EXPERIMENTAL BEHAVIOR OF FLEXURAL STRENGTHENING OF PRELOADED REINFORCED CONCRETE CONTINUOUS BEAMS

By

AMIRA ADEL ABDEL HAMED RADWAN

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
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Title of Thesis:

"Experimental Behavior of Flexural Strengthening of Preloaded Reinforced Concrete Continuous Beams"

Key Words:

Flexural Strengthening, Preloaded RC Continuous Beams, RC Layers, CFRP Sheets.

Summary:

The thesis presents an experimental investigation of the flexural strengthening of preloaded reinforced concrete continuous beams. Two types of strengthening were used; strengthening with RC layers and strengthening with CFRP sheets. Parameters which were studied were the preloading level and the type of strengthening. The results demonstrated that decreasing the preloading level in case of strengthening with RC layers has an essential role in increasing the flexural load-carrying capacity and the deflection of RC continuous beams, while in case of strengthening with CFRP sheets it doesn't influence the flexural load-carrying capacity and the deflection of RC continuous beams. In addition, strengthening by extremely cheap and traditional materials like RC layers resulted in an increase in the load-carrying capacity plus high deflections conservation. While strengthening with CFRP was not an effective strengthening technique due to its high cost, low deflections and the sudden failure resulted.

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I would like to gratefully acknowledge the significant assistance and guidance of my advisors during my work on this thesis. I would also like to thank all the people who have helped me in any way to accomplish my thesis.

DEDICATION

Dedicated to my parents, my sister and my brother with love

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NOMENCLATURE

AFRP: Aramid Fibre Reinforced Polymer

A_p: Area of FRP laminate

A_s: Area of tension steel reinforcement

b: Width of Beam

CB: Control Beam

CFRP: Carbon Fibre Reinforced Polymer

d: Distance from extreme compression fiber to centroid of tension reinforcement

E_p: Modulus of Elasticity of the FRP laminate

f_p: Tensile stress in the FRP laminate

f_{pu}: Ultimate tensile stress in the FRP laminate

FRP: Fibre Reinforced Polymer

f_y: Yield stress of steel reinforcement

GFRP: Glass Fibre Reinforced Polymer

h: Depth of Beam

LVDT: Linear Voltage Differential Transducers

M_n: Nominal moment capacity corresponding to either crushing of concrete in compression or tension failure of the reinforcing steel in the tension zone of the beam after yielding.

M_u: Ultimate bending moment

M_y: Yield bending moment

NSM: Near Surface Mounted

P: Applied load

$P_{cr.}$: Cracking load

$P_{max.}$: Maximum load

P_u: Load capacity of beam (ultimate load)

P_y: Yielding load

RC: Reinforced Concrete

t: Thickness of FRP laminate

t_{max}: Maximum thickness of FRP laminate

t_{min}: Minimum thickness of FRP laminate

UHPFRC: Ultra High Performance Fibre Reinforced Concrete

β_1: Ratio of the rectangular compression block to the depth of neutral axis

εp: Strain in the FRP laminate, corresponding to fp

$\Delta_{max.}$: Mid-span deflection corresponding to the maximum load

$\Delta_{ult.}$: Mid-span deflection corresponding to the ultimate load

ABSTRACT

Nowadays, there is a considerable concentration among researchers and engineers with the strengthening of the existing structures which became no longer safe. Structures became no longer safe due to the increased load specifications in the design codes in the recent years, overloading, and under-design of existing structures or the insufficiency of quality control. Therefore, further techniques for strengthening have been developed in order to improve the capacity of the standing structures and to fulfill specific serviceability requirements as well. The main idea of these techniques is to strengthen the major members of the standing structure, for example, beams, columns and beam-column joints, which will eventually strengthen the structure itself. All these structural members exposed to damage before strengthening, so experimental programs need to be performed on preloaded members to be reliable.

An experimental study had been executed to investigate the preloading effect on the flexural trend of reinforced concrete strengthened continuous beams. Five continuous RC beams were tested; they all had the same dimensions and the same reinforcement detailing. Two types of strengthening were used; strengthening by RC layers and strengthening by CFRP sheets. The five specimens were tested before and after applying the strengthening techniques, but under different damaging levels. For all specimens, deflections and reinforcement strains were registered throughout the test duration before and after strengthening.

The results demonstrated that decreasing the preloading level in case of strengthening with RC layers has an essential role in increasing the flexural load-carrying capacity and the deflection of RC continuous beams, where preloading the beam with preloading levels 90% and 70% increased the flexural load-carrying capacities than loading it up to failure (100%) before strengthening by 16.6% and 23.8%, respectively. Also, preloading level 70% increased the ultimate deflection by 14% than loading it up to failure before strengthening, while preloading level 90% made almost the same improvement in the ultimate deflection as preloading level 100%.

On the other side, decreasing the preloading level in case of strengthening with CFRP sheets doesn’t influence the flexural load-carrying capacity and the deflection of RC continuous beams, where preloading the beam with a preloading level 90% gave almost the same ultimate deflection as preloading level 100%, while it increased the flexural load-carrying capacity than preloading level 100% but with a small percentage.

The results also compared between the two used strengthening techniques. It is clear from the results that strengthening with CFRP sheets improves strength, ductility and dissipated energy of RC continuous beams. However, it decreases the mid-span deflection at ultimate load and affects the mode of failure of RC continuous beams. On the other side, strengthening with RC layers improves strength, dissipated energy and deflection at ultimate load of RC continuous beams. Also, in case of getting rid of shear failure, strengthening with RC layers will not affect the predominant mode of failure and improve the ductility of RC continuous beams.