Flexural Strengthening of RC Continuous T-Beams At Hogging Zone Using Different Strengthening Techniques And Materials

By

Ayman Mohamed Mahmoud Aboraya

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
2016

Flexural Strengthening of RC Continuous T-Beams At Hogging Zone Using Different Strengthening Techniques And Materials

By

Ayman Mohamed Mahmoud Aboraya

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.Hamed M. Hadhoud

Professor of Structural Engineering
Structural Engineering Department
Faculty of engineering, Cairo University

Dr. Sayed H. Hassanin

Lecturer Of Material Engineering
Housing & Building National Research Center

Faculty of Engineering, Cairo University
Giza, Egypt
2016

Flexural Strengthening of RC Continuous T-Beams At Hogging Zone Using Different Strengthening Techniques And Materials

By
Ayman Mohamed Mahmoud Aboraya

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. Hamed M. Hadhoud, Thesis Main Advisor
Professor of Structural Engineering
Faculty of engineering, Cairo University

Prof.Dr. Mustafa Fouad El Kafrawy, Internal Examiner
Professor of Structural Engineering
Faculty of engineering, Cairo University

Prof.Dr. Heba Hamed Bahnasawy, External Examiner
Professor of Material Engineering
Housing & Building National Research Center, Cairo, Egypt

Faculty of Engineering, Cairo University
Giza, Egypt
2016

Engineer: Ayman Mohamed Mahmoud Aboraya
Date of Birth : 8/8/ 1987

Nationality: Egyptian

E-mail : Eng_ayman_aboraia@hotmait.com

Eng.Ayman.Aboraia@gmail.com

Phone. : 01008954383

0842170595

Address : 13 khateery st., Mustafa Hassan district, ELFayoum city, ELFayoum, Egypt.

Registration Date: 1/10 /2010

Awarding Date: / /2016

Degree: Master of Science

Department: Structural Engineering

Supervisors : Prof. Dr. Hamed Mohamed Mahmoud Hadhoud

Dr. Sayed Hussain Sayed Hassanin

Examiners :
Prof. Dr. Hamed Mohamed Mahmoud Hadhoud Thesis (Main Advisor)
Prof. Dr. Mustafa Fouad El-Kafrawy, (Internal Examiner)

Prof. Dr. Heba Hamed Bahnasawy, Housing & Building National Research Center , (External Examiner)

Title of Thesis :

Flexural Strengthening of RC Continuous T-Beams At Hogging Zone Using Different Strengthening Techniques And Materials

Key Words:

Carbon Fiber Polymers, Continuous beam strengthening , Hogging Zone

Summary :

The aim of the current thesis is to study the flexural behavior of RC continuous T-beam at hogging zone with column restriction. A seven specimens were strengthened by three different strengthening materials. The behavior of strengthening materials was studied in two different strengthening positions namely the flange and web regions. The results indicated that strengthening Beams in flange region gave better results than strengthening them in web region. Using Reinforcing steel bars in strengthening the flange region proved to be an effective technique in terms of both capacity and ductility.

ACKNOWLEGMENT

First of all, thanks to ALLAH who guided and helped me to finish this work in this proper shape.

The support of my father, my mother and my family cannot be praised enough; to them this thesis is dedicated.

I wish also to express my sincere gratitude to my research supervisor, Prof. Dr. Hamed M. Hadhoud., for his valuable advice, comments and his efforts in reviewing the manuscript.

I wish to record my special appreciation and gratitude to my advisor, Sayed H. Sayed, for his valuable guidance, helpful suggestion and continuous support during the research program.

Special Thanks to MSc. Shady M. Nabil for his valuable help; especially through his supervision on experimental program and result analysis.

Finally, I would like to thank The effort of the technicians of the reinforced testing materials laboratory, Housing & Building National Research Center is also appreciated.

Table of contents

List of Tables

List of Figures

Abstract

Even though Reinforced Concrete (RC) continuous beams are widely used in the field of civil engineering, not many experimental work for repairing and strengthening continuous T beams has been done; particularly, experiments for strengthening the hogging zone of continuous T beams with existence of a column restraint are not very popular.

This study concentrates on studying the flexural behavior of RC continuous T-beam with a column restraint using different materials and different methods of strengthening.

Seven experimental specimens were designed in order to give equal flexural capacity by using three strengthening materials. Those strengthening materials were Reinforcing Steel bars, fiber reinforced polymer Sheets (FRP sheet), and near surface mounted laminates (NSM laminates).

