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DIFFERENT TECHNIQUES IN STRENGTHENING T-REINFORCED CONCRETE BEAMS UNDER NEGATIVE BENDING MOMENTS

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By

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بسم الله الرحمن الرحيم

قَالُواْ سُبْحَانَكَ لاَ
عِلْمَ لَنَا إِلاَّ مَا
عَلَّمْتَنَا إِنَّكَ أَنتَ
الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة اية (32)

To MY Father,

MY mother,

My friend,

End Every One Support me

Alaa Qaseem Abd allah

March ,2021

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Before anything, start with in the name of God, most compassionate, most merciful.

First, all thanks to ***ALLAH HIS MAJESTY*** for helping me to achieve this research helping me to complete this work and enabling me to accomplish this stage of my life.

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Alaa Qaseem Abd allah

March ,2021

Different Techniques in strengthening Reinforced Concrete Beams under Negative Bending Moments

BY

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Abstract

Deterioration is one of the laws of nature that effect on building structure that from the first structure were established until the modern structures Therefore, the needs for upgrading and strengthening is growing worldwide in recent decades. Strengthening of reinforced concrete is very common and important functions in civil engineering, becoming obtainable options for those structures which are more economical to strengthen than to demolish, and therefore techniques of strengthening have been proposed and developed over years of practical and laboratory works. There are many strengthening methods for RC beams and different materials, each with different advantages, disadvantages and practical limitations.

In this study suggest using different techniques (external bonded, hybrid strengthening and near surface mounted) for strengthening T reinforced concrete beam by steel plate and CFRP sheet. Strengthening of specimens were using two percentage of length of span and width of flange (40% and 80%), Also thickness is different (2mm when percentage 40% and 1mm when percentage 80%)so that the mount used for strengthening is the same. Eleven reinforced concrete T –beams were cast T-beams divided into five groups were cast and tested under negative bending moment. First group strengthened by external bonded with percentage 40%, second group strengthened by external bonded with percentage 80%, third group strengthened by hybrid strengthening with percentage 40%, forth group strengthened by hybrid strengthening with percentage 80% and fifth group strengthened by near surface mounted.

All beams had the same amount of reinforcement and dimensions of 2300 mm length, overall depth of 265 mm (200mm web depth and flange thickness of 65mm), an effective flange width of 390 mm and a 130 mm web width.

The experimental result showed that, the presence of strengthened beams with external bonded by using steel plate and CFRP sheet with 40% increase in ultimate load about 4.34% and 10.43% and decrease of deflection about 47.8% and 46%, respectively, when compared with the reference solid beam. While when increase the percentage to 80% increase in ultimate load about 20%and 16%, decrease of deflection about 42.25% and 33%. while specimens strengthened by hybrid strengthening (steel plate +CFRP) with percentage 40%of length of span and width of flange, once put steel plate on sides of flange and CFRP sheet put on middle and others put CFRP sheet on sides of flange and steel plate on middle, increase in ultimate load about 7.39% and 4.95% and decrease of deflection about 43.34% and 36.7%. when increase percentage of 40% of length of span and width of flange to 80% with decease of thickness from 2mm to 1mm, increase in ultimate load about 25.65% and 16% and decrease of deflection about 29.17% and 45.87%. while specimens strengthened with near surface mounted with two groove and three groove, increase of ultimate load about 10.43% and 31.3% and decrease in deflection.

The near surface mounted (NSM) technique and hybrid strengthening give approximate and better result from the external bonded (EB) technique in ultimate load capacity and first crack load ,while deflection at first crack for specimens strengthened with hybrid strengthening and external bonded techniques was lower near surface mounted ,but deflection at ultimate load from specimens strengthened with near surface mounted was lower than hybrid strengthening and external bonded method.

The strengthening by percentage 40%(two layer CFRP sheet or 2mm thickness of steel plate)lead increasing in the first cracking load and decrease in deflection at ultimate load is better than when strengthening by percentage 80%(one layer CFRP sheet or 1mm steel plate).The strengthening by percentage 80%(one layer CFRP sheet or thickness 1mm of steel plate)lead increasing in the ultimate load and decrease in deflection at first crack load is better than when strengthening by percentage 40%(two layer CFRP sheet or 2mm steel plate).

When strengthening two beam by 40% ,but the material is different .one beam strengthened by steel plate while other beam by CFRP sheet .CFRP sheet has first crack load and ultimate load. While strengthening two beam by 80% ,but the material is different .one beam strengthened by steel plate while other beam by CFRP sheet .steel plate has first crack load and ultimate load.

