deflection behavior, and load-carrying capacity of hollow RCC members. Additionally, the effect of varying hollow core areas on the structural strength,

stiffness, and cost efficiency of RCC columns has not been systematically compared.

IV. GAP IDENTIFICATION

- Performing a comparative finite element analysis of hollow and solid RCC beams and columns using ANSYS Workbench.
- Analyzing different hollow areas (2500 mm², 5625 mm², and 10000 mm²) with rectangular and square cross-sections to determine the optimal configuration.
- Evaluating both structural performance and cost optimization to establish a balance between material efficiency and strength.

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- IS 3370:2009 – Concrete Design Parameters
- IS 10262:2019 – Concrete Mix Proportioning