Elastic And Strength Based Studies of Concrete In-Filled Steel Tubular Section With Its Behaviour

Atul Wadhi[1], Pallavi Bhende[2], Assistant Prof. Kshitij Thate[3]
[1]Dept of Computer Aided Structural Engineering
[2] Professor,Dept of Civil Engineering
[1, 2, 3] Wainganga College of Engineering & Management, Nagpur,India

Abstract- *Reinforced cement concrete is a highly versatile and widely used construction material, essential for its ability to enhance tensile strength through the incorporation of twisted steel bars of varying diameters. Structural hollow steel sections, when filled with concrete, offer numerous advantages, such as increased load-carrying capacity and reduced sectional dimensions, leading to more slender and efficient members. These sections eliminate the need for formwork during casting and installation, reducing labor and cost as they do not require reinforcement fabrication. Additionally, while concrete is protected from fire hazards by being encased in steel, the steel itself is prone to corrosion; however, this can be mitigated with appropriate anti-rust or anti-corrosive coatings. Precast elements have become increasingly popular in modern construction, particularly in housing, and are valuable for repairs and retrofitting in cases of structural damage due to natural disasters or the need for rehabilitating old structures. This project focuses on confining concrete within hollow steel tubes, enhancing the elements' load-carrying capacity, flexural stiffness, and rigidity. These concrete-filled tubes are then evaluated against hollow tubes of the same dimensions, comparing their flexural and compressive strengths through finite element analysis and corresponding graphical representations.*

Keywords- Reinforced cement concrete (RCC), Twisted steel bars, Tensile strength, Structural hollow sections, Load-carrying capacity, Reduced sectional dimensions

I. INTRODUCTION

Reinforced cement concrete (RCC) has become a cornerstone in construction due to its enhanced tensile strength provided by steel reinforcements. Typically, steel TMT or HYSD bars, varying from 8mm to 32mm in diameter, are embedded within the concrete to counteract its poor tensile strength. This combination of concrete and steel creates a material capable of withstanding diverse stresses, making RCC one of the most versatile and widely used construction materials available today.

Concrete itself is a composite material composed of four main components: Ordinary Portland Cement (OPC), fine aggregates (ranging from 600 microns to 4.75mm), coarse aggregates (ranging from 4.75mm to 12.5mm), potable water, and admixtures. Self-Compacting Concrete (SCC) represents a significant advancement in concrete technology. SCC can flow and consolidate under its own weight without the need for mechanical vibration, which not only reduces labor requirements by over 50% but also enhances the quality of the finished structure by minimizing defects like bugholes and honeycombing (RILEM, 1999).

In modern construction, particularly in the housing sector, structural hollow steel sections filled with concrete are increasingly favored. These sections serve as efficient compression members and eliminate the need for traditional reinforcement and formwork. Filling these hollow sections with concrete improves their load-bearing capacity and reduces the overall section diameter, offering practical advantages such as increased durability and fire resistance. Moreover, these sections protect the concrete from environmental exposure, although the steel itself may require protective coatings to prevent corrosion. This method finds extensive applications in precast elements, maintenance, repair, rehabilitation, and retrofitting projects, providing a robust solution that simplifies construction processes and enhances structural integrity.

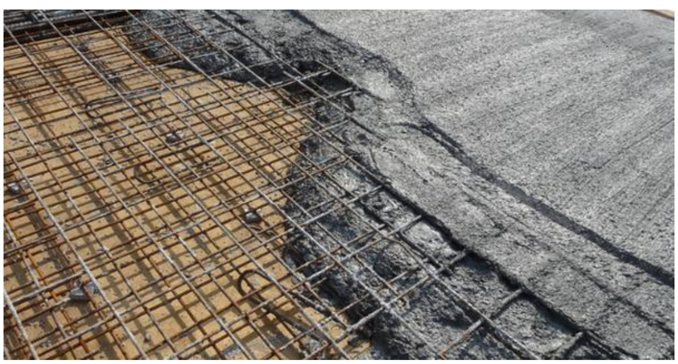

Fig.1 RCC

The need for this study arises from the numerous benefits of concrete-filled tubular sections, including eliminating formwork, negating the need for reinforcement fabrication, and protecting the concrete from environmental exposure. Furthermore, while concrete is vulnerable to fire hazards, confining it within steel tubes enhances its resistance compared to conventional methods. The scope of the work is confined to experimenting with hollow rectangular steel sections of 1 gauge measure and one grade of SCC concrete of M20. The study focuses on testing the flexural and compressive strengths and comparing experimental results with analytical predictions to validate the effectiveness of this construction approach.

II. LITERATURE REVIEW

Brian Uy et al. explores the renewed global interest in concrete- filled steel box columns, attributing their resurgence to the substantial benefits offered by this construction method. The paper delves into the strength behavior of short columns subjected to both axial compression and bending moments, focusing on how the slenderness limits of steel plates influence this behavior. A comprehensive series of experiments were conducted, complemented by the calibration and enhancement of a pre-existing numerical model. Additionally, a straightforward model for determining the strength-interaction diagram was validated against both experimental results and the developed numerical model. Although the rigid plastic method of analysis used in international codes of practice does not consider local buckling effects, these effects are shown to be significant, especially with larger plate slenderness values and higher axial forces. Consequently, the paper suggests modifications to include slender plated columns in design calculations.