When strengthening two beam by adhesive steel plate at middle span and put CFRP sheet on side of flange,one beam strengthening by 40%while other beam strengthening by 80% gives the first crack load higher than beams strengthening with adhesive CFRP sheet at middle span and put steel plate sheet on side of flange. Also ,deflection at first crack load was lower .

strengthening two beam by adhesive CFRP sheet at middle span and put steel plate sheet on side of flange,one beam strengthening by 40%while other beam strengthening by 80% gives the ultimate load higher than beams strengthening with adhesive steel plate at middle span and put CFRP sheet on side of flange.The strengthening by steel plate on middle span and CFRP sheet divided to two part and adhesive on side of flange lead to increase in first cracking load is better than the strengthening by CFRP sheet on middle span and steel plate divided to two part and adhesive on side, but, increase in ultimate load of CFRP on middle is better than steel plate on middle.

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List of Abbreviation and Symbols

Abbreviations	Explanation
a	Depth of equivalent rectangular stress block, mm Effective
	tension area of concrete surrounding the flexural tension reinforcement and having the same centroid as that reinforcement, divided by the number of bars or wires, mm^2
A_s	Area of nonprestressed longitudinal tension reinforcement, mm
b_e	Area of shear reinforcement within spacing s, mm
b_f	Area of reinforcement in flange, mm
C	Distance from extreme compression fiber to natural axis, mm
c	Least distance from surface deformed reinforcement to the tension face
d	Effective depth of beam, distance from extreme compression fiber to centroid of longitudinal tension reinforcement, mm
D	Overall depth of beam, mm
	Depth of opening, mm
	Thickness of concrete cover measured from extreme tension fiber to center of bar, mm
L	Overall length of T-beam, mm
	Clear span length of deep beam, mm
M_n	Nominal flexural strength at section, N.mm
	Ultimate load of T-beam, kN
	Load at yield, kN

ACI	ACI American Concrete Institute
AFRP	Aramid Fiber Reinforced Polymer
ASTM	American Society for Testing and Materials
CFRP	CFRP Carbon Fiber Reinforced Polymer
GFRP	Glass Fiber Reinforced Polymer

CHPTER ONE
Introduction

1.1General

Concrete is famous to be very important structural material in respect of most benefit specifications like the high compressive strength but it doesn't have high tensile strength. if concrete beam without any type of reinforcement concrete and subjected to comparatively a small load, it will be crack and the failure occurs suddenly In most cases. To be eliminated this problem, reinforce a concrete structure is to used steel reinforcing bar is that are placed in the structure before the concrete is cast. The structure may have to transfer higher loads at a later date, or perform new standards. A structure will have to be repaired and strengthened concrete structure all over the world in most cases. There are numerous reasons for strengthening or improvement due to the regularly increased loads and high cost of modern construction. An additional reason can be found need inside the structure due to mistakes that occurred during design and construction phase resulting in the need to strengthened the structure before use; If any of these situations arises; it should be decided whether it is better to strengthen or replace the existing structure. In comparison to building a new structure (Nordn, H. et .al 2003).

Strengthening of reinforced concrete is very common and important functions in civil engineering, becoming obtainable options for those structures which are more economical to strengthen than to demolish, and therefore techniques of strengthening have been proposed and developed over years of practical and laboratory works. There are many different techniques and material to repair a concrete structure. Choosing the correct strengthening technique is one of the most important to fulfill the successful strengthening. The decision on which method is to be applied for strengthening a structural build on economic considerations and the suitability of the adopted method.

Strengthening techniques including (a)External bonding steel plate or CFRP sheet (EB), (b)Near surface mounting (NSM) steel bar, (c)hybrid strengthening using combination of (EB) steel plate and (EB) carbon fiber reinforced polymer (CFRP) sheet. Most popular materials used for strengthening and repairing are steel plates and fiber reinforced polymers (FRP). Strengthening by steel plate is one of the most common method due to its availability, cheapness, easy to work, high ductility and high fatigue strength.

FRP is a very desirable rehabilitation material in recent years due its advantage of high tensile strength and stiffness compared to other composite materials

1.2 Fiber Reinforced Polymer FRP

In last decades, there was an increase in using the nonmetallic and lightweight fiber reinforced composite materials to repair and strengthen the concrete structures" Strengthening a structural members "is done when the strength of the existing member is insufficient, these deficiencies may arise from errors in the construction During the service life , like steel bars forced too far into the cross section during construction and when the capacity was decrease due to natural impacts or human error (Binici, B. (1969)), reinforced concrete structures often experience improvement and modification of their performance. The main contributing factors for strengthening or retrofitting of existing structures are the change in their use, new design standards, impairment due to steel corrosion and accidents.

This strengthening method has many advantages over the traditional techniques. FRP have low specific mass, very low coefficient of thermal expansion in the fiber orientation, and are easy to handle, particularly when operating in constrained and enclosed situations (Spadea, G (1998)).

