Ain Shams University
Faculty of Engineering
Department of Structural Engineering - Reinforced Concrete Structures

Flexural Behavior of Hollow Reinforced Concrete Encased Steel Tube Composite Beams

By

Mohammad Mostafa El Basha Ibrahim Abo El Fotoh
B.Sc. Civil Engineering - Ain Shams University, 2006
M.Sc. Structural Engineering Division
Civil Engineering
Ain Shams University, 2012

A Thesis

Submitted in Partial Fulfillment of the Requirements

For the Degree of the Doctor of Philosophy (Ph.D.) in Civil Engineering

Structural Engineering - Reinforced Concrete Structures

Supervisors

Prof. Dr. Omar Ali Mousa El-Nawawy
Professor of R.C. Structures
Structural Engineering Department
Faculty of Engineering
Ain Shams University

Prof. Dr. Tarek Kamal Hassan
Professor of R.C. Structures
Structural Engineering Department
Faculty of Engineering
Ain Shams University

Dr. Mohamed Nabil Mohamed Mohamed
Assistant Professor
Structural Engineering Department
Faculty of Engineering
Ain Shams University

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<u>Examiners' Committee</u>

Name and Affiliation	**Signature**
Prof. Dr. Hesham Marzouk Professor of Structural Engineering Ryerson University, Canada	
Prof. Dr. Ali Sherief Abd El-Fayad Professor of Reinforced Concrete Structures Faculty of Engineering Ain Shams University, Cairo, Egypt	
Prof. Dr. Omar Ali Mousa El-Nawawy Professor of Reinforced Concrete Structures Faculty of Engineering Ain Shams University, Cairo, Egypt	
Dr. Tarek Kamal Hassan Professor of Reinforced Concrete Structures Faculty of Engineering Ain Shams University, Cairo, Egypt	

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Statement

This thesis is submitted as a partial fulfillment of Doctor of Philosophy in Civil Engineering, Structural Engineering, Reinforced Concrete Structures, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Mohammad Mostafa El Basha Ibrahim Abo El Fotoh

Signature

Mohammad Mostafa El Basha

Date:14 August 2018

Researcher Data

Name : Mohammad Mostafa El Basha Ibrahim Abo El Fotoh

Date of Birth : October 27th, 1983

Place of Birth : Cairo, Egypt

Qualifications : B.Sc. Civil Engineering (Structural Engineering)
Faculty of Engineering, Ain Shams University, 2006

Cumulative Grade : Excellent – With Honor Degree

Project Type/Grade : Reinforced Concrete Structures / Excellent

Last academic degree : M.Sc. Civil Engineering - Structural Engineering Division
Reinforced Concrete Structures, Ain Shams University, 2012

Field of specialization : Reinforced Concrete Structures

University issued the degree: Ain Shams University

Date of issued degree : 2012

Current Job : University Assistant Teacher, Civil Engineering
Structural Engineering Department,
Reinforced Concrete Structures,
Faculty of Engineering, Ain Shams University,
Cairo, Egypt

Signature : *Mohammad Mostafa El Basha*

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Abstract

Composite construction employs structural members that are composed of two materials: structural steel (rolled or built-up) and reinforced concrete, concrete encased steel tube (CEST) is an example of composite members. Concrete encased steel tubes (CESTs) are efficient members in structural applications including high rise building & bridges, and their use in the building industry is increasing. The concrete encased steel tube (CEST) composite beam members have many advantages compared with the conventional concrete structural members. Steel members have the advantages of high tensile strength and ductility, while concrete members have the advantages of high compressive strength and stiffness. Composite members combine steel and concrete, resulting in a member that has the beneficial qualities of both materials. It is widely recognized that the innovative use of two or more material in structures generally leads to more efficient economical systems. Concrete encased steel tube (CEST) composite beams offer significant advantages over the conventional beams made of either steel or concrete alone, such as large energy dissipation (large energy absorption capacity) and increased strength and stiffness. In this area utilizing of concrete encased steel tubes are new idea which increasingly finding application in design practice. This type of composite beams possess excellent flexural resistant properties such as high strength and

