AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

FACTORS AFFECTING CONFINEMENT BEHAVIOR OF AXIALLY LOADED REINFORCED CONCRETE SHORT COLUMNS

BY

Eng. Mohamed Abdel Halim Hassan

B.Sc. Civil Engineering 1993, Zagazig Uneversity

M.Sc. Civil Engineering 2002**,** Ain Shams University

A Thesis

Submitted in partial fulfillment for the requirements of the degree of Doctoral of Philosophy in civil engineering (Structural)

Supervised by

Prof. Dr. Osama Hamdy Abdel-Wahed

Professor of R.C. structures

Faculty of Engineering-Ain Shams University

Dr. Amgad Ahmed Talaat

Assistant Professor - Structural Engineering Dep.

Faculty of Engineering-Ain Shams University

Dr. Marwan Tarek Shedid

Assistant Professor - Structural Engineering Dep.

Faculty of Engineering-Ain Shams University

2013


وقل رب زدني علما

EXAMINNING COMMITTE

1. **PROF.DR. GHANI RAZAQPUR**
   PROF. OF RC STRUCTURES - FACULTY OF ENGINEERING
   McMASTER UNIVERSITY- CANADA

2. **PROF.DR. OMAR ALI MOUSA EL-NAWAWY**
   PROF. OF RC STRUCTURES - FACULTY OF ENGINEERING
   AIN SHAMS UNIVERSITY-EGYPT

3. **PROF.DR. OSAMA HAMDY ABDEL-WAHED**
   PROF. OF RC STRUCTURES - FACULTY OF ENGINEERING
   AIN SHAMS UNIVERSITY-EGYPT

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Doctoral of Science in Civil Engineering (Structural).

The work included in this thesis was carried out by the author in the Department of Civil engineering (Structural Division), Ain Shams University, from April 2009 to October 2013.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institute.

Date: / / 2013

Signature:

Name: Mohamed Abdel - Halim Hassan

INFORMATION ABOUT THE RESEARCHER

Name	: Mohamed Abdel-Halim Hassan Allam
Date of Birth	: July 13, 1970
Place of Birth	: El-Darrassah-Cairo-Egypt.
Qualifications	: B.Sc. Degree in Civil Engineering, Faculty of Engineering, Zagazig University, 1993.
	: M.Sc. Degree in the civil Engineering, Faculty of Engineering, Ain Shams University, 2002.

ACKNOWLEDGEMENTS

The writer is deeply indebted to ***Prof. Dr. Osama Hamdy Abdel-Washed,*** *Professor of R.C. Structures, Faculty of Engineering, Ain Shams University for his constant supervision, planning, guidance, valuable suggestions, precise advice and constant encouragement during all stages of this research work.*

The writer wishes to express his deepest gratitude and appreciation to ***Dr. Amgad Ahmed Talaat ,*** *Assistant Prof. of R.C. Structures, Ain Shams University, for his kind supervision, guidance, constructive criticism, generous support and patience during the coarse of this research work.*

The writer wishes to express his sincere appreciation to ***Dr. Marwan Tark Shedid,*** *Assistant Prof. of R.C. Structures, Ain Shams University, for his kind supervision, guidance, constructive criticism, generous support and patience during the coarse of this research work.*

Further more, the writer is grateful to all members of the ***Reinforced Concrete Laboratory Staff,*** *Faculty of Engineering, Ain Shams University for their kind help during the experimental phase of this study.*

Finally, The writer dedicates this thesis to his ***Father, Mother, wife, sons, sisters and brothers*** *for their continuous encouragement and fruitful care.*

AIN SHAMES UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

Abstract of the Ph.D. Thesis submitted by

Eng. Mohamed Abdel-Halim Hassan Allam

Title of the thesis:

FACTORS AFFECTING CONFINEMENT BEHAVIOR OF AXIALLY LOADED REINFORCED CONCRETE SHORT COLUMNS

Supervisors:

Prof. Dr. Osama Hamdy Abd-el Wahed	Prof. of RC Structures
Dr. Amgad Ahmed Talaat	Ass. Prof. of RC Structures
Dr. Marwan Tarek Shedid	Ass. Prof. of RC Structures

Abstract

Reinforced concrete (RC) columns are considered the most important structural element in the skeleton type structures. The design of RC columns has been developed in the last third of 20th century through a large number of experimental and theoretical researches all over the world. Previous researchers studied the general behavior of RC columns under various loading types, different reinforcement details, several concrete grades, exposure to severe environmental conditions and verifications of code provisions.

