STRENGTHENING OF REINFORCED CONCRETE DEEP BEAMS USING DIFFERENT TECHNIQUES

By

Osama Megahed Ahmed El-Battawy

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

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Under the Supervision of

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Strengthening of Reinforced Concrete Deep Beams Using Different Techniques

Key Words:
Deep Beam; Shear Strengthening; CFRP; Strut and Tie; Inclined Stirrups

Summary:

The aim of this study is to investigate the effect of strengthening reinforced concrete deep beams. An experimental study was done using six reinforced concrete deep beams have the same dimensions, But different in the type, Location of strengthening and the ratio of reinforcement. Beams were divided into three groups. The first group included beams strengthened internally by single strut and either vertical or horizontal additional reinforcement. The second group included beams strengthened using double embedded strut or using CFRP as external strengthening. The third group included one beam strengthened using inclined stirrups. The results of the experimental study shown remarkable improvement for using each type of strengthening. By this study comparison between each type of strengthening was done and the optimum type to be used in accordance with parameters of cost and gained load capacity of tested deep beams.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Date:

Signature:

Dedication

To the spirit of my father

Acknowledgments

First I would like to Thank ALLAH for helping me in the completion of this thesis.

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Nomenclature

CFRP	Carbon Fiber Reinforced Polymer
Af	Area of CFRP
As	Steel reinforcement Area
B	Width of Beam
CS	Control Specimen
Ep	Modulus of Elasticity of the FRP laminate
Fp	Tensile stress in the FRP laminate
Fy	Yield stress of steel reinforcement
H	Depth of Beam
LVDT	Linear Voltage Differential Transducers
Mu	Ultimate bending moment
My	Yield bending moment
P	Applied load
Pcr.	Cracking load
Pmax	Maximum load
Pu	Load capacity of the beam (ultimate load)
RC	Reinforced Concrete
Δult	Mid-span deflection corresponding to the ultimate load
C1-CS	Control Specimen
C2-EB	Beam with Embedded double strut
C3-SC	Beam strengthened using single strut and horizontal additional rebar
C4-FR	Beam strengthened using CFRP
C5-IS	Beam strengthened using inclined stirrups
C6-HC	Beam strengthened using single strut and vertical additional rebar

Abstract

Deep Beam is one of the most important structural elements used in the construction industry which has the ability to carry heavy loads in long spans. It has many applications such as high rise buildings and transfer girders. Nowadays strengthening of structural elements became an important issue. An Experimental study was done to investigate the effect of strengthening reinforced concrete deep beams internally and externally on the capacity of the beam section. In this research, different techniques are used to strengthen deep beams. These include using embedded steel struts with different configurations and using carbon fiber reinforced polymer CFRP sheets. The experimental program includes testing of six simply supported deep beams having the same dimensions of 1150 mm x 800 mm x 150 mm.

The main parameters considered in this study were the type of strengthening whether adding single strut, double strut or inclined stirrups; and type of strengthening material whether steel or CFRP. All beams were subjected to mid-span concentrated load up to failure. Different ratios of steel bars and stirrups were used in the horizontal, vertical, and inclined directions to act as embedded strengthening struts. One of the specimens was tested without any strengthening and one specimen was strengthened by external CFRP sheets for comparison purposes.

The results showed great improvement in the ultimate capacity of tested deep beams due to proposed strengthening methods and confirmed the ability to use CFRP sheets as external strengthening in case of retrofitting deep beams. A cost analysis was done in this research to calculate accurately cost of each type of strengthening and relation between gained section capacity and cost.