Cairo University

NUMERICAL INVESTIGATION ON COMPRESSIVE STRENGTH OF COLUMNS WITH ELLIPTIC HOLLOW CROSS-SECTION

By

Adel Abdullah Mohammed Musleh

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

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

NUMERICAL INVESTIGATION ON COMPRESSIVE STRENGTH OF COLUMNS WITH ELLIPTIC HOLLOW CROSS-SECTION

By

Adel Abdullah Mohammed Musleh

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

Under the Supervision of

Prof. Dr. Sherif S. Safar

……………………………..

Professor of Steel Structure and Bridge
Structural Engineering Department
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

NUMERICAL INVESTIGATION ON COMPRESSIVE STRENGTH OF COLUMNS WITH ELLIPTIC HOLLOW CROSS-SECTION

By
Adel Abdullah Mohammed Musleh

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

Approved by the
Examining Committee

Prof. Dr. Sherif S. Safar Thesis Main Advisor

Prof. Dr. Hesham S. Khedr Internal Examiner

Prof. Dr. Abdel Raheem K. Desoky External Examiner
Professor of Steel Structure and Bridge
Structural Engineering Department
Faculty of Engineering, Ain Shams University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Adel Abdullah Mohammed Musleh
Date of Birth: 01/ 01/1990
Nationality: Yemeni
E-mail: Eng.adelalghaithy@gmail.com
Phone: 01125500635
Address: Giza, Egypt

Registration Date: 01/10/2014
Awarding Date: .../..../2018
Degree: Master of Science
Department: Structural Engineering

Supervisors:

Prof. Sherif S. Safar

Examiners:

Prof. Abdel Raheem K. Desoky	(External examiner)
Prof. Hesham S. Khedr	(Internal examiner)
Prof. Sherif S. Safar	(Thesis main advisor)

The title of Thesis:

NUMERICAL INVESTIGATION ON COMPRESSIVE STRENGTH OF COLUMNS WITH ELLIPTIC HOLLOW CROSS-SECTION

Key Words:
Elliptical Hollow Section; Compression Strength; Flexural Buckling; Local buckling; Slenderness ratio; Geometric Imperfection; Non-linear Analysis.

Summary:
Compressive Strength of columns composed of elliptic hollow cross section, EHS, is not covered in current codes. The purpose of this research is to investigate numerically the effect of geometric and material properties of EHS on its compressive strength using the finite element method. A three dimensional finite element model was established using ANSYS software incorporating both material and geometric nonlinearities. The numerical model was verified by comparison to experimental and numerical research published in literature. The numerical model was used to conduct extensive parametric analysis to assess the effect of geometric and material properties on compressive strength and to explore the slenderness limit distinguishing elastic and inelastic buckling. Numerical results of more than three hundred models revealed that current design equations adopted by AISC-360-10 for circular hollow sections were not suitable to predict the compressive strength of EHS especially in the inelastic buckling range. A slenderness correction factor was established for non-slender EHS and a stress reduction factor was established for slender EHS based on numerical results. The application of the proposed slenderness correction factor and stress reduction factor in the AISC360-10 design formula provided compatible results with numerical results obtained herein for slender EHS. The proposed compressive strength formula was also validated by comparison to numerical results that were not included in parametric analysis.

Acknowledgments

The author is honored to obtain his M.Sc. degree from Cairo University under distinguished supervision. He would like to express his deepest gratitude to **Prof. Sherif S.Safar** for his advice, continuous guidance, encouragement support, valuable discussion, and his great effort in mentoring the author and reviewing his work to accomplish the thesis objectives.

Last but not least, it is incumbent upon me to thank my lovely wife who, in one way or another, has helped in making this work possible. Finally, the author would like to thank his parents, as well as his family, his sisters and his brothers for their continuous support and believing in him even through hardest times away from home. To them the author says thank you, but he knows that no words of appreciation could be sufficient. The author would not have achieved this work without their help.

Table of Contents

List of Tables

List of Figures

Abstract

The use of columns with elliptic hollow section (EHS) in construction has been spreading notably in a range of structural and civil engineering applications. Recently, EHS columns are widely used due to their aesthetic appearance, structural efficiency and variable sectional properties about major and minor axes. The British standard (BS) started to develop and provide some standards and specifications for geometric shape and sectional properties of structural steel hot-rolled EHS, because of that, more work is needed to cover all design cases where this type of elements might be used; and it is important to assess the overall stability of EHS in both elastic and inelastic ranges of buckling.

The aim of this research is to investigate the compressive strength of EHS subjected to concentric compression. The study accounts for the effect of material nonlinearity, geometric nonlinearity, and geometric imperfection. Due to wide variety of geometrical parameters of EHS, a three dimensional finite element model of EHS columns was constructed using ANSYS software. Numerical results were verified by comparison to experimental and numerical results published in literature and design equations adopted by the current AISC360-10 specification. The verified numerical model was used to conduct an extensive parametric analysis to assess the effect of geometric and material properties on compressive strength. Additionally, diameter to thickness ratio (λ_L) was varied to determine the slenderness limit distinguishing slender from non-slender EHS.

