MECHANICAL BEHAVIOR OF REINFORCED CONCRETE SHORT COLUMN-CFRP COMPOSITE BASED ON ABAQUS FINITE ELEMENT ANALYSIS

PEZHMAN TAGHIA

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Universiti Teknolog Malaysia

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DEDICATION

To my beloved mother and father

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ABSTRACT

Strengthening of the structural members and frames is one of the engineering concerns, so this study will present some structural behavior of the reinforced concrete (RC) short column wrapped by carbon fiber reinforced polymer (CFRP) sheets under pure axial static load. The nonlinear finite element analysis (NLFEA) is conducted. ABAQUS/STANDARD software is used to analyze the reinforced concrete short column wrapped in CFRP and is compared the finite element analysis results to experiment results which are included in literature. Several aspects of the confinement effect on column response such as different in cross section size, number of CFRP layers, volumetric ratio of CFRP and column size effect are examined. It is found that externally bonded CFRP sheets are very effective in enhancing the axial strength and ductility of concrete columns. In order to validate the results which obtained by the finite element analysis, a comparison with experimental work is conducted. Inspection of results shows that there is a good agreement between the NLFEA and the experimental test results.

ABSTRAK

Pengukuha anggota struktur dar kerangka adelah penting day perlu perhatan yang lebih dalam kejuruteraan kajian ini akan membertangkan trigkah laku struktur tiang pendek korkrit bertetulang yang disalut dergan polimer gertian karbon bertetulang (CFRP) yang dibebani dergan pembebanan paksi statik. Analisis kaedah unsur terhingga tak linear (NLFEA) telah dijalankan. Perisian ABAQUS/STANDARD digunakan bagi mengara lisis tiang pendek konkrit bertetulang yang disalut CFRP dan membandingkan keputusan analisis dengan keputusan ujikaji yang didapati daripada literature. Beberapa aspek tentang kesan salutan CFRP ke atas tiang seperti perbezaan saiz keratan rentas bilangan lapisan CFRP nisbal isipadu CFRP dan siaz tiang turut dikaji. Kepingan luaran CFRP ditemui cukup berkesan dalam menguatkan dan meninggikan kekuatan paksi dan kemuluran tiang konkrit. Bagi pengesahan keputusan yang didapati darpada analisis unsur terhingga, perbandingan dengan ujikaji telah dijalankan. Pemeriksaan keputusan menunjukkan keputusan NLFEA dan keputusan ujikaji adalah baik.

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d - Diameter of the cross section of specimen

D - Column diameter

h - Height of the column

k - stiffness

l - maximum unbraced length

r - radius of gyration

t - hoop thickness

E_c - Young's modulus

ε_c - strain

f'_c - compressive stress

f_{ct} - tension stress

$\sigma_l, \sigma_2, \sigma_3$ - principle stress

σ_c - specific stress in ε_c strain

σ_f - stress in hoop direction

σ_l - confining stress

$\bar{I}_1$ - moment of inertia

S_{ij} - effective deviatoric stress tensor

CHAPTER 1

INTRODUCTION

1.1 Background

The traditional material used in the strengthening of concrete structures is steel. Because of some problems they have such as corrosion resistance, fiber reinforce polymer (FRP) size and high weight, researchers looked for new material to retrofit of concrete, so the use of FRP sheets became more important. There are some advantages by using FRP sheets. They have high tension strength, light weight, excellent resistance to corrosion. Although steel jacketing has been widely used in practice, the society is also looking for other alternatives to improve the retrofitting process for the vast number of existing, structurally deficient bridges throughout the world. Advanced composite materials have been recently recognized and applied to bridge retrofit.

The general expectations from composite retrofit systems include light weight, high stiffness or strength to weight ratios, etc. These composite retrofit measures can be categorized as in-situ fabricated jacketing that involves hand or automated machine placement of epoxy saturated glass or carbon fabrics on the surface of existing concrete. An in-situ fabricated jacket can match the shape of the existing column. However, due to the fact of in-situ fabrication, these systems may need special attention to the jobsite quality control and curing of the composite jackets. Under multiaxial combinations of loading, the failure strengths of concrete are different from those observed under uniaxial condition.

The wrapped carbon fiber reinforced polymer (CFRP) sheet around the RC columns improves shear strength and ductility of concrete which improves seismic behavior of column. The magnitude of these structural improvements depends on several parameters, such as concrete strength; CFRP percentage; geometric confinement arrangement; column aspect ratio; arrangement and percentage of existing steel reinforcement. When reinforced concrete columns are subjected to seismic loading, the large lateral earthquake force will degrade the concrete and the reinforcing bar very quickly, and the columns will fail prematurely.

In most applications, the lateral confinement provided by an CFRP jacket to concrete is passive in nature. When the concrete is subject to axial compression, it expands laterally. This expansion is confined by the CFRP jacket, which is loaded in tension in the hoop direction Different from steel-confined concrete in which the lateral confining pressure is constant following the yielding of steel, the confining pressure provided by the CFRP jacket increases with the lateral strain of concrete because FRP does not yield.

