BEHAVIOUR OF REINFORCED CONCRETE COLUMNS CONFINED WITH CFRP

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Degree of Master of Science

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June 2013

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DECLARATION

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Abstract

In worldwide reinforced concrete is the major construction material used for buildings and general structures. The requirement of strengthening of reinforced concrete structures may emerge not only due to timed degradation but also due to various reasons like construction faults, increased loads and changes in utilization purpose etc. Rehabilitation of reinforced concrete structures using Carbon Fiber Reinforced Polymer materials is recognized as a very effective retrofitting method in all over the world and provides advantages like durability, water proofing capability, ease of application due to less weight etc. CFRP materials can be used for strengthening of almost all the components of a RC structure like beams, slabs columns, beam column joints etc. Among these, strengthening of columns should be done with greater care because of failure of a major column may lead to failure of complete structure. In this research attention was given to study the behavior of short RC columns strengthened with CFRP composites.

The current practice on strengthening reinforced concrete columns with external CFRP jacketing is to provide full confinement all over the column with less care on the required strength increment. As CFRP is a costly material providing partial confinement where necessary may be a viable option for cost reduction, rather than providing full confinement. The numbers of studies that have been carried out on partially confined rectangular columns are relatively less and only some available design guidelines provide design process for providing partial confinement using CFRP.

It is obvious that the best way to identify the structural behavior is through a thorough experimental study. But behaviour CFRP confined columns depends on many parameters such as, failure stresses and strains of CFRP jacket, jacket thickness, number of CFRP layers, percentage of steel reinforcement etc. Studying of all those parameters experimentally is not a cost effective option as the structural form and load sharing will be specific for a single case. Finite element modeling is the best way to study a criterion that depends on this kind of large number of input variables. But still the finite element modeling of confined concrete column is in evolving stage and there is no globally accepted finite element model to predict the behavior of CFRP confined columns.

The experimental and theoretical studies available in Sri Lanka regarding CFRP strengthening are next to zero. When design guidelines available for CFRP design are considered, there are various design codes for different countries like USA, Japan, Canada and Switzerland. Under this background designers and contractors in Sri Lanka are in a fuzz regarding which design guideline system will provide adequate safety factor while maintain the feasibility of the project

Three major objectives were setup under this study. An experimental study was carried out to investigate the ductility and ultimate load carrying capacity increment of both reinforced and unreinforced square columns due to full confinement and to understand the behaviour of reinforced concrete columns with partial confinement. Second objective was to develop a finite element model using ANSYS software to simulate the behavior of confined concrete columns and study an analytical model capable of predicting stress strain behaviour and ultimate load carrying capacity of CFRP confined columns. Also a study was carried out about different available guidelines and attempt was made to identify the factor of safety provided for each design methods against obtained experimental results.

Under experimental study total number of 17 columns with dimensions of 150 × 150 × 350 mm was tested. The test specimens consist of 6 plain concrete columns with 3 control

specimens and 3 fully confined columns. 11 reinforced concrete columns with 3 control specimens, 3 columns with full confinement and 5 columns with partial confinement. Two wrapping patterns were used for partially confined columns, three specimens with two sets of 75mm width wraps at top and bottom of the column and two specimens with three 50mm wraps at top bottom and middle of the column. The volumetric ratio of CFRP for partially confined column specimens were kept constant to study the effect of wrapping pattern and jacket location for strength and ductility increment. All the columns were tested for axial compression. Under analytical study the model proposed by "Harajli" was studied. CFRP design specifications published by American Concrete Institute (ACI) and International Federation for structural concrete (fib), Switzerland were reviewed against the experimental results to identify the factor of safety against ultimate load carrying capacity estimation.

The results of experimental study revealed that any kind of external confinement, full or partial with external CFRP jacketing is capable of increasing the load carrying capacity and ductility of a column to a considerable extent. The load carrying capacity increment for fully wrapped reinforced concrete columns were 100% while for plain concrete columns it was 47%. When load carrying capacity increment of partially confined columns considered, the specimens with two 75mm wraps showed a capacity increment of 59% while specimens with three 50mm wraps showed an increment of 83%. From above observation it was realized that for partially confined columns not only the volumetric ratio of the CFRP wrapping but also the wrapping pattern have a large influence on load carrying capacity. When ductility increment is considered it was observed that ductility increment is proportional to the strength increment, more the strength increment more the ductility increment.

The finite element model based on Extended Drucker Prager plasticity model for concrete showed a good prediction of horizontal strain vs. vertical stress variation for fully confined models and could predict the failure load with an error of 1.8% hence the developed finite element model can be treated as an acceptable model.

The analytical model proposed by Harajli showed a considerable variation of stress strain behaviour prediction but the ultimate failure load prediction according to above analytical model showed a good agreement with experimental failure loads with an error of 1.1%

The estimated failure loads from ACI guidelines showed a factor of safety of 3.5 against experimental results while fib guidelines showed a factor of safety of 1.6 for fully confined reinforced concrete specimens. Only fib guidelines gives a method to estimate failure load of partially confined columns and showed a factor of safety of 2 for specimens with 75mm wrappings and 2.1 for specimens with 50mm wrappings. As the current practice is to provide full confinement for columns and two guidelines shows a considerable variation of factor of safety the designers are advised to select the suitable design system based on the risk level associated with a specific project.

Keywords: CFRP, reinforced concrete columns, partial confinement, strength, ductility, finite element modeling

Acknowledgement

I would like to express my special thanks of gratitude to my supervisor Dr. C.S. Lewangamage for the sincere guidance and motivation gave to make this project a success.

My special thank is given to Prof. M.T.R. Jayasinghe the former head of department of civil engineering for the advices and support given through the project and for being the chairperson of the progress review committee. I should mention the support given by Dr. L.L. Ekanayeke as a progress review committee member.

I should convey my thanks to Prof H.S. Thilakasiri, research coordinator of department of civil engineering for the support given throughout the project.

All the required Carbon Fiber materials was provided by NAVCORP Engineering Consultants – Sri Lanka, my special thanks is given to the chair person Mr. Dhammika Wimalarathne for the great support.

I would like to convey my special thanks to Prof. Ranjith Dissanayake and Mr. Bandara, University of Peradeniya for providing facilities for specimen testing.

Finally I would like to thank all other members of academic staff and nonacademic staff of department of civil engineering, University of Moratuwa and all other personnel who gave me support and courage to make this research project a success.

This project was supported by University of Moratuwa Senate Research Grant Number SRC/LT/2011/26.

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