



Study Effect the Shear Spacing and Width of Beam on Behaviour of Reinforced Concrete Wide Beams

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ABSTRACT

This paper presented an experimental study of the behaviour of wide reinforced concrete beams with different shear spacing and beam width. Eight specimens in two groups, the group one contains four specimens with the dimensions of (200x500x1600mm) and shear reinforcement spacing ($d/2$, $0.65d$, $3/4d$ and $1.0d$), the group two contains four specimens with the dimensions of (200x600x1600mm) and shear reinforcement spacing ($d/2$, $0.55d$, $3/4d$ and $1.0d$). Variables studied in this study shear reinforcement spacing and width of wide beam, the increasing of shear reinforcement spacing gives close results in RC wide beam, increased shear reinforcement spacing decreased the ultimate load by 6.6% and when increasing width of beam the ultimate load decreased by 9.5%, The ultimate deflection decreased by 16.5% and when increasing width of beam decreased by 7.2%. The number of flexural cracks was equal in all beams, when increasing width of beam the number of flexural crack increased by 2 cracks, The average spacing between shear cracks decreased by 7%, when increasing width of beam average spacing between shear cracks decreased by 19%.

1. Introduction

The use of wide concrete beams in the structural sector Framing technologies have improved in recent years. This is an adjustment that responds to the need for low-cost keys that reduce structural and building complexities. For instance, New high-rise building engineers are Frequently tasked with carrying column loads Free spaces in the pedestal or parking areas below are required from the tower portion above. Wide beams may provide suitable cross-section areas to provide the necessary capacity at a shallower depth than the slender beam system at parallel spacing in the plan.

Reinforced concrete wide beams are commonly used in commercial buildings, parking buildings, and large warehouse with large spans. The main use of reinforced concrete

wide beams is to reduce story height (Kim, M. S., [1].

Ibrahim, A. M. et. al., [2]. Eight specimens with dimensions of 215x560x1800 mm were examined. The variables studied struggle with the substitution of 10 mm diameter stirrups spaced at 125 mm by shearing steel plates providing an equal cross-section area for stirrups in the middle legs Height with circular openings of various thicknesses (3, 4 and 5 mm). Four specimens had no bubbles, and the others had no bubbles. This study has shown that shear steel plates are a good alternative for the replacement of stirrups and provide improved yield, eventually. Load and deflection (at duty load) with an average of 5 percent, 15 percent and 9 percent when using bubbles.

Said, M., & Elrakib, T. M. [3]. The experimental program consisted of nine 29 MPa concrete beams tested with a shear span depth

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Ratio is equivalent to 3.0. One of the beams examined did not have a web reinforcement as a control specimen the flexicurity mode of failure was protected for all specimens to allow the shear mode of failure. The main parameters covered by this investigation are the effect of the life, spacing, quantity and yield stress of the vertical stirrups on the shear ability and ductility of the large beams tested. The study shows that the contribution of web reinforcement to shear capability is important and is directly proportional to the volume and spacing of the shear reinforcement.

Lubell, A.S., et. al., [4], stated that the concrete large, wide beams, and thick slabs are used as transfer elements when the structural depth must be kept to a minimum value, these members have large cross sectional area which is used to resist shear demands; however, shear reinforcement might be still required. Wide beams are the most desired construction members that can be used for low depth structural members, it can provide small depth in the cross-sectional area, moreover, it can be used when semi unequal loads in the plan should be supported, where a heavy transfer slab can prove to be an expensive solution.

Kim, M. S., [1] made experimental program to study the shear behavior of concrete wide beams taking into account the reinforcement spacing, and support conditions. From this experimental program shear strength was estimated by a developed equation. The results showed that when the transverse reinforcement spacing increased the shear strength decreased.

Abass, A. L. et.[5] al The current study presents the results of four full-scale wide RC beams in order to study their shear behavior and investigate the effectiveness of carbon fiber reinforced polymer (CFRP) when using as shear reinforcement to improve the shear capacity of wide RC beams, The results showed an increasing in ultimate load of strengthened beams with inclined, vertical CFRP and beam with shear reinforcement by (19.9%), (7.14%) and (39.8%) respectively as compared with the control beam, and this results means possibility of replacing the internal shear reinforcement with externally bonded CFRP.

Sherwood, E. G. et. al, [6] this paper discusses nine recent issues Tests designed to resolve these issues. The width of the Member was Finding to have no major impact on shear stress at failure for one-way slabs and wide beams. In addition, the presence of Reduction and temperature reinforcement did not have an effect on the One-way shear capacity. Based on the findings of the experiment and Related narrow slab strip tests in the literature, the paper concludes That the provisions of the ACI 318-05 Shear can result in insufficient levels of Safety for both thick slabs and wide beams 2.

2.The significance of the research

The focus of the study is behavior of shear reinforced concrete wide beam whin increase the spacing between stirrups and increasing the width of beam, this study handled the Crowding between shear reinforcement and reduced time and cost, also this study Explained The effect of increase beam width on shear capacity, and study the effect that to: load, deflection and crack patterns.

3. Details of the experimental tests

The experimental program consists of eight beams in two groups each group four beams. with nominal compressive strength of (f_c) =30MPa, Concrete tensile strength (f_t) =2.59MPa, Concrete flexural strength (f_{cr}) =3.77MPa, Ordinary Portland Cement (OPC)(Type-I) (TASLUJA-BAZIAN) was used for all test beams the chemical and physical tests were in accordance with the Iraqi specification (Iraqi standards/No.5, 1984). Al-Siddur natural sand with a maximum size (4.75mm) has been used for this purpose, crashed gravel with a maximum size (19mm) of the AL-Suddor fields has been used in the work. each was tested in a four-point loading arrangement. All beams were constructed in the laboratory of the Engineering College of the University of Diyala. All beams in group one was 500 mm wide, 200 mm deep, 1600 mm long, and shear reinforcement spacing ($d/2$) (control beam), and other three beams with variable shear reinforcement spacing (S , $3/4d$, d), where $S=0.65d$ in this group, these group all beams are identical in width to depth ratio (2.5),

tension steel reinforcement area ($A_s=1280\text{mm}^2$), This beam with flexural reinforcement; (7 \varnothing 16) and (2 \varnothing 12) in the tension and compression zone of RC beams respectively.

