Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering

FLEXURAL BEHAVIOR OF CONCRETE BEAMS REINFORCED WITH STEEL PLATES AS MAIN REINFORCEMENT

A Thesis Submitted to the Council of College of Engineering University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

By

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June, 2021 IRAQ Thu AI-Qida , 1442

بسم الله الرحمن الرحيم

(وَاتَّقُوا اللَّهَ ۖ وَيُعَلِّمُكُمُ اللَّهُ ۗ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ)

صدق الله العظيم

من سورة البقرة – جزء من الآيـــــة (282)

SUPERVISOR CERTIFICATION

We certify that the thesis entitled **"Flexural Behavior of Concrete Beams Reinforced with Steel Plates as Main Reinforcement"** presented by **"Khalid Ibrahim Qaddoori"** was prepared under our supervision in the Civil Engineering Department, The University of Diyala, in partial fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering.

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Date: / /2021

In view of the available recommendation, we forward this thesis for debate by the Examining Committee.

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COMMITTEE CERTIFICATION

We certify that we have read the thesis entitled **(Flexural Behavior of Concrete Beams Reinforced with Steel Plates as Main Reinforcement)** and we have examined the student **(Khalid Ibrahim Qaddoori)** in its content and what is related with it, and in our opinion, it is adequate as a thesis for the Degree of Master of Science in Civil Engineering.

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Date: / /2021

Dedication

To my Father, who taught me the right path

To my mother the light of my eyes

To whom their love flows in my veins, and my heart remembers them, the air that I breathe …

my brothers and sisters

To our teachers and distinguished professors who taught me the letters of gold. Who redefined my knowledge simply and from their ideas, made me a beacon to guide me through knowledge and the path of success.

Everyone, who wishes success for me in my life

I dedicate this humble work.

Khalid Ibrahim Qaddoori

2021

Acknowledgments

First, thanks are to Allah for all things, which led me into the light during the hard times.

I would like to express my thanks and gratitude to the Deanship of College of Engineering and to the Department of Civil Engineering at University of Diyala

I would also like to express my thanks to my supervisor ***Assist. Prof. Dr. Ahmed Abdullah Mansor*** *for supervising this thesis.*
Great thanks to the staff of Structural Engineering Laboratory

Finally, sincere thanks are extended to all who gave a helpful hand to complete this work.

Khalid Ibrahim Qaddoori

2021

Flexural Behavior of Concrete Beams Reinforced with Steel Plates as Main Reinforcement

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ABSTRACT

In the past few years, new techniques have emerged using steel plates instead of traditional reinforcement in reinforcing concrete beams to resist flexural stresses. This study deals with the use of a new technique for reinforced concrete beams using plates instead of traditional steel bars with different thicknesses while maintaining a constant cross-sectional area. The experimental work consists of two groups, each group contains (5) specimens, which are (3) specimen with a plate thickness of (4,5,6) mm placed vertically and a specimen with a thickness of (6 mm) plate placed horizontally. In addition to the reference specimen with a diameter of (16 mm) for the first group and a diameter of (20 mm) for the second group, noting that the steel plate that used is from checker type and keeping the equivalent area for conventional steel bar constant for all specimens. The dimensions of the specimen for all specimens are (2100 mm) in length, (350 mm) in height, and (250 mm) in width. These specimens were tested under four points bending.

The results showed that as the thickness of the steel plate increases, the samples will have greater resistance until more deflection is produced. In addition, there is a reduction in the crack load, yield load, and ultimate load when replacing reinforcing bars with steel plate. In which, a reduction in crack load by about (11.10%, 15.50%, 22.20%, and 33.30%) for plate thicknesses of (4,5,6) mm vertical and (6 mm) horizontal, respectively, compared to reference. The yielding load is reduced by about (42%, 53%, 60%, and 51%) for (4,5,6) mm vertical and (6 mm) horizontal plate

models, respectively, compared to the reference specimen. In addition, ultimate load was reduced by (36%, 40%, 33%, and 40%) for (4,5,6) mm vertical and (6 mm) horizontal plate models, respectively, compared to the reference specimen.

Moreover, the deflection at yield load increased by (110%, 108%, 98%, and 55%) for vertical plate thicknesses of (4,5,6) mm and horizontal plate thickness of (6mm), respectively, compared to the reference specimen. In addition, the deflection at ultimate load was reduced by about (29.00%, 27.31%, 27.18%, and 23.00%) for vertical plate thicknesses of (4,5,6) mm and horizontal (6 mm), respectively, compared to the reference specimen.