Parametric analysis results revealed that current code equations for circular hollow sections were not suitable to predict the compressive strength of non-compact and slender EHS columns. A multiple linear regression analysis was conducted to establish a slenderness correction factor (η) that account for reduction of stiffnes due to ovalization of EHS during flexural buckling. The factor (η) can be applied to current AISC 360-10 design equations to predicted successfully the compressive strength of non-compact EHS. Evaluation of numerical results of slender EHS revealed that the stress reduction factor (Q) adopted by AISC360-10 for slender circular hollow section , CHS, can be utilized with EHS after substituting the diameter of circular hollow section (D) by the larger diameter of EHS devided by aspect ratio of EHS (D_L/r) and can be adequatly applied with the proposed factor (η) to estimate the compressive strength of slender EHS columns. The proposed strength equations establisged herein based on factors (η &Q) and design equations adopted by AISC360-10 were validated by comparison to numerical results that were not included in the parametric analysis. It was shown that the proposed formulas can sucssesfully predict the compressive strength of both slender and non-slender EHS columns.

Chapter 1 : Introduction

1.1. General

The use of columns with an elliptic hollow section, EHS, in construction have been widespread in many engineering applications due to their attractive and aesthetic appearance, structural efficiency and different sectional properties about its major and minor axes. Now, most of the structural steel hollow sections including square, rectangular and circular have large scale production worldwide. Recently, EHS products also became available as hot-rolled sections

In a good design process, many of the interactive features that include architectural and functional requirements as well as strength and manufacturing requirements should be taken into account in a balanced way, [23]. Due to the elliptical hollow sections have special features, the design engineer should be familiar with all of these features and design requirements. On the other hand, what makes EHS are particularly favorable than the rest of the other structural steel hollow sections is less prone to friction during exposure to wind loads or water power.

The structural performance of EHS columns differs from the columns with square, rectangular and circular hollow section. Application of a uniaxial load to the column centroid has an affect on flexural buckling, ovalization and local buckling. However, it is worth mentioning that most of the design codes lack any specification or limitation related to the design of elliptical hollow section. In addition, not enough work is available to improve design and understand the behavior of columns with elliptic hollow section.

This chapter lists the objective, scope, organization, methodology and steps of the implemented research on columns with EHS.

1.2. Problem Statement

Due to the widespread of civil and structural engineering applications that use columns with elliptic hollow section and its aesthetic appearance, it is so important to provide a practical procedure of design to assess the overall stability of columns with elliptic hollow with both slender and non-slender cross section. Recently, design codes and previous research work focused on the circular, square and rectangular hollow sections behavior. However, the research work on the compressive strength of columns with elliptic hollow section in both elastic and inelastic zones is limited and design requirements and strength formulas for EHS are not available in most of design standards. On the other hand, numerical and experimental research work is indeed required to help understand the effect of geometric and material properties of EHS columns on behavior and strength to help and encourage designers and practitioners to use such type of columns in engineering applications.

1.3. Objective

The objective of this thesis can be summarized as follow:

- ❖ Investigate the effect of geometric and material properties on the elastic and inelastic buckling load of EHS columns.
- ❖ Determine column strength curves of slender and non-slender EHS columns.
- ❖ Determine the diameter – to – thickness ratio that distinguish slender and non-slender EHS columns.
- ❖ Determine critical slenderness ratio that distinguish elastic and inelastic buckling of EHS columns.
- ❖ Investigate the post-buckling behavior of slender and non-slender columns with elliptic hollow section.
- ❖ Investigate the effect of initial geometric imperfection on the compressive strength of columns with elliptic hollow section.
- ❖ Establish suitable design equations for slender and non-slender EHS columns.

1.4. Scope of work

The scope of work in this thesis is to conduct numerical investigation using the finite element method to investigate the compressive strength of slender and non-slender columns with elliptic hollow cross section. The numerical analysis accounts for the effect of geometric and material nonlinearities as well as geometric imperfection. The parameters included in the research work include, slenderness ratio, diameter – to – thickness ratio, ratio of shorter to larger diameter, and geometric imperfection.

1.5. Organization of thesis

The thesis is organized as follows:

- ❖ Chapter one provides an introduction to the topic of the research together with problem statement, scope of work, organization of thesis and research methodology and applications.
- ❖ Chapter two introduces the theoretical background of the overall buckling columns and the methods used to calculate elastic and inelastic column buckling. In addition, provides summary of previous research work on EHS columns.
- ❖ Chapter three introduces the numerical modeling and procedures which was employed using ANSYS finite element program. Numerical results were compared to both experimental and analytical results as well as theoretical results published in literature.
- ❖ Chapter four reports numerical model results, and investigate the effect geometric and material properties on strength. Finally, the effect of initial geometric imperfection on compressive strength was discussed.
- ❖ Chapter five explains the mathematical model used to obtain correction factors which can be used to predict the compressive strength of columns with elliptic hollow section.
- ❖ Chapter six presents the thesis summary and conclusions based on numerical work conducted heren. It also introduces the recommendations for the future work.