Kenji Sakino et al. conducted a five-year research project as part of the U.S.–Japan Cooperative Earthquake Research Program, focusing on concrete-filled steel tubular (CFT) columns. The study aimed to elucidate the synergistic interaction between steel tubes and the concrete they encase and to establish methods for characterizing the load-deformation relationship of CFT columns. In the experimental phase, 114 specimens were tested under central loading conditions. The research examined various parameters, including tube shape, tensile strength, diameter-to- thickness ratio, and concrete strength, to develop a broadly applicable design method for CFT columns. Based on the test results, design formulas were proposed to estimate the ultimate axial compressive load capacities for both circular and square CFT columns.

W. F. Chen and C. H. Chen investigated the elastic-plastic behavior of pin-ended, concrete-filled steel tubular columns subjected to symmetrical and asymmetrical loading. The study utilized the Column Curvature Curve method to analyze columns with circular and square cross-sections. Three stress-strain relationships for concrete were considered: uni-axial stress, tri-axial stress (increasing ductility but not strength), and tri-axial stress (increasing both ductility and strength). Using these stress-strain curves, the researchers developed interaction curves relating axial force, end moment, and slenderness ratio for maximum load capacity. The results showed good agreement with previously reported experimental data.

Arivalagan S. and Kandasamy S. examined the flexural and cyclic behavior of steel hollow beam sections filled with various types of concrete, including normal mix, fly ash concrete, quarry waste concrete, and low-strength brick-bat-lime concrete. Strain and deflection measurements were taken under two-point loading conditions. A theoretical model was developed to predict the moment-carrying capacity of the beams, and the results were compared with international standards (EC4-1994, ACI-2002, and AISC-LRFD-1999). The study found that the moment-carrying capacity of the beams increased with the compressive strength of the filler materials, and the energy absorption capacity was also enhanced. The analytical results closely matched the experimental findings.

Yaohua Deng et al. conducted an analytical investigation into the flexural behavior of concrete-filled steel tubes (CFTs) and post-tensioned CFTs. The study employed finite-element analysis (FEA) using an elastic-perfectly plastic uniaxial material model for steel and the Drucker-Prager plasticity model for concrete. The theoretical sectional analysis (TSA) involved dividing the cross-section of circular CFT members into horizontal layers parallel to the axis of bending. The study applied the elastic- perfectly plastic uniaxial material model to the steel tube and incorporated confined concrete theory for the concrete core. The results highlighted the composite nature of CFTs, which leverage the strengths of both concrete and steel.

III. EXPERIMENTAL STUDIES

Material used

1. **Cement:**

Any cement meeting Indian Standards is suitable for concrete. The choice depends on strength requirements, durability exposure class, and the minimum fines needed for the mix.

2. **Fine Aggregates:**

Sand fills voids between powders and coarse aggregates, ensuring cohesion and resistance to segregation. Well-graded sand, including particles finer than 150 microns, enhances mix stability.

3. Coarse Aggregates:

Concrete uses normal concreting aggregates, with a maximum size of 40mm, adjusted for reinforcement and formwork. For this project, the size is limited to 12.5mm. Natural aggregates use less water than crushed ones; elongated aggregates are unsuitable.

4. Water:

Potable borewell water, compliant with Indian Standards, is used for mixing and curing concrete.

5. Admixtures:

Admixtures control flow and workability. Super plasticizers are crucial for SCC. Other types include Viscosity Modifying Agents (VMA) for stability, Air Entraining Admixtures (AEA) for freeze-thaw resistance, and retarders for setting control. Additional admixtures like ultra-fine silica or air-entrainers may be needed for segregation control.

Fig. 2 Material Used

Role of Superplasticizers:

Superplasticizers enable the creation of flowing concretes with slumps up to 250mm without significant bleeding, provided an adequate cement factor is used. Originating in the 1970s, these admixtures allow for highly flowable and cohesive concrete, reducing segregation and bleeding. The key to effective SCC and other flowable concretes is combining superplasticizers with a high content of powder materials, including Portland cement, mineral additions, ground filler, and fine sand. Partial cement replacement with fly ash enhances rheological properties, segregation resistance, strength, and crack prevention in mass concrete structures subject to thermal stresses. Coarse aggregates smaller than 20mm are preferred for optimal performance.

IV. CONCLUSION

The study revealed that both hollow and in-filled specimens possess distinct advantages and disadvantages. In-filled specimens exhibited a significantly higher load-carrying capacity compared to hollow specimens, indicating their superior performance in structural applications. During flexure testing, the failure mode of in-filled specimens was characterized by cracking on the tensile face, showcasing their ability to withstand tensile stresses better than their hollow counterparts. On the other hand, hollow specimens primarily failed due to local buckling at the points of loading, a behavior well-documented in the photographs taken during the testing process. This comparison highlights that while in-filled specimens are more robust in terms of load- bearing, hollow specimens may be more susceptible to deformation under localized stress, emphasizing the need to consider the specific application requirements when choosing between these two types of structural elements.

REFERENCES

[1] E. K. Mohan Raj, S. Kandasamy, and A. Rajaraman, "Seismic behaviour of concrete filled steel tubular beams," Kongu Engineering College, India; Anna University Tiruchirappalli, India; Indian Institute of Technology Madras, India.

[2] S. Aminuyunusa, "Behavior of concrete in filled duplex stainless steel circular columns and beams," M. Tech thesis, Dept. of Structural Engineering, SRM University, Chennai, India.

[3] M. Elchalakani, X. L. Zhao, and R. H. Grzebieta, "Concrete-filled circular steel tubes subjected to pure bending," Journal/Conference details if available.

[4] W. F. Chen and C. H. Chen, "Analysis of concrete filled steel tubular beam-columns," Journal/Conference details if available.

[5] B. Uy, "Strength of concrete filled steel box columns incorporating local buckling," Sr. Lecturer in Civil Engineering, School of Civil and Environmental Engineering, University of New South Wales, Sydney, NSW 2052, Australia.