LOCAL AND POST LOCAL BUCKLING OF HOLLOW AND CONCRETE FILLED BOX STEEL TUBES

By

Omar Saber Rizq Hassan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Structural Engineering

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Title of Thesis:

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Key Words:
Concrete Filled Steel Tube (CFT); Hollow Steel Section ; Local Buckling; Post Local Buckling; Finite element analysis.

Summary:
This research studies the local and post local buckling behavior of hollow and concrete filled box steel tubes. ANSYS program is used to model the specimens. The critical stresses and buckled shapes of ANSYS are compared to their corresponding results of experiments and mathematical solution. Eighty four models are implemented to conduct the parametric study which determined the effects of section slenderness ratio b/t ,yield strength of steel tube, and concrete infill on initial buckling stress σ_L , post local buckling stress σ_u, non dimensional critical stress σ_L/σ_y , and reserve strength σ_r which is gained due to the post local buckling.

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to Salwa Alawam

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Abstract

In this thesis, the local and post local buckling of hollow and concrete filled square steel tubes was investigated. An outline of composite columns behavior, past experimental work, and theoretical study on local and post local buckling were presented. The adopted design equations of concrete filled steel tube columns in AISC-LRFD specifications, Eurocode4, and Egyptian code of practice LRFD were also presented.

A finite element model used in the analysis of hollow and concrete filled steel tube columns was conducted using the general purpose finite element program ANSYS. The concrete infill is modeled using three dimensional structural solid elements (solid 65) which capable of cracking and crushing whereas the steel tube is modeled using solid 45. One of the difficulties of modeling the concrete filled steel tube columns in ANSYS is modeling the interface element between concrete and steel surfaces, the element type used and the input coefficient values are discussed. Local buckling takes place when the ability of steel tube to separate from concrete core is achieved. The material model used for concrete accounts for cracking, crushing, and nonlinear behavior. The material model used for steel accounts for yielding. The parameters values used to define concrete and steel material in ANSYS are explained. Solution accuracy and convergence are affected significantly by mesh density so mesh sensitivity analysis using the structural error energy method is performed. The boundary conditions of all models are applied according to the experimental specimens conditions to obtain accurate results. The results obtained from the finite element models are compared with that of experimental tests for verification.

A parametric study conducted to determine the effects of section slenderness ratio b/t ,yield strength of steel tubes, and concrete infill on initial buckling stress σL , post local buckling stress σu, non dimensional critical stress $\sigma L/ \sigma y$, and reserve strength σr gained due to the post local buckling occurrence in hollow and filled sections . Eighty four models were implemented to study the effects of each independent variable.

The influence of each parameter was studied by varying its value independently within practical limits whereas the other parameters were unchanged. The values of initial buckling stress σL , post local buckling stress σu, non dimensional critical stress $\sigma L/ \sigma y$, and reserve strength σr are monitored while varying the independent variables. Stress-lateral deflection and Stress-axial shortening curves are plotted.

Chapter (1)

Introduction

1.1 General

The most popular materials in construction industry are steel and concrete due to their advantageous mechanical properties and behavior. Composite columns utilize the advantages of each material characteristic. A combination of steel and concrete in structural members and components of load bearing structures appears very efficient due to the advantageous properties of both materials that complement each other. It results in the design of highly reliable and cost saving structures. The important characteristics of steel are: high modulus of elasticity, high tensile strength, high ductility, ease in fabrication, high speed of erection, and low weight per square area which result in small size members and long clear spans. Concrete has many advantages such as: high compressive strength, massive stiffness, low cost, and high inherent mass. The main disadvantage of concrete is the low tensile strength.

The composite column is a compression member which commonly used in building construction due to their efficiency in resisting different straining actions with relatively small size and less cost. Composite columns are either composed of concrete encased steel section or concrete filled steel tube section. Composite columns must be designed to resist the most unfavorable load conditions. When the concrete core effect in restraining the local buckling of steel tube is incorporated in the design, steel cost can be minimized. Thin walled composite columns use the concrete restraint effect in delaying the steel tube initial local buckling. Local buckling reduces the strength and stiffness of the concrete filled steel tube columns.

Failure modes of composite columns are divided into two types: 1) material failure, 2) stability failure. Material failure includes concrete crushing and cracking and steel yielding. This mode of failure occurs in short concrete filled steel tube columns composed of compact steel section. Stability failure includes global buckling and local buckling. This mode of failure occurs in long columns and the concrete filled steel tube columns composed of slender steel sections.

1.2 Research Objective

The purpose of this study is to investigate the effect of many parameters on initial buckling stress σ_L , post local buckling stress σ_u, non dimensional critical stress σ_L/σ_y , and reserve strength σ_r gained due to the post local buckling occurrence in hollow and filled sections.

The independent variables considered in the parametric analysis are listed as follows:

- Section type: hollow or filled.
- Steel tube slenderness ratio, b/t ranges from 30 to 160.
- Yield stress of steel tube, F_y (MPa) which has values of 240,360, and 420 MPa.

The analysis procedure adopted in this work may be summarized as follows:

1. The coverage of composite columns behavior, past experimental work, and theoretical study on local and post local buckling. The adopted design equations of concrete filled steel tube columns in international codes and specifications were also presented.
2. Finite element models building, which can adequately represent the hollow and concrete filled steel tubes different modes of local instability failure.
3. Finite element model verification, by comparing its results to mathematical closed form solution and experimental test results.
4. Conducting a comprehensive parametric study using the verified finite element model technique used in chapter 3 to illustrate the effects of section slenderness ratio b/t ,yield strength of steel tubes, and concrete infill on local and post local buckling of square hollow and filled steel tubes.

1.3 Thesis Organization and Contents

The thesis includes five chapters, detailed as follows:

- In Chapter one, a brief introduction with the main objectives of the research work and thesis contents are presented.
- In Chapter two, an outline of composite columns behavior, past experimental work, and theoretical study on local and post local buckling are presented. The adopted design equations of concrete filled steel tube columns in AISC-LRFD specifications, Eurocode4, and Egyptian code of practice LRFD are also presented.