In addition, the yielding load decreased by (42%, 53%, 60%, and 51%) for plate thicknesses of (4,5,6) mm vertical and (6mm) horizontal, respectively when decrease the cross-sectional area of steel by using equivalent are from (20mm) to (16mm) of reference specimen. Moreover, as the thickness of the steel plate increases, the measured crack load, ultimate load and yield load are increased.

Finally, by increasing the cross-sectional areas of the steel from (16mm) to (20mm) the crack load measured increases by (33.33%) (for reference specimens), and increases by (37.50%, 18.42%, and 14.28%) for (4, 5, and 6 mm) plate thickness. The horizontal direction of steel plate samples of (6mm) thickness increase about (50.00%) when increasing the cross-sectional area.

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LIST OF SYMBOLS

Symbol	Description
a	Depth of Rectangular Stress Block / mm
A_s	Area of Flexural Reinforcement (Steel) / mm2
A_b	Area of bar / mm2
A_v	Cross Sectional Area of Shear Reinforcement / mm2
b	Width of Beam / mm
B	The Ratio of Distance Between Neutral Axis and Extreme Tension Face to Distance Between Neutral Axis and Centroid of Reinforcing Steel
d	Effective Depth / mm
E_c	Modulus of Elasticity of Concrete / MPa
E_s	Modulus of Elasticity of Steel Reinforcement / MPa
E_c	Compressive Strain in the Concrete
$f_{c'}$	150mm*300mm Cylinder Compressive Strength of Concrete / MPa
f_{ct}	Indirect Tensile Strength (Splitting Tensile Strength) / MPa
f_{cu}	Compressive Strength of Standard Cube / MPa
f_r	Modulus of Rapture / MPa
f_y	Yield Stress / MPa
f_u	Ultimate stress / MPa
h	Depth of the Cross Section / mm
H	Overall height of beam
L	Beam Span / mm
P	Applied load on Beam / kN
P_y	Yield load of deep Beam / kN
P_u	Ultimate Load of Deep Beam / kN
P_{cr}	Cracking Load / Kn
P	Flexural Reinforcement ratio Coefficient
p_d	Balanced Steel Ratio
ϕ	Diameter of bar / mm
μ_d	Ductility Index

V	Poisson's ratio
V_u	Factored Shear Force of the Section / kN
V_n	Nominal Shear Strength / kN
Vc	Shear in Concrete / Kn
Vs	Shear in Steel / Kn
W_c	Crack Width / mm
Δ_u	Deflection of Ultimate Load / mm
Δ_y	Deflection of Yield Load / mm
Δ_{cr}	Deflection Cracking of Load / mm
ε	Strain
ε_y	Strain at Yield
ε_u	Strain at Ultimate
ε_{cr}	Strain at Cracking
ε_s	Strain in Steel at Level Considered, Calculation on the Basis of Cracked Section
β_1	Factor Relating Depth of Equivalent Rectangular Compressive Stress Block to Depth of Neutral Axis
ρ	Flexural Reinforcement Ratio

LIST OF ABBREVIATIONS

Abbreviation	Meaning
a/d	Shear Span to Effective Depth Ratio
a/h	Span Depth Ratio
ACI	American Concrete Institute
AISC	American Institute of Steel Construction Load and Resistance Design
ASTM	American Society for Testing and Materials
B.S	British Standard
c/c	Center to center of span / mm
CA	Coarse Aggregate
CNC	Computer Numerical Control
HSC	High Strength Concrete
I.Q.S	Iraqi Standard Specification
kN	Kilo Newton
LRFD	Specification
mm	Millimeter
MPa	Mega Pascal (N/mm2)
No.	Number
NSC	Normal Strength Concrete
RC	Reinforced Concrete
PRC	Plate-reinforced Composite
HP	Horizontal Plate uses Bolts as Fasteners
HBP	Horizontal Plate uses angles as Fasteners
VP	Vertical Pate uses Steel threads as Fasteners
VBP	Vertical Pate uses Angles as Fasteners

Chapter One

Introduction

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Concrete beams use as a significant part of structural frames has witnessed a noticeable improvement since last decades. The reinforced concrete structure consists of beams to carry the horizontal loads over the openings. These loads, which are shear and bending, generate tensile stresses, and therefore adding steel to these areas greatly increases the durability. Generally, the design of the beams assuming that tensile stresses caused the concrete to fail and that the addition of reinforced steel leads to carry all the tension.

The advantages of the use of reinforced concrete beams. in constructions such as marketable buildings, warehouses, and office buildings as follows (Meynagh, et al, 2013):

1.Easy formwork

2. Lower depth to allow services to run under the floor.

3. Long span minimum structural depth to provide inter- story height.

4. Possibility to use flying forms, and

5.Consequently good cost/time solutions.

