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

Structural Behavior of Reinforced Concrete Rectangular Beams with different Hight to Width Ratios

A Thesis Submitted to 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 **Zul Qi'dah, 1442**

بسم الله الرحمن الرحيم

"وَيَسْأَلُونَكَ عَنِ ٱلرُّوحِ قُلِ
ٱلرُّوحُ مِنْ أَمْرِ رَبِّي وَمَآ أُوتِيتُم
مِّنَ ٱلْعِلْمِ إِلاَّ قَلِيلاً "

صدق الله العظيم

مـــن ســورة الاســراء – آيـــة ٨٥

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I certify that the thesis entitled **"Structural Behavior of Reinforced Concrete Rectangular Beams with different Hight to Width Ratios"** was prepared by **"Marwa Saleem Meteab"** under my supervision at the Department of Civil Engineering-College of Engineering-Diyala University in a partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering.**

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In view of the available recommendation, I forward this thesis for debate by the examining committee.

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We certify that we have read the thesis titled **(Structural Behavior of Reinforced Concrete Rectangular Beams with different Hight to Width Ratios)** and we have examined the student **(Marwa Saleem Meteab)** 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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Prof. Dr. Khattab S. Abdul-Razzaq …………….....(Head of Department)

The thesis/ was ratified at the Council of College of Engineering / University of Diyala.

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Dean of College of Engineering / University of Diyala

Date:

SCIENTIFIC AMENDMENT

I certify that this thesis entitled (**Structural Behavior of Reinforced Concrete Rectangular Beams with different Hight to Width Ratios**) presented by **"Marwa Saleem Meteab"** has been evaluated scientifically, therefore, it is suitable for debate by examining committee.

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Dedication

I dedicate this work

To my deceased father and mother, for her love, encouragement and support me

To my husband Abbas , who always stood with me

To my brothers , who always encouraged me

To my lovely Daughters "Celine, Zahraa and Musk "

To all my friends and everyone who supported me

With my Love and Respect

ACKNOWLEDGEMENTS

*In the name of **Allah**, the most gracious, the most merciful, before anything, I thank Allah who enabled me to achieve this research.*

*First, I wish to express my sincere gratitude and appreciation to the supervisor; **Asst. Prof. Dr. Ahmed Abdullah Mansoor** for the guidance, encouragement, endless generosity and kindness she offered throughout supervising of this thesis.*

*Likewise, I wish to express my gratitude to the **all-Academic Staff and Chiefs of Department of Civil Engineering** and a big thank to all staff of the Laboratory of Structural Inspection of Daiyla University/Engineering College, represent by **Dr. Wissam D. Salman**, **Eng. Hutheifa J.Khalifa** and **Mr. Yass**. For their remarkable patience and for keeping all needed resources accessible during the long experimental work.*

*Great thanks to **my friends** for their great help.*

Finally, thank you very much for what you made and for what you presented for me on hope that your endeavors crowned me the fruit of my success to prove to you that it will not go in vain.

Marwa Saleem Meteab

2021

ABSTRACT

STRUCTURAL BEHAVIOR OF REINFORCED CONCRETE RECTANGULAR BEAMS WITH DIFFERENT HIGHT TO WIDTH RATIOS

By
Marwa Saleem Meteab

Supervised by
Assist. Prof. Dr. Ahmed Abdullah Mansor

This research work studied the behavior of structural strength of reinforcement concrete rectangular beams with different hight to width ratio (h/b) with normal concrete strength (NCS), high strength concrete (HSC), and ultra-high strength (UHSC). Twelve reinforced concrete beams with the dimensions of (150*416.6) (200*312.5) (250*250) (312.5*200) mm were investigated. The variables studied in this work were the concrete compressive strength (27-62-90 MPa), the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) It is worth to mention that self-compacted concrete used to produce the normal strength concrete, the high strength concrete (HSC), and ultra-high strength (UHSC).

The experimental results showed that, the increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) is much increasing the cracking load, yielding load, ultimate load and the ductility index. The increase in the (h/b) ratio leads to curvature and concrete compressive strain. The increase in the compressive strength of the concrete with increase in the (h/b) reduces the high defamation that caused by the plastic deformation of the steel reinforcement. The increase in the compressive strength of the concrete with increase in the (h/b) causes (74% -122%), (66.67% -116.67%) and (57.14% - 128.6%), respectively increase in cracking load, increase yielding load in the ranges of ((41.2%-

70.6%), (30%-60%) and (76.3% - 96.6%), respectively, increase the ultimate load in the range of (41.67% to 115%), while reduce the ductility index in the range of (1.2% - 31.1%) as compared with control beams (BN1, BH1 and BU1). The variation of the concrete compressive strength with constant (h/b) shows conflict in the improvement of cracking load, yielding load, ultimate load and the ductility index.