The FRPs especially used for civil engineering applications are carbon fiber reinforced polymer (CFRP), glass fiber reinforced polymer (GFRP), and aramid fiber reinforced polymer (AFRP). Figure (1-1) shows Aramid, Glass and Carbon fiber sheet. The different FRP materials and systems have varying properties and behavior. A qualitative comparison of the performance of carbon, glass, and aramid composites is presented in Table (1-1).

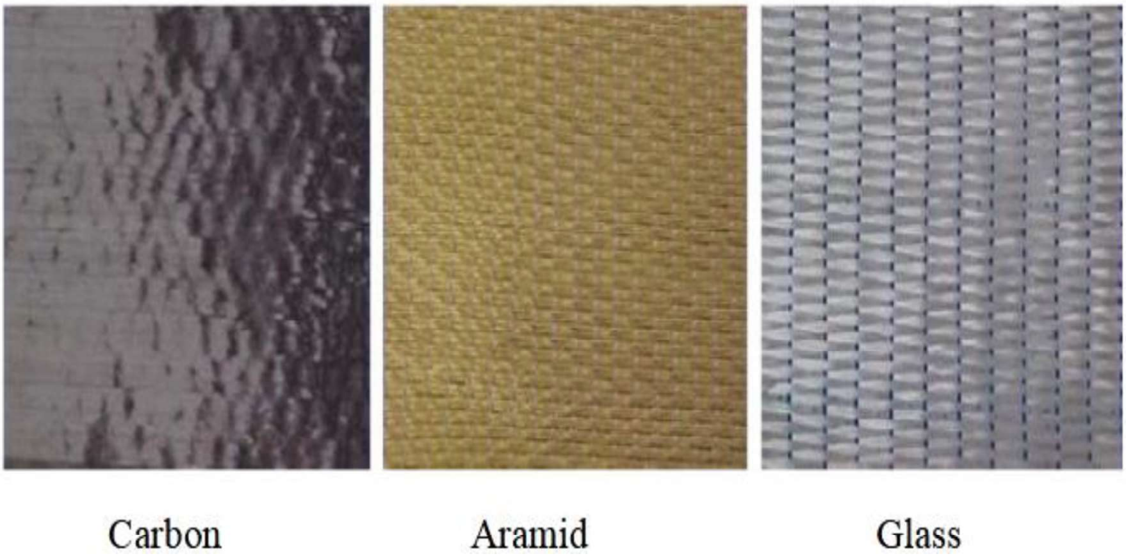

Figure (1-1) Aramid, Glass and Carbon FRP sheet (Carolin, A. (2003)).

Table (1-1) Qualitative comparison of different fibers used in composites (Meier, U., & Winistorfer, A. (1995))

Criterion	Type of fibers used in composite		
	Carbon Fibers	Glass Fibers	Aramid Fibers
Tensile Strength	Very good	Very good	Very good
Compressive Strength	Very good	Inadequate	Good
Young's Modulus	Very good	Good	Adequate
Long-term behavior	Very good	Good	Adequate
Fatigue behavior	Excellent	Good	Adequate
Bulk density	Good	Excellent	Adequate
Alkaline resistance	Very good	Good	Inadequate
Price	Adequate	Adequate	Very good

Carbon fibers are the best suited to the post strengthening of structures. Carbon performs better than glass and aramid based FRP in almost every category (MEIER, U. (1997)) ,based on a set of criteria. Carbon fibers are the stiffest, more durable, and most expensive fibers. Glass fibers have lower strengths and stiffness, compared to carbon fibers but with a reduced cost.

1.2.1 Carbon Fiber Reinforced Polymer (CFRP)

CFRP material had proved to be more efficient than other composites when applied to concrete as an external reinforcement because of its enhanced durability characteristics compared to glass or aramid, and itis relatively high elastic modulus. They are much stronger and stiffer than most other fibers, and are more corrosion resistant, lower in density, and more widely available as a raw material. Thus researches on its behavior under various types of loads, its contribution to the stiffness and ductility, and its effect on the stages and mode of failure and on the deformation progress have been the main aspects of structural engineering research

1.3 External Boned Using Steel Plates

External strengthening gives a practical and advantages when compared other rehabilitation methods include; low cost, ease of maintenance and the ability to strengthen part of the structure while it is still in use. The disadvantage of this method, however, is the premature de bonding of the externally bonded strips which is brittle and undesired mode of failure (Alam, M 2014). The steel plates are usually located in the tension region of a beam; however, plates located in the compression and shear zones have also been utilized. The adhesive provides a shear connection between the reinforced concrete beam and the steel plate, resulting in a composite structural member. The addition of plates in the tension zone not only increases the area of tension steel, but also lowers the neutral axis, resulting in a reduction of live load stresses in the existing reinforcement. The tension plates effectively increase the flexural stiffness, there by reducing cracking and deflection of the member(Eberline, D .et 1988).

