AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL DEPARTMENT

STRENGTHENING OF REINFORCED CONCRETE SLABS USING EXTERNAL PRESTRESSED FIBER REINFORCED POLYMERS

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STATEMENT

This thesis is submitted to Ain Shams University, Cairo, Egypt, on 2017 for the degree of doctor of philosophy in Civil Engineering (Structural).

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No part of this thesis has been submitted for a degree or qualification at any other University or Institute.

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ABSTRACT

Nowadays, many existing reinforced concrete structures need structural repair and strengthening in order to keep the minimum performance requirements or to increase its performance due to new loads. Fiber Reinforced Polymers (FRP) have immerged as strengthening systems due to their advantages when compared to conventional steel. Although the use of non-prestressed FRP laminates in strengthening of flexure members has a significant effect on increasing the load carrying capacity, strengthening with FRP laminate has a negligible effect on the serviceability limit states due to the low stiffness of the FRP laminates. Moreover, using non-prestressed FRP laminates limit the utilization of the full strength of FRP materials due to the premature bond failure of the laminates.

External prestressing has long been recognized as an effective means of strengthening existing concrete structures. This is due to the better performance of the concrete members under service loading conditions and high capacity of the externally prestressed members. However, the lack of data regarding the durability of externally prestressed concrete elements can be considered as the main obstacle for wide use of this system.

Strengthening with externally prestressed FRP laminates combines the benefits of excellent durability and structural improvement in terms of serviceability and ultimate limit states.

Behavior of reinforced concrete (RC) structures strengthened with externally bonded non- prestressed FRP laminates, have been improved and addressed in previous researches, but strengthening using externally bonded prestressed FRP laminates was studied only by few researches. The prestressing systems used in previous researches had some limitations and difficulties in field application. In addition, repair of damaged RC elements using this technique is very limited.

This thesis investigates the flexure behavior of simply supported RC one way slabs strengthened using prestressed Carbon FRP (CFRP) laminates. Different systems was proposed to apply the prestressing force of FRP laminate. Finally, a prestressing system was introduced to overcome previous prestressing system limitations. An experimental program consisted of eight full scale RC slabs to investigate efficiency of prestressed CFRP laminates in strengthening of RC slabs. The tested slabs had free span of 4000 mm, 500 mm width and 200 mm thickness and tested under four point flexure load. The main test parameters were the effect of prestressing level, CFRP Laminate profile, and long term losses of the prestressing force. Behavior of RC slabs repaired using prestressed CFRP under sustained load after cracking was also studied.

The adopted prestressing and anchoring system was very effective in prestressing the slabs. The results obtained from this research showed an increase in the load carrying capacity of the tested slabs, and enhancement in the serviceability limit states was noticed for slabs strengthened with prestressed CFRP laminates.

An analytical study was carried out using strain compatibility approach and non-linear finite element software to predict analytically the actual behavior of the RC slabs strengthened with external prestressed CFRP laminates. The analytical results showed good agreement with the experimental results.

Keywords: CFRP; External Prestressing; slabs; Strengthening; Stiffness.

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List of Symbols

CFRP	Carbon Fiber Reinforced Polymer
DF	Debonding Failure
FCF	Flexural Compressive Failure
FRP	Fiber Reinforced Polymer
GA	Gradient Anchorage
GFRP	Glass Fiber Reinforced Polymer
LVDT's	Linear Variable Displacement Transducers
MA	Mechanical Anchorage
RC	Reinforced Concrete
SRP	Steel fiber reinforced polymers
A_c	area of concrete section
A_s	area of steel bars in tension zone of the RC section
A_{ps}	area of prestressed CFRP laminate
c	Neutral axis depth
Δ_y	Mid-span deflection of slabs at yielding of steel
Δ_u	Mid-span deflection of slabs at ultimate load
ε_{cc}	Concrete strain in compression
ε_{ct}	Concrete strain in tension
ε_{st}	Tension strain in steel
ε_{CFRPm}	Maximum tension strain in CFRP laminate
K_{nn}	Normal stiffness of the adhesive layer
K_{ss}, K_{tt}	Tangential stiffness of the adhesive layer in the two directions
P_y	Vertical load at steel yielding
P_{max}	Maximum vertical load carried by the slab
f_c	Compressive stress in concrete
f_c'	Cylinder compressive strength of concrete
ε_c	Compressive concrete strain

ε_0	Compressive strain in concrete at the peak stress
ε_{ps}	Strain of the prestressed CFRP laminate due to the prestressing
ε_s	Strain in the internal steel bars
ε_{pc}	Strain in the prestressed CFRP resulting from strain compatibility
ε_{pe}	Effective strain in the prestressed CFRP laminate after losses
ε_{ce}	Concrete strain at level of the prestressing CFRP laminate due to the prestressing force
f_s	Stress of the steel bars in tension zone of the RC section
f_{ps}	Stress of the prestressed CFRP laminate

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