The maximum crack width decreases gradually with gradual increase in the (h/b) ratio (from 0.36 to 0.64, 1 and 1.56) for constant (27 MPa or 62 MPa or 90 MPa) compressive strength of concrete in the range of (11.11% - 25.9%), (5.3% and 21%) and (13.33% - 33.33%) respectively, as compared with control beams (BN1, BH1 and BU1). The gradual increase in the compressive strength of concrete from (27 MPa to 62 and 90 MPa) with constant (0.36 or 0.64 or 1 or 1.56) (h/b) ratio leads to increase the first crack load with range of (5.3%-33.33%), increase yielding load in the range of (17.65% -70.8%), increase the ultimate load in the range of (4.35%-71.88%), while reduce the ductility index in the range of (1.16% and 18.8%) as compared with control beams (BN1, BH1 and BU1). The maximum crack width decreases gradually with gradual increase in the compressive strength of concrete from (27 MPa to 62 and 90 MPa) with constant (0.36 or 0.64 or 1 or 1.56) (h/b) ratios in the range of (25% - 50%) as compared with control beams (BN1, BH1 and BU1).

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a	**Depth of equivalent rectangular stress block, mm**
A	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^2
A_v	Area of shear reinforcement within spacing s, mm^2
A_{sf}	Area of reinforcement in flange, mm^2
C	Compression force of concrete, N
c	Distance from extreme compression fiber to natural axis, mm
c_c	Least distance from surface deformed reinforcement to the tension face, mm
d	Effective depth of beam, distance from extreme compression fiber to centroid of longitudinal tension reinforcement, mm
D	Overall depth of beam, mm
d_c	Thickness of concrete cover measured from extreme tension fiber to center of bar, mm
E_c	Modulus of elasticity of concrete, MPa
E_s	Modulus of elasticity of steel reinforcement, MPa
f'_c	Specified compressive strength of concrete, MPa
f_r	Modulus of rapture of concrete, MPa
f_{ct}	Measured average splitting tensile strength of concrete, MPa
f_y	Specified yield stress for nonorestressed reinforcement, MPa
f_s	Stress in deformed reinforcement closest to the tension face at service load, MPa
f_{yv}	Yield stress of vertical web reinforcement, MPa
$\sqrt{f'_c}$	Square root of specified compressive strength of concrete, MPa
h_{top} & h_{bot}	Depth of top and bottom chords, respectively.
h_{max}	is the larger of h_{top} and h_{bot}
I_b & I_t	moments of inertia for the bottom and top chords, respectively.
M_n	Nominal flexural strength at section, N.mm
P_{ult}	Ultimate load of T-beam, kN
P_{yield}	Load at yield, kN
$P_{cr-flex}$	First flexural cracking load, kN
$P_{cr-diag}$	First diagonal cracking load, kN
$P_{Buckling}$	Buckling load, N
T	Tension force, N
V_n	Nominal shear strength, N
V_c	Nominal shear strength provided by concrete, N
V_s	Nominal shear strength provided by shear reinforcement, N
w	Crack width
ϕ	Diameter of bar, mm
ε_{yield}	Strain at yield

$\boldsymbol{\rho}$	Flexural reinforcement ratio, $\frac{A_s}{bd}$
$\boldsymbol{\rho_b}$	Balanced ratio of flexural reinforcement
$\boldsymbol{\rho_{max}}$	Maximum ratio of flexural reinforcement
$\boldsymbol{\rho_{min}}$	Minimum ratio of flexural reinforcement
$\Delta_{cr-flex}$	Deflection corresponding to the 1st flexural crack load, mm
$\Delta_{cr-diag}$	Deflection corresponding to the 1st diagonal crack load, mm
Δ_{fail}	Deflection corresponding to the ultimate load, mm
Δ_{fail}	Deflection at yield, mm
$\boldsymbol{\beta_1}$	Factor concerning equivalent rectangular compressive stress block depth to neutral axis depth.

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
RC	Reinforced Concrete
I.Q.S	Iraqi Standard Specification
c/c	Center to center clear span, mm

CHAPTER ONE
INTRODUCTION

1.1General

A beam is a structural ingredient that resists the loads, when some external loadings are applied on the beam, it tends to bend and deflect under loading, therefore it is also called flexural member because it behaves as a flexural member in the structure. It is considered one of the significant parts in the structure because it carries the slab load and transfers it to the column. (Tejaswi and Ram, 2015; Khan, et al, 2017) Basically, there are two most significantly modes of failure occurs in reinforced concrete beams: flexural and shear. For attaining a total flexural ability of reinforced concrete beams under maximum loads, it should be designed to represent a ductile flexural failure mode. (Eskenati and Pour, 2015). Four significant events are occurring in the beam during the flexural failure, which can be identified it as follows:

- Cracking of concrete in the tension zone.
- Yielding of tensile reinforcement.
- Concrete cover is crushing and spalling in the compression zone.
- Disintegration of the compressed concrete. (Rashid and Mansur, 2005)

There are several factors influence the flexural behavior of beam, such as the tensile reinforcement ratio, compressive reinforcement ratio, compressive strength of concrete, height to width (h/ b) ratio, and confinement in the pure flexural zone by closed stirrups.