In recent years, repair and seismic retrofit of concrete structures with CFRP sheets has become more and more common. The strengthening of RC columns with wrapped CFRP sheets to improve seismic performance is one of the major applications of this new strengthening method. The wrapped CFRP sheet around the plastic hinge region of

RC columns provides not only enough shear strength which results in a ductile flexure failure mode in accordance with the concept of strong shear and weak flexure, but also confinement of concrete in the plastic hinge region to increase the ductility of the column. When reinforced concrete columns are subjected to seismic loading, the large lateral cyclic earthquake force will degrade the concrete and the reinforcing bar very quickly, and the columns will fail prematurely.

Properly detailed lateral reinforcement cans also prevent the sudden loss of bond and buckling of the longitudinal rebars. One approach is by the use of fiber-reinforced polymer (FRP), which offers ease of handling and speed of installation, durability, resistance to corrosion, and high strength-to-weight ratio among many other properties compared to steel, in particular. The fiber orientation of the composite material is the important characteristics of the orthotropic material properties. For composite material, the elastic modulus is much higher when a load is applied in the direction of the orientation of fiber than when it is applied transverse to it.

A carbon fiber is a long and thin filament which is about 5-10 μm in diameter and has a crystal bonding of carbon atoms which are more or less aligned parallel to the longitudinal axis of the fiber. This type of bonding makes the fiber very strong compared to their size. Today carbon fiber reinforced composite materials are widely used in air and space craft parts, racing car bodies and in lots of other fields where light weight and high strength are needed. Steel jacketing has been proved to be an effective measure to retrofit bridge columns for increased strength and ductility.

Advanced composite materials have been recently recognized and applied to bridge retrofit. The general expectations from composite retrofit systems include light weight, high stiffness or strength to weight ratios, etc. Several composite jacketing systems have been developed and validated in laboratory or field conditions. Matsuda et al. (1990)

tested a system for bridge pier retrofit using unidirectional carbon fiber sheets wrapped longitudinally and transversely in the potential plastic hinge region or in the region of main bar cutoff.

Another composite wrapping system using glass fiber, which is much more economical than carbon fiber, has been experimentally studied by Priestley and Seible (1991) and Seible and Priestly (1993). Priestley et al. Test results on 40% scale bridge piers wrapped with the glass fiber composite jacketing demonstrated significant improvement of seismic performance with increased strength and ductility. Priestley and Seible also developed a full design package for seismic retrofit of existing columns using different retrofit jacketing systems. Saadatmanesh et al. (1994) have proposed a wrapping technique using glass fiber composite straps for column retrofit. Most recently, Seible et al. (1995) have experimentally validated a carbon fiber retrofit system that uses an automated machine to wrap carbon bundles to form a continuous jacket. Successful field construction demonstration is also reported by Seible et al. (1995).

These composite retrofit measures can be categorized as in-situ fabricated jacketing that involves hand or automated machine placement of epoxy saturated glass or carbon fabrics on the surface of existing concrete. Also a prefabricated composite jacketing system for retrofitting reinforced concrete columns has been recently investigated at the University of Southern California (USC). The retrofit system uses a series of prefabricated E-glass fiber reinforced composite cylindrical shells with slits. When a column is retrofitted, the shells are opened and clamped around the column in sequences with their slits staggered. Adhesive is applied to bond the shells to each other and to the column to form a continuous jacket. The slit for each layer is not butt-bonded and the continuity relies on the subsequent layer. For this reason, the effective layer number is considered as the total number of installed layers subtracting the last layer. The prefabricated jacketing system is expected to have superior constructability in terms of the quality control and the speed of installation. This paper describes the experimental and analytical results from a research program designed to validate the effectiveness of the prefabricated composite jacketing system for improving flexural ductility of bridge columns with lap-spliced longitudinal reinforcement.

1.2 Problem statement

Weakness of the structural members due to over loading or because of some natural disasters such as earthquake and building age effects are some of the main reasons to collapse. Renewing the building could be expensive rather than strengthening them. Also the main member in building is column, so strengthening the column can prepared the building to resist against complete failure and reduce fatality of the events. To achieve this aim one of the techniques can be used is finite element method which used for a lot of engineering problems. It seems that finite element analysis using scientific and commercial software such as ABAQUS to study the behavior of column wrapped by CFRP behavior is very limit. While, finite element analysis was conducted extensively on normal reinforced concrete beam. In this study try to assess and confirm accuracy of abovementioned method to strengthening the columns in comparison with experimental results those carried out by pervious researchers. Whenever the finite element method can be in good agreement with other results it can be used in empirical works and can be reliable.

1.3 Research objectives

The objective in this research is:

i. To predict the effect of number of (CFRP) layers on the stress-strain curve or mechanical properties behavior of reinforced concrete short column.

ii. To examine the effect of different cross section and height of RC column wrapping by external CFRP sheets on the mechanical behavior of RC short column.

iii. To study the confinement with CFRP can enhance the ductility of RC short column.

iv. To study the convergence of ultimate strength and stress-strain curve predicted by finite element analysis.

1.4 Research scope

In this study model of the circular short reinforced concrete column which is fixed in bottom and restrained about lateral movement in top of the column (where the load is applied) will establish. in this thesis try to assess behavior of the RC column with a suitable material (CFRP) in strengthening with using one of the engineering methods (finite element method) and simulation behavior of the column by using ABAQUS/STANDARD software.

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