The main goals of theses experiments are:

1. Studying the behavior of different types of strengthening materials (Steel, Carbon sheets and Near Surface Carbon Fiber Reinforced Laminates) at hogging zone.
2. Strengthening material adjustment, like different places of strengthening ,for example strengthening web region versus flange region.
3. Studying the Strengthening material-Cost effectiveness.

The investigation indicated that strengthening RC Beams in the flange region gave better results than strengthened beams in web region. Using the CFRP sheets and NSM laminates in flange region increased the failure load. But using Reinforcing steel bars in strengthening the flange region was effective technique to preserve ductility and increase failure load.

Chapter (1)

Introduction

1.1 Background

Recently, strengthening the existing structures have become one of the most essential challenges in the field of civil engineering. Mostly, the primary reasons for strengthening of structures include:

- improving resistance to withstand underestimated loads;
- increasing load-carrying capacity for higher permit loads;
- reducing premature failure owing to inadequate detailing;
- retaining lost load-carrying capacity due to corrosion of other types of degradation caused by aging; etc.

Accordingly, a variety of strengthening techniques have been improved in order to satisfy the requirement to increase the load carrying capacity as well as to meet serviceability requirements. Some of the conventional strengthening techniques for concrete structures include:

- Expanding the member`s cross-section.
- Offering extra support to shorten the span of flexural member.
- Increasing reinforcement by consequently removing and casting concrete.
- Applying additional internal or external prestressing.
- Bonding external steel plates.
- Externally bonded steel reinforced polymers (SRP)
- Externally surface bonded FRP laminates.
- Near surface mounted technique (NSM).

The continuous development of fiber reinforced polymer (FRP) materials in different forms and configuration provides an alternate design technique for constructing new structures and rehabilitation of existing civil engineering infrastructure. FRP materials have successfully been used in aerospace industry across many decades.

Problems due to Corrosion in concrete reinforced steel structures are usually expected and most engineers are concerned about them. So as to eliminate the possibility of steel corrosion, the last choice seems to be non corrosive reinforcement. Recently, fiber reinforced polymer (FRP) for reinforcing bars have been used as a prestressing tendons reinforcement in newly slabs construction, for coastal and marine structures, and for structures wherein nonmagnetic properties are required like large transformer foundation pads. The exclusive advantages of FRP materials such as perfect in corrosion resistance, high strength to weight ratio, neutrally electromagnetic, and ease of handling make these materials probably suitable for the utilization in reinforced concrete defected by serviceability problems.

Currently, they are also used for repairing - rehabilitation of concrete with externally bonded laminates **(Lerchental,1970) [1].** The use of EFRP materials for external strengthening technique of reinforced concrete, prestressed concrete (PC), and masonry structures has showed as one of the effective and rising technologies in materials and structural engineering **(Kajfasz et al.,1970) [2].**Of the current techniques of Rehabitation, the utilization of FRP bars as near-surface-mounted (NSM) reinforcement was widely spread as a promising technology for increasing flexure and shear strength of deficiently RC members **(Swamy et al.,1987) [3]**. NSM bars is a better technique than externally bonded FRP laminated due to the possibility of anchoring the laminates into adjacent surfaces cut of the concrete member, and the minimum work preparation of surface and time of installation.

Even though, the utilization of FRP rods for strengthening applications is still a new technique, NSM steel rods were used as a strengthening technique of RC structures starting from the early 50s in Europe. although, Several disadvantages emerged from using steel bars in NSM method, like difficulty in site handling and corrosion possibility.

1.2 Problem statement

Lately, a large deal of research has been performed on simply supported reinforced concrete (RC) beams which strengthened with Fiber-Reinforced Polymer composites (FRP), a little literature has focused on continuous beams; especially experiments carried out on strengthening the negative moment regions of continuous T beams are so uncommon to have.

The negative moment region of continuous RC T-beam, which also called the hogging zone is a critically region due to the concurrence of maximum Flexure and shear in addition to the strengthening restrictions due to the presence of the mid-column .This Research also Compares different methods & materials of strengthening the negative moment region of a continuous beams in existence of column.

1.3 Objectives

This proposal attempts to concentrate on an important practical problem that is encountered in strengthening the hogging zone of RC continuous T beam with different strengthening techniques and different materials such as CFRP sheets, NSM laminates and reinforcing steel bars.

1.4 Methodology

An experimental program of seven beams was conducted to achieve the required objective. One control beam and the others strengthened by CFRP sheets, NSM laminates and Reinforcing steel bars.
Beams are divided into three groups and were selected ,designed and instrumented to verify the flexural behavior of hogging zone of RC continuous T beams.

- The first group labeled as B-ST, Beams Strengthened by Reinforcing steel bars.