Ministry of Higher Education
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University of Diyala
College of Engineering

EXPERIMENTAL STUDY ON MAXIMUM SPACING OF SHEAR REINFORCEMENT FOR WIDE BEAMS

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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بسم الله الرحمن الرحيم

وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ

وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ

وَالشَّهَادَةِ فَيُنَبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ

صدق الله العظيم

التوبة - 501

DEDICATION

All praise to Allah, today we fold the days' tiredness and the errand summing up between the covers of this humble work…

To the utmost knowledge lighthouse, to our greatest and most honored Prophet Mohamed (Peasce Be Upon Him) …

To whom he strives to bless comfort and welfare and never stints what he owns to push me in the way of success, who taught me to promote stairs of life wisely, and patiently, to my dearest father…

To the spring that never stops giving, to my mother who weaves my happiness with strings from her merciful heart …

To the fulfillment symbol and my life companion, and the secret of my happiness my dear wife…

To my heart and the focus of my eyes, my son and my daughter Taha and Ghazal…

To my second halves, brothers and sisters …

Mustafa Jawad Taha

2021

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Mustafa Jawad Taha

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ABSTRACT

Experimental study on maximum spacing of shear reinforcement for wide beams

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The main objective of this study is to investigate the behavior of reinforced concrete wide beams when increasing the maximum shear reinforcement spacing (Smax) from d/2 (limitation of ACI 318M-14). to (0.75d, S, d), Twelve specimens of reinforced concrete beams were experimentally carried out, all beams were tested as simply supported beams under two-point loads with normal concrete strength (30MPa). The experimental program consisted of casting and testing three groups of wide beams specimens with constant dimensions of 1600mm length, 200 mm height with different width. The group one consisted of four wide RC beams by width of 400mm: one of these beams was designed according to ACI-Code (Smax) d/2 (control beam) and the other three beams were designed by increasing shear reinforcement spacing to (0.75d), (0.81d) and (d), the group two consists of four wide RC beams by a width of 500mm:one of these beams was designed according to ACI-Code (Smax) d/2 (control beam) and the other three beams designed by the increasing spacing to (0.65d),(0.75d) and (d),the group three consists of four wide RC beams by width 600mm:one of these beams was designed according to ACI-Code (Smax) d/2 (control beam) and the other three beams designed by increasing spacing to (0.55d),(0.75d) and A(d).

No significant effect in ultimate load for the experimental program by increasing shear spacing to (0.75d ,0.81d and d), where the different was decreased around **5%** in group one (width 400mm), where decreased by (2%,4.9%,8.8%) for spacing (0.75d,0.81d, d) but decreased around **6.5%** in group two (width 500mm), where decreased by (4.25%,6%,9.5%) for spacing (0.65d,0.81d, d) and decreased around **14.5%** in group three (width 600mm), where decreased by (0.5%,13.5%,15.6%) for spacing (0.55d,0.81d, d).

No large difference in first flexural crack loud and first diagonal crack loud where the different around (5% and 7.5%) in group one, (10% and 10.5%) in group two and (10.5% and 15.5%) for group three.

The test results also indicated that when (Smax) increased from (0.5d to 1.0d), the deflection decreased by about 0.7% to 14%, 6.9% to 22% and 10.8% to 13.25% for group one, two and three. When increasing width of wide beams from 400mm to 500mm in group two and to 600mm in group three, the ultimate load increasing by 2.8% in group two and17.25% in group three, the first flexural crack load increasing by 27.75 in group two and 20% in group three, the first diagonal crack load decreasing in all beams by average 10.6% in group two, and decreased by average 35.75 in group three, the ultimate deflection decreased in all beams of group two by average 15.75%, in group three the ultimate deflection increased in all beams by 16.7 except the beam with spacing (Smax=d) decreased by 1.3%.