1.4Effective Use of FRP With Steel Plate (Hybrid strengthening)

In the civil engineering , the two most popolar materials used for rehabilitation and strengthening RC structues are Steel and fiber reinforced polymers (FRP). Each materials for advantages for external bonded application. But every one of materials have special weaknesses . Steel plates are heavy and have low corrosion resistance,and their thickness is of limited for strengthening RC structues due to lack of shape flexibility. While the applications of FRPs are limited for more extensive applications due to the cost of material is still high relatively and the strength of FRP has not been fully used ,due to the bonded interface is the weakest connect in strengthened concrete members, resulting in sudden and brittle debonding failure.

In this research , an innovative strengthening method combining of used FRP and steel plate so that overcome these weaknesses.

1.5 Near Surface Mounted

In the recent year several efforts were done to increase the conversence in terms of bond , flexural , and shear responses of NSM techanique . This technique shows high levels of efficiency for upgrading the flexural and shear carrying capacities of reinforced concrete(RC) structures.NSM method included cutting of shallow grooves with in the demand direction at the bottom of the beam. The concrete cover must be larger than the depth of groove c so that the existing reinforcement is not harm. Fiber reinforced polyermer (FRP) or steel reinforcements are placed in the grooves ,after these grooves are fully with epoxy resin adhesive (Aiswarya, A. P., & Prabhakaran, P. 2017).

Some of the advantages of NSM strengthening method are

a) NSM reinforcements are less prone to debonding from the concrete substrate, (Khalifa, A. M. (2016)).

b) NSM bars can be installed more easily

c) NSM bars are protected by the concrete cover i.e. they are less exposed to accidental impact, mechanical damage, fire, and vandalis. (Peng, H ,2014)

Someof the disadvantages of NSM strengthening method are; (Aiswarya, A., & Prabhakaran, P. (2017)).

Disadivantage of NSM method

a) Groove Cutting necessitates accuracy, time and labour,

b) Very important of groove positioning. Cutting of the main reinforcement in RC members must be avoided.

c)NSM techaniques requires surface finishing after the strengthening of the structural element

1.6 Problem Definition:

The volume of the infrastructure that needs upgrading, strengthening is growing worldwide. There are many different techniques and material to repair and strengthening a concrete structure . Choosing the correct strengthening technique is one of the most important to fulfill the successful strengthening . The decision on which method is to be applied for strengthening a structural build on economic considerations and the suitability of the adopted method . The present research is understanding of flexural behavior of reinforced concrete beams strengthened different techniques and two materials ,so that select best techniques and material deponded on any techniques giving best results with less cost.

1.7 Objectives and Scope

This thesis aims to increasing information about strengthening of concrete reinforced T-beam strengthening with different techniques and materials subject nagative bending moment .

The objectives of the investigation are summarized as follows:

1. Study the behavior of simply supported concrete T-beams strengthened with different techniques (external bonded ,hybrid strengthening and near surface mounted) by using two different percentage (40% and 80% of length of span and width of flange) for strenthgening ,but the mount used for strengthening of materials (steel plate and CFRP sheet) is the same .
2. Investegation of effect using different percentage for sterengthening when used the material is the same
3.Also,investegation of effect using two different material (steel plate and CFRP sheet) for sterengthening when used the percentage is the same
4.Investagation of effect using different material or percentage on position of adhesive the material using for strengthening

These techniques are to be compared experimentally and degree of reliability.The main parameters are

1. Type of technique and material
2. The percentage of length of span and width of flange for material of strengthening

1.8 Mothodology of study

Experimental proram consist cast eleven reinforced concrete T beam at all same dimention (length span 2300mm,width of web 130mm ,height of flange 65mm and width of flange 450mm) . Ten beams strengthened and one beam unstrengthened as reference beam .The researcher ends up with discussing the results in terms of ultimate load , load-deflection relationship, concrete compressive strain, crack pattern

1.9 layout

This study is presented in five chapters:

Chapter One:

Presents the general introduction about strengthening, techniques of strengthening and the objectives of the study.

Chapter Two:

A summary of a review of the related studies in the literature is presented. Literature survey has been reported for current strengthening techniques.

Chapter Three:

Experimental work is presented with a description of the properties of the materials used. So, in this chapter describes the procedures of cast, strengthening, for specimens used in the present work.

Chapter Four:

In this chapter included the present results and discussion.

Chapter Five:

Present conclusions emerged from it are given and recommendations for future work