NUMERICAL ANALYSIS ON SHEAR BEHAVIOR OF HIGH STRENGTH CONCRETE BEAMS WITH OPENINGS

By

Eng. Mahmoud Hegazy Bassiony Fouda

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 ANALYSIS ON SHEAR BEHAVIOR OF HIGH STRENGTH CONCRETE BEAMS WITH OPENINGS

By

Eng. Mahmoud Hegazy Bassiony Fouda

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. Hatem Mostafa Mohamed

Professor of Concrete Structures
Structural Engineering Department

Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

NUMERICAL ANALYSIS ON SHEAR BEHAVIOR OF HIGH STRENGTH CONCRETE BEAMS WITH OPENINGS

By

Eng. Mahmoud Hegazy Bassiony Fouda

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. Hatem Mostafa Mohamed **(Thesis Main Advisor)**
Professor of Concrete Structures- Faculty of Engineering, Cairo University

_____

Prof. Dr. Mohamed Talaat Mostafa **(Internal Examiner)**
Professor of Concrete Structures- Faculty of Engineering, Cairo University

_____

Prof. Dr. Hatem Hamdy Gheith **(External Examiner)**
Professor of Concrete Structures-R.C. Institute of Housing & Building Research Center

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Mahmoud Hegazy Bassiony Fouda
Date of Birth: 7 / 3 /1992
Nationality: Egyptian
E-mail: Hegazy.fouda92@yahoo.com
Phone: 01013891188
Address: Maryotya Haram, Giza

Registration Date: 1 / 3 / 2015
Awarding Date: …./…./2018
Degree: Master of Science
Department: Structural Engineering

Supervisors:

Prof. Dr. Hatem Mostafa Mohamed.

Examiners:

Prof. Dr. Hatem Mostafa Mohamed (Thesis main advisor)
Prof. Dr. Mohamed Talaat Mostafa (Internal examiner)
Prof. Dr. Hatem Hamdy Gheith (External examiner)
Professor of Concrete Structures-R.C. Institute of Housing & Building Research Center

Title of Thesis:

Numerical Analysis on Shear Behavior of High Strength Concrete Beams with Openings

Key Words:
Shear Behavior- High Strength Concrete – Beams with Openings

Summary:

This thesis investigates the behavior of simply-supported high strength reinforced concrete beams with rectangular cross section having one rectangular opening at the mid height of the beam and subjected to two symmetrical-concentrated loads using a finite element model program (ANSYS 17). For this purpose, a set of forty-eight beams were analyzed and divided into five groups to study the behavior of beam with opening under different conditions. Main parameters were: Opening Length (l_o), Opening Height (h_o), and Position of the opening along the beam axis (S), The wide range for these parameters was taken as follows: l_o= (0.7 D, 1.02 D, and 1.4 D), h_o= (0.228 D, 0.342 D, and 0.457 D), where D is the beam thickness; S= (5.3% L, 9.7% L, 14.2% L, 18.7% L, and 23% L) where L is the beam span ; f_{cu} = (60) MPa ; (As'/As)= 0.156. All beams have cross section 120mm width, 350mm height, and the length between centers of two supports 2250mm.and all over span is equal 2500 mm. There are two alternatives of strengthening methods to compensate the beam strength, reduced by the existence of the opening. The two alternatives are: 1) Adding extra stirrups, and 2) adding diagonal bars, all around the opening zone. The conclusion indicate that the shear capacity increases by adding extra stirrups and adding diagonal bars all around the opening zone. Applied load, cracking load, crack pattern, deflection at mid-span, and failure load have been recorded.

Acknowledgments

First and foremost, praise and thanks to Almighty **ALLAH**, the most Gracious, the most merciful, and peace is on His Prophet, **Mohamed**.

I wish to express my sincere gratitude and thanks to my supervisor, **Prof. Dr. Hatem Mostafa Mohamed** , Professor of Concrete Structures, Faculty of Engineering, Cairo University, for his continuous help, support, suggestions, advice and guidance throughout the research program.