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List of Symbols and Terminology

Symbol	**Definition**
ACI	American Concrete Institute
As	Area of tension steel reinforcement, mm2
Av	Area of shear reinforcing steel, mm2
As) req.	Required area of tension reinforcing steel, mm2
As) prov.	Provided area of tension reinforcing steel, mm2
ASTM	American Society for testing and materials
B.S	British Standards
h	Overall height of a flexural member, mm
b=bw	Width of rectangular cross section, mm
d	Distance from extreme compression fiber to centroid of tension reinforcement, mm
f_y	Specified yield stress of non-restressed steel reinforcement
$f`_c$	Specified compressive strength of concrete for cylinder at 28, days, MPa
$\sqrt{f`c}$	Square root of specified compressive strength of concrete, MPa
$Ø_b$	Bar diameter, mm
$Ø_{bs}$	Bar diameter of stirrups, mm
ρ	Steel reinforcement ratio
ρ_{Max}	Maximum steel reinforcement ratio
ρ_{Min}	Minimum steel reinforcement ratio

Symbol	**Definition**
Mn	Nominal moment capacity, kN.m
Mu	Ultimate moment capacity, kN.m
Ø	Strength reduction factor (equal to 0.9 for flexural and 0.75 for shear)
P	Applied load, kN
S	Spacing of steel reinforcement, mm
SMax.	Maximum spacing of steel reinforcement, mm
Vu) d	Factored shear force at section, kN
Vc	Nominal shear strength provided by concrete with steel
Vs	Shear resistance provided by steel stirrups, kN
Vn	Nominal shear strength at section, kN
RC	Reinforced concrete
Pcr	Cracking load, N
P ultimate	Ultimate applied load, N
Δy	Deflection at yield load, mm

Note: other notations are explained where they appear in the text

CAPTER ONE
INTRODUCTION

1-1 Introduction:

In recent years, the use of wide concrete beams in structural frame systems has increased. This change responds to the need for low-cost keys that reduce the complexities of structure and construction. The engineers of new high-rise buildings, for example, are frequently tasked with conveying column loads from the tower portion directly above the desired column, open spaces in the pedestal or parking spaces below. Wide beams can be used to provide suitable cross-section areas to perform the required capability at a shallower depth than the slender beam system at the plan's parallel spacing. Where semi-incomparable loads are in the Plan should be supported, a heavy transfer slab can prove to be a low-cost solution that avoids a formwork complication. Plate (1-1) shows a floor structure in a new building project in Toronto with wide beams. In this example, the use of wide beams reduces the amount of building height, while allowing higher adjacent slabs with reduced effective span. (**Al-Mashhadani,2016**).

Plate (1-1): Toronto high-rise with wide beams building (**Al-Mashhadani,2016**).

Reinforced concrete wide beam (RCWB) is a horizontal member used on RC joists and ribbed slabs, its depth is equal to or slightly higher than the slab depth as shown in plate. (1-2). Wide beams have begun to be used more in structural buildings in recent years because they provide a reasonable cost for longer clear span, minimize the overall slab depth to achieve more clear height of the floor, easy to construct, preferred by architects and designers as it is less obstructing and give more flexible space (**Elsouri and Harajli, 2015**). It is used in a number of places, such as warehouses, parking garages, high buildings and commercial buildings. Wide beam having width to depth ratio not less than (2) (**Mohammadyan-Yasouj, et al., 2013**).

Plate (1-2) : Ribbed slabs with wide beams (**SACRAMENTO & OLIVEIRA 2018**).

There are many uses for use of wide beams, such as:

1. Reinforced concrete wide beams are used for lateral load resistance, especially in high-rise buildings in higher seismic regions.
2. Reinforced concrete wide beams are commonly used as a main concrete structure in buildings or bridges.
3. Its shape will be beautiful from the architectural perspective, if used in a wide area, so it is mostly chosen by architects as the main gravity load transport system because they allow more flexibility in the explanation of the spaces and are very important in the reduction of the formwork.
4. Connections of reinforced concrete, wide beam column, has high efficiency to resist earthquake loads.
5. Wide reinforced concrete beams are used in buildings to minimize reinforcement and floor heights for headroom requirements.
6. In the design of buildings, recent architectural limitations allow engineers to provide a longer clear span at a reasonable cost.