According to ACI (American concrete Institute) code 318-14 minimum depth of simply supported beam is (L/16) (L: length of beam). In the current study the length of beam is (210mm) that produced a minimum depth of (131 mm) which exceeded the depth of beams for current.

This study deals with the use of a new method for reinforced concrete beams by using plates instead of traditional steel and with different thicknesses while keeping the cross-sectional area constant. Assume the failure of reinforced concrete beam is failed as flexure not in shear.

Figure (1-1) shows the failure of reinforced concrete beam fails in flexure, so the spacing of stirrups are constant about (10mm spacing).

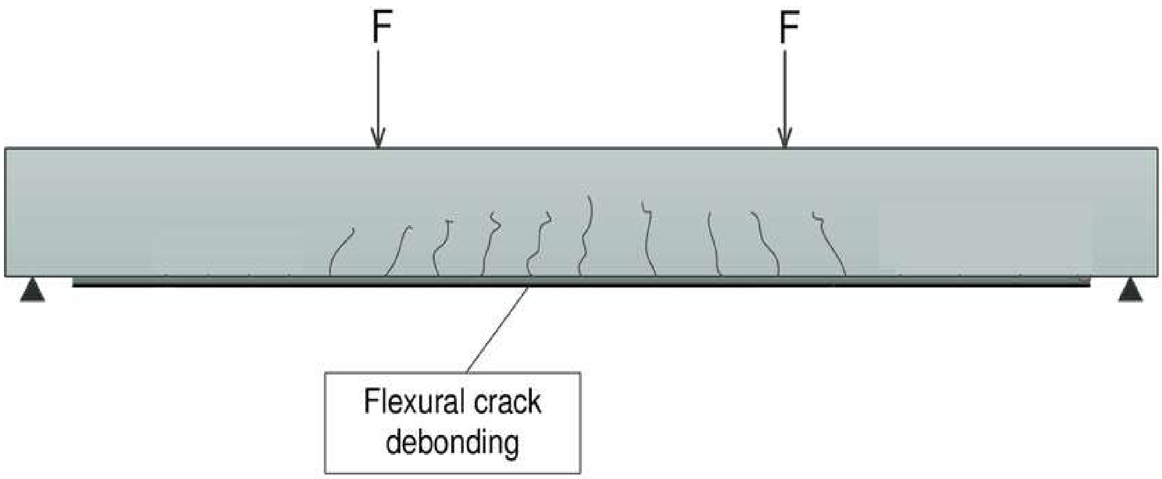

Figure (1-1) Proposed Failure of Flexure in reinforced concrete beam in current Study.

1.2 Use of Steel Plate

Indeed, very little literature have been seen to discuss the utilizing of steel plate as a flexural member up to date, although it has been used to strengthen the reinforced concrete beams, but there are no attempts to use the plates as an alternative to reinforcing stirrups, and other used the external steel plate or internal instead of flexural reinforcement.

In this research, due to fast development of manufacturing by Computer Numerical Control (CNC) machine and high cost and time entailed, some efforts have been made to discover new techniques are adopted for longitudinal reinforced concrete beam depend on using the elongated steel plate as flexural reinforcement instead of deformed steel bars.

1.3 Aim of Study

The aim of the study is investigating the flexural behavior of reinforced concrete beams by replacing the main reinforcement with steel plates and study the changing of cross-sectional area as an equivalent and dimension of steel plate in concrete beams that lied in two directions (vertical and horizontal). The experimental program consists of two groups, each group consisted of five specimens were studies in details. All tested specimens were simply supported reinforced concrete beam with the same rectangular cross section.

1.4 Objective of the research

Determining and evaluating the factors affecting the acceptability of using steel plate compared to steel bar. To identify how much difference between steel plate and steel bar in terms of cracking, yielding and ultimate load? In addition, to evaluate the deflection and monitoring the strain in (steel and concrete) and the crack width (and pattern of cracks) for all beams due to the changing of steel plate thickness.

1.5 Layout of Study

The contents of this research work are presented in five chapters as outlined below:

1. **Chapter One**: It presents the introduction about reinforced concrete beam and using of steel plate and show the scope and objective of study.
2. **Chapter Two**: shows a review of literature of using steel plate in beams.
3. **Chapter Three**: It presents the full details of experimental work that contains.
4. **Chapter Four**: It presents the results of the tests and their discussions.
5. **Chapter Five**: It includes the main points concluded from this work. Moreover, recommendations and suggestions for future studies are presented.