ductility. Hollow (CEST) composite beams that can provide an economical form of construction as the hollowed part of the composite beam could be used to reduce the self-weight of the member. Despite the excellent engineering properties of these types of composite beams, they are not as widely used as traditional structural steel and reinforced concrete members. To date their primary use has been in axial applications, with the design methodology based on theory and tests of columns under loads applied axially or at relatively small eccentricities. Limited in to research into the behavior of CESTs subjected to large eccentricities or loading in pure flexural loading have been conducted. Composite framing system consisting of hollow concrete encased composite beams, has been as a viable alternative to the conventional steel or reinforced concrete system in the high-rise construction because of their construction efficiency and provision of high stiffness and strength. Complications in the analysis and design of composite structures have led numerous researchers to develop simplified methods so as to eliminate a number of large scale tests needed for the design. Current design codes and standards provide little information on the flexural behavior of hollow CEST composite beams as there have been few experimental studies.

An ongoing research program on the hollow CEST composite beams is being undertaken at the University of Ain Shams with a particular emphasis on the flexural behavior of this type of composite beams.

This paper presents experimental and analytical research programs to investigate the flexural behavior of hollow CEST composite beams subjected to pure bending and to find out the ultimate moment carrying capacity for the tested composite beams. Experimental results from nine simply supported hollow (CEST) composite beams subjected to pure flexure loading by applying vertical concentrated load in the mid-span of the beam, are provided in this paper. The beam specimens were one RC solid beams of dimensions 250x600 mm in cross sections, two RC solid beams of dimensions 250x480 mm in cross sections and six hollow CEST composite beams of dimensions 250x480 mm in cross sections with hollow rectangular steel tube with variable dimensions / spans. All specimens were 6100 mm long. Three-dimensional non-linear finite element analysis adopted by ATENA software till failure is performed to predict the flexural behavior of this type of composite beams and to investigate the load versus lateral deflection behavior of this type of composite beams. For the purpose of validation of the finite element model developed, the numerical study was carried out on a nine simply supported concrete beam that was experimentally tested. The Analytical models have been used also in a parametric study to examine the effects of dimensions & thickness of the steel tube, and the area of the hollowed part, which could be used to reduce the self-weight of the member. The results obtained from experimental and analytical research programs is used to compare the behavior of traditional reinforced concrete solid beams with the hollow CEST composite beams under pure bending and compare the predictions (results obtained) from the FEA (Finite Element Analytical) model with the experimental results. The effects of steel tube area, dimensions, depth, thickness and length of hollow CEST composite beams are examined. Failure modes of this type of composite beams under pure flexural loading are determined. The benefits of this type of composite beams have been demonstrated experimentally and analytically. The load-carrying capacity of each beam specimen has been obtained.

The predictions from the FEA model are in reasonably close agreement (in a good agreement) with the experimental results. Analytical results show good agreements with experimental results. Experimental results were found to be in good agreement with the predicted values. The FE analytical model presented in this paper is capable of predicting the flexural load strength of hollow CFST composite beam members. In comparison with the conventional solid reinforced concrete beam specimens, larger elastic deformation, higher strength, higher ductile behavior were observed in the hollow CEST composite beams. The test results indicate that the behavior of this type of composite beams is greatly affected by the steel tube. The test results indicate that the failure mode of the tested beam specimen is crushing of concrete at the middle at the compression top side of each beam at mid-span. The results presented in this paper show that these hollow CEST composite beams have a ductile response because the steel tube provides ductile longitudinal reinforcement. The solid beams' flexural response, including the flexural stiffness, ultimate load, and cracking, can be substantially improved by introducing steel tubes in the tension side of the solid beams. The test results indicate also that the behavior of the hollow CEST composite beam is greatly affected by the steel tube area / depth.

List of Figures