1.2 Shear Failure of Reinforced Concrete Beams

As well as designers' expertise, buildings are designed against bending and shear stresses, torsion, axial loads, lateral louds. longitudinal reinforcement bars are used to resist bending failure and steel stirrups are typically used to resist shear failure that occurs suddenly without any warning. Unlike initial type failure. The shear failure of reinforced concrete beams usually occurs on the support and can be identified from a crack angle approximately equal to 45° with the beam axis as shown in plate (1-3)

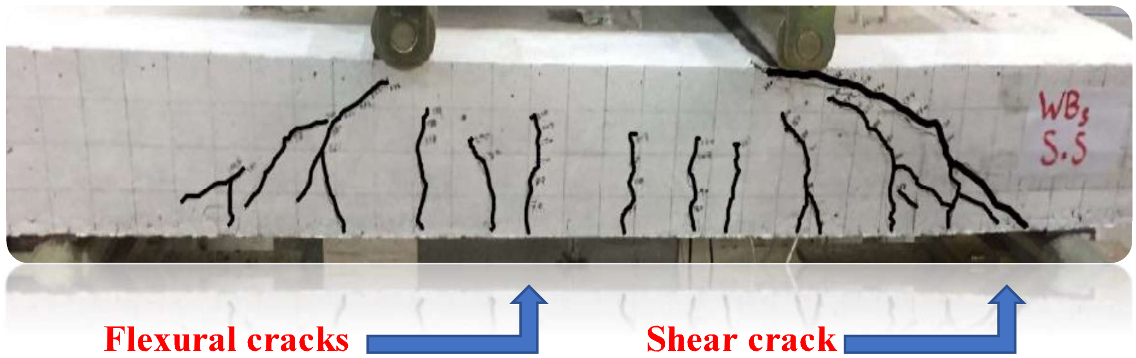

Plate (1-3): flexural and shear cracks in wide beam

It should be noted that the shear strength of the beam depends on many factors such as: concrete compressive strength (fc`), effective depth ratio (d), shear span to effective depth ratio (a/d), beam width (b_w), steel reinforcement ratio (ρ_w) and shear strength ratio in beam design. (**Abbas Ali 2018**).

In previous years, many buildings and structures had collapsed as a result of beam failure in shear, whether it was a structural design error or an execution error or a result of earthquakes, perhaps the most prominent was in the year (2003) when a ten-story parking garage collapsed in the Atlantic town of Tropicana resort which resulted in the death of four workers and many others were injured. Despite the collapse of these decks, the shear walls of the columns remained standing after failure as shown in the plate (1-4)

Plate (1-4): shear failure in beams of the parking garage in the Atlantic City (**Bosela 2018)**

1-3 Aim of the study

The aim of this study can be summarized by increasing the spacing between shear reinforcement from (**d/2**) According to ACI-code to(**d**), without much effect on shear strength of reinforced concrete wide beam.

When using d/2 or d/4 As stipulated ACI code the spacing between stirrups will be very close as it leads to a large crowding in the steel reinforcement in addition to an increase in weight, cost and delay in construction.

1-4 Objective of the Study

The objective of the current study is to experimentally investigate the behavior of wide RC beams by increasing the shear reinforcement spacing. The experimental program involves:

1. The behavior of the beams with the gradual increase of the shear spacing.
2. The effect of increasing shear spacing on the shear capacity for wide reinforced concrete beams.
3. The performance of reinforced concrete wide beams when increasing width of beam with increasing maximum spacing (Smax).
4. - Finally, the possibility of change the term of maximum spacing (Smax.) which are dominant in determining of the maximum shear reinforcement spacing in the longitudinal direction from (d/2) to the (d) of (ACI-Code318) limitations.

1-5: Layout of the study

- **Chapter One:** General introduction about RC wide beams structures, shear failure in beams and the Objective of the Study.
- **Chapter Two:** Most of the previous researches on wide concrete beams, shear of concrete beams and Shear design equations by number of codes.
- **Chapter Three**: Deals with the properties of the materials, in addition to the details. It's experimental work. It also highlights the details of the test specimen and the Testing of the RC beams.
- **Chapter Four:** Experimental results and discussion.
- **Chapter Five:** Presents the conclusions of the current study, suggestions and recommendations for further studies.