1.2 High Strength Concrete

Although high- strength concrete is often considered a relatively new material, its development has been gradual over many years. As the development has continued, the definition of high- strength concrete has changed in the 1950s; concrete with a compressive strength of 34 N/mm2 was considered high strength. In the 1960s, concrete with 41 and 52 N/mm^2 compressive strengths were used commercially. In the early 1970s, 62 N/mm^2 concrete was being produced. More recently, compressive strength approaching 138 N/mm^2 have been used in cast-in-place building (Annadurai and Ravichandran, 2014). High compressive strength is achieved by using supplementary cementitious materials such as silica fume and slag which improve the dispersion of cement in the mix. Most of high-strength concretes also have a low water-to-cementitious-materials ratio ranging from 0.25 to 0.35 (Wight and Macgregor, 2009).

1.3 Self-Compacting Concrete (SCC)

Self-compacting concrete constituents are like to other plasticized concrete. It involves of cement, coarse and fine aggregates, mineral and chemical admixtures, etc. Self-compatibility of concrete can be influence by the physical properties of materials and mixture proportions. The mixture proportions are according upon producing a high-degree of flow ability however maintaining a low-water/cementitious materials ratio, w/c ($\leq$ 0.40). This is attained using high-range water reducing (HRWR) admixture put together with stabilizing agents to satisfy homogeneity of the mixture. A number of approaches exist to improve the concrete mixture proportions for self-compacting concrete. The simplest technique for mixture proportioning for self-compacting concrete is proposed by Okamura and Ozawa (1997) in this method:

1. Coarse aggregate quantity is fixed within 50% of the solid volume.
2. Fine aggregate is placed within 40% of the mortar fraction volume.
3. Water-to-cementitious materials ratio in volume is certain as 0.9 to 1.0 depending on properties of the cement.

4. Superplasticizer dosage and the final W/Cm ratio are determined so as to confirm the self-compatibility. Since, the self-compacting concrete involves a large portion of fine aggregate, a rational mixture proportioning method for self-compacting concrete using a variety of materials is necessary .

Fresh SCC concrete must be characterized by the following properties: -

- Filling ability.
- Passing ability.
- Segregation resistance.

1.4 Wide Beams and Deep Beams

Reinforced concrete wide beam is a horizontal members which are used in reinforced concrete joist and ribbed slabs, its depth equals or slightly higher of slab depth. Wide beams have become more popular in structural buildings in recent years because they provide longer clear spans at a lower cost, reduce overall slab depth to achieve more floor clear height, are simple to construct, and are preferred by architects and designers because they are less obstructive and provide more flexible space (Elsouri and Harajli, 2015). It can be found in warehouses, garages, high-rise buildings, and commercial structures. A wide beam with a width-to-depth ratio of at least (2) (Mohammadyan-Yasouj, et al., 2013). .describes deep beam as: Member subjected to loads on one surface and supported on the opposite surface so that the compression struts can grow between the points of load and the supports. Deep beam has one or the other:

1) Clear spans *Ln*, less than or equal to 4 times the whole member depth; or

2) Concentrated load zones within double the member depth from the support face. For deep beams that loaded uniformly, the shear critical section should be

taken into consideration at a distance from face of support about (0.15 Ln ≤ d) and of (0.5 a ≤ d) for concentrated loaded deep beams, where (a) is the shear span, or distance from concentrated load to the support center and (d) is the distance from extreme compression fiber to the centroid of the tension steel bars (Merritt and Ricketts, 2000).

1.5 Aims and Objectives of the study

The study aim is to change the dimensions of the reinforced concrete beams to satisfy the building requirements .An experimental investigation results are reported in this thesis on the strength and behavior of reinforced concrete beams. Significant parameters which considered in strength analysis for beam with different height to width ratio (h/b) under different compressive strength values. In the context of this study, beams subjected to two concentrated load.

There are principal objectives in this study:

1. To investigate, the strength and behavior of reinforced concrete beams with different (h/b) ratio under different compressive strength values.
2. To investigate, the strength and behavior of reinforced concrete beams with fixed (h/b) ratio under different compressive strength values.

Twelve reinforced concrete beams with the dimensions of (150x416.6) mm, (200x312.5) mm, (250x250) mm, and (312.5x200) mm, and fixed length 1400 mm were investigated. Based on the above different variables, the specimens are divided into Two groups. The groups are:

1. Group A: This group consists of four beams all have different cross section dimensions(h/b) and different compressive strength values NSC of 27 and HSC 62 and UHSC 90 MPa.
2. Group B: This group consists of three beams all have the same cross section dimensions but with different compressive strength values.

1.6 Organization

The organization of this thesis is consists of five chapters, as shown below:

- ✓ **Chapter One** presents a general introduction about high strength concrete and self-compacting concrete in addition to the aim and objectives of study.
- ✓ **Chapter Two** presents a review of some previous researches with experimental studies carried out on RC beams with high strength concrete and size effect on beams.
- ✓ **Chapter Three** deals with the used construction material properties in addition to the experimental work.
- ✓ **Chapter Four** deals with presenting test results of the laboratory specimens, discussing and evaluating the experimental results of this study.
- ✓ **Chapter five** provides the conclusions drawn from this study, recommendations and suggestions for further studies