The objective of this research is to establish a mathematical formula to predict the ultimate load capacity for axially loaded short columns taking into consideration the variation of lateral steel reinforcement represents the confinement effect for both square and circular RC columns. The effect of concrete compressive strength $f_{cu,}$, the effect of concrete cross section shape (square – circular – rectangular) and the concrete cross section area were studied as well.

For this purpose, a total number of 12 specimens were prepared and tested experimentally under axial load to study the parameters that correlated to confinement. Tested columns were divided into 2 main groups in which one of them contains 9 specimens with a concrete compressive strength equal to 25 MPa and varying in transverse steel volumetric ratio, concrete cross section shape in addition to cross section area. The second group contains 3 specimens with a concrete compressive strength equal to 40 MPa. to study the effect of concrete compressive strength.

The results of all tested specimens (ultimate loads-strains-deformations…etc) were recorded and discussed. Different gains of strength, stiffness and ductility were recognized. Mathematical formulas to correlate the axial capacity for both square and circular specimens were determined as well. the longitudinal steel for all specimens was kept constant with a ratio of 1.28% of the concrete cross section area.

To verify the experimental results, the tested specimens were analyzed numerically using a non linear finite element program and the obtained results were compared to those obtained experimentally. the ultimate loads, deformations and strains were also recorded and compared.

Also, a parametric study was carried out using the non linear finite element program mentioned above. The parameters studied were the concrete compressive strength and transverse steel volumetric ratio for both square and circular columns and the concrete cross section area of square columns.

For all of the two phases of the research (experimental work, numerical analysis) the equations correlating axial capacity of the column to transverse steel volumetric ratio were obtained. For the parametric study, the equations correlating the axial capacity of the column to the transverse steel volumetric ratio and concrete compressive strength were obtained for both square and circular columns. The equation correlating the axial capacity of the square columns to the concrete cross section area of the columns was obtained as well.

The overall research conclusions were listed at the end of the research in addition to the future research suggestions.

Keywords

Axial loads; Confinement; Transverse (Tie) steel; Compressive concrete strength; Volumetric ratio; Short columns; Cross sectional area: Numerical study, Parametric study, Mathematical formula.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 General

Reinforced concrete (RC) columns are considered the most critical structural elements in any buildings. Although steel and composite columns are often used in buildings, reinforced concrete columns consist the majority of columns found in most of the low-rise and medium-rise buildings worldwide.

It is well known that one of the functions of the transverse reinforcement in reinforced concrete columns is to provide lateral confinement to the concrete cross section which in turns increases the axial compressive strength of the concrete core and improves the ductility of the structural elements as will be discussed in the next chapter.

Also, it has been observed that columns with a good distribution of lateral reinforcement (spacing& configuration), besides shape of the transverse steel reinforcement (circular, square, or rectangular) lead to higher ductility and higher capacity. However, confinement doesn't affect stiffness except at later stages of loading once lateral tensile stress increase and ties are engaged by restraining volume increase of concrete.

Another important aspect which affects the behavior of reinforced concrete columns is the concrete compressive strength. However, the major problem when higher concrete strength is used in compression members is the sudden and brittle failure without enough warning.

1.2 Objectives of the study

The main objectives of the research are:

1. Studying the factors affecting the confinement behavior of the axially loaded RC short columns.
2. Experimentally investigating the effects of different variables such as concrete compressive strength f_{cu}, transverse steel volumetric ratio μ_t, shape of the cross section, and concrete cross section area A_c; on the axial capacity, displacement and strains of RC short columns.
3. Modeling of the experimental results using a finite element computer program based on non-linear finite element formulation.
4. Conducting a parametric study using the verified model to investigate the effect of different parameters such as transverse steel volumetric ratio, concrete compressive strength and concrete cross section area on the axial