I am indebted with great favor to **Dr. Kamal Ghamry** for his generous supervision, motivation, continuous hard work, fruitful positive discussions, guidance, and following me up through the study.

I would also like to express my heartfelt appreciation to my family; my father, my mother, and my brothers for lots of support.

Special thanks to my wife (Noran Mohsen) and my son (Mohsen) who's guided me with all possible means throughout my life and many thanks to her family.

Finally, I would like to express my gratitude to all those who encouraged me to complete this thesis.

Table of Contents

List of Tables

List of Figures

Abstract

The construction of modern buildings requires many pipes and ducts to accommodate necessary services such as air conditioning, electricity, telephone, and computer network. Presence of openings in reinforced concrete beams is enable the installation of these services and minimizes the required floor height as well as decreases the construction cost.

Also, the presence of these openings in RC beams effect on their structural behavior. Thus, this thesis investigates the behavior of simply supported RC beams with openings and subjected to two symmetrical-concentrated loads using a finite element model program (ANSYS 17). The focus is on developing simplified recommendations for the design of RC beams with openings.

For this purpose, relevant published research is compiled and critically reviewed including both the experimental and theoretical ones. Results of these publications are deliberately presented in new formats and utilized to obtain simplified recommendations for the design of RC beams with openings. In addition to complement the published data, several RC beams with openings are analyzed in this thesis by using the finite element model computer package (ANSYS 17). All the analyzed simply supported beams were rectangular cross section, 120mm width, 350mm depth, with over a span 2500mm, and with clear span between the two supports 2250mm loaded by two symmetrical-concentrated loads. For this purpose, a set of forty-eight beams were analyzed and divided into five groups to study the behavior of beam with opening under different conditions. Main parameters were: Opening Length (l_o), Opening Height (h_o), and Position of the opening along the beam axis (S). All the analyzed beams had designed with low shear strength and high flexural strength to ensure shear failure.

Besides, few beams with openings in which special additional reinforcement details are placed around the opening are analyzed. This helped to increase the strength and stiffness of these beams. Finally, simplified analysis and design method for beams with openings are proposed and design recommendations as well as guidelines concerning the opening size and location are developed.

Chapter 1 : Introduction

1.1. General

In high rise and modern building construction, the designer may need to make a transverse openings in reinforced concrete beams to allow the utility ducts and pipes pass through beams. These ducts or pipes are necessary to accommodate essential services such as water supply, computer network, sewage, air-condition, telephone, and electricity network. As shown in Figure 1.1, these ducts and pipes are usually placed beneath the soffit of the beam and for aesthetic reasons, are covered by a suspended ceiling, thus creating a dead space. In each floor, the height of this dead space adds to the overall height of the building depending on the number and depth of ducts. Therefore passing these ducts through transverse openings is enabling the designer engineers to reduce the height of the structure, especially with regard to tall building construction, thus leading to a highly economical design.

Due to sudden change in the beam's cross-section, the edges of the opening can be subjected to high-stresses concentration and transform simple beam behavior into a more complex behavior. Consequently, the opening has an effect on the ultimate strength, shear strength, crack pattern, and stiffness. Furthermore, the provision of openings produces discontinuities or disturbances in the normal flow of stresses, thus leading to stress concentration and early cracking around the opening region. Similar to any discontinuity, special reinforcement or enclosing of the opening close to its periphery, should therefore be provided in sufficient quantity to control crack widths and prevent possible premature failure of the beam [1].

On the other hand, the designer engineer use in small opening additional reinforcement around the surrounding of the opening. But when large openings are used, particularly in reinforced or pre-stressed concrete structure, they show a general objection to deal with them because adequate technical information is not readily available. There is also a lack of specific guidelines in building codes of practices. Also, the behavior of the beams with large opening is greatly affected by the time of inclusion of the opening. When the service systems are preplanned and sizes and locations of openings required achieving the necessary layout of pipes and ducts are decided upon well in advance, adequate strength and serviceability may be ensured during the design stages. But, when the openings are not preplanned as that in cases of existing beams, the openings are created by removing concrete cross from the beams. Unless adequate repair is provided, the strength of the beams may be reduced to critical degree [2].