Group two consists of four beams one beam has shear reinforcement spacing ($d/2$) (control beam), and other three beams with variable spacing shear reinforcement (S, $3/4d$, d), where $S=0.55d$ in this group, these group all beams are identical in width to depth ratio (3), tension steel reinforcement area ($A_s=1536\text{mm}^2$), This beam with flexural

reinforcement; (8 \varnothing 16) and (2 \varnothing 12) in the tension and compression zone of RC beams respectively.

LVDT gauges were used for deflection reading, the data logger was used to read the steel and concrete strains and measurements of micro cracks were used to measure crack widths at loading stages due to failure of beams. Development of deflection, strain and crack width at each stage was measured on the beams to track the growth, sequence and pattern of cracking. as shown in Table (1) and plates (1A, B) and (2A, B).

Table 1. Details of beams in groups one and two

Group	Beam's designation	Spacing Between Stirrups	Spacing (mm)	Width to depth ratio	Width of beam (mm)
one	WB1-G1	$d/2$	81	2.5	500
one	WB2-G1	$0.65d$	105	2.5	500
one	WB3-G1	$0.75d$	121.5	2.5	500
one	WB4-G1	$1.0d$	162	2.5	500
two	WB1-G2	$d/2$	81	3	600
two	WB2-G2	$0.55d$	88	3	600
two	WB3-G2	$0.75d$	121.5	3	600
two	WB4-G2	$1.0d$	162	3	600

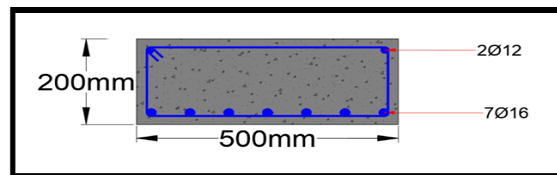
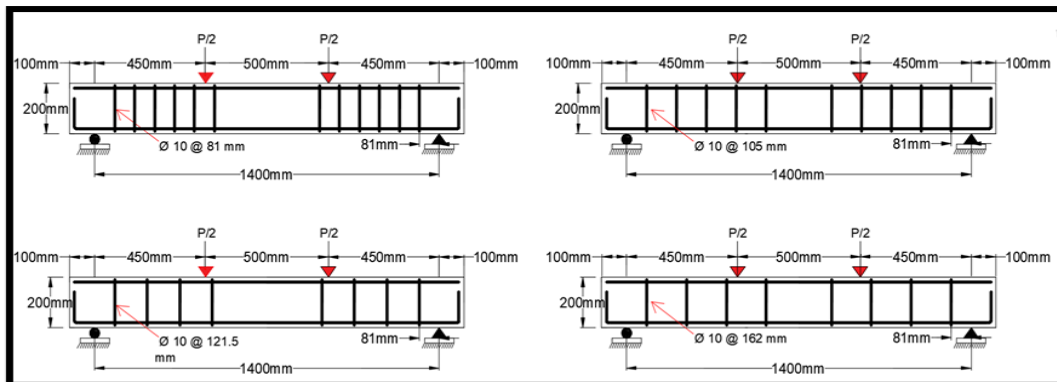


Plate (4-1A): Beam section for group one



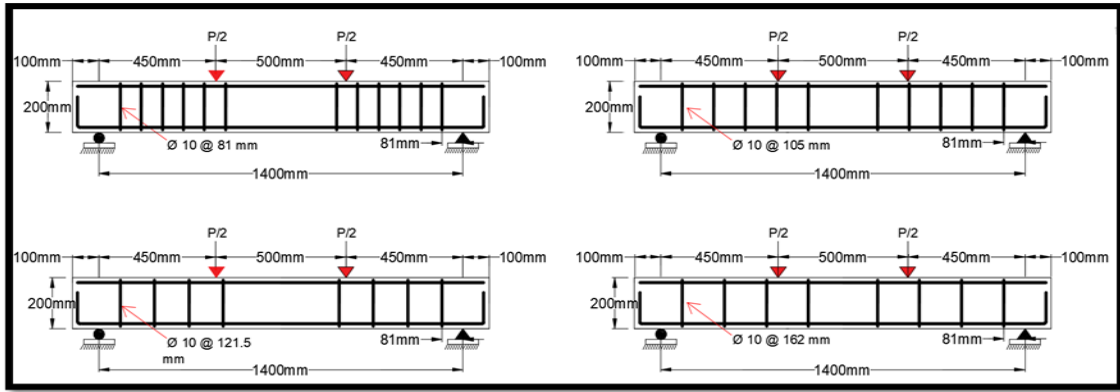


Figure 1. Plate (4-1B): Longitudinal Profile of Wide RC Beams in Group One

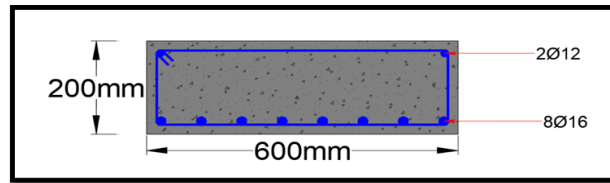


Plate (4-2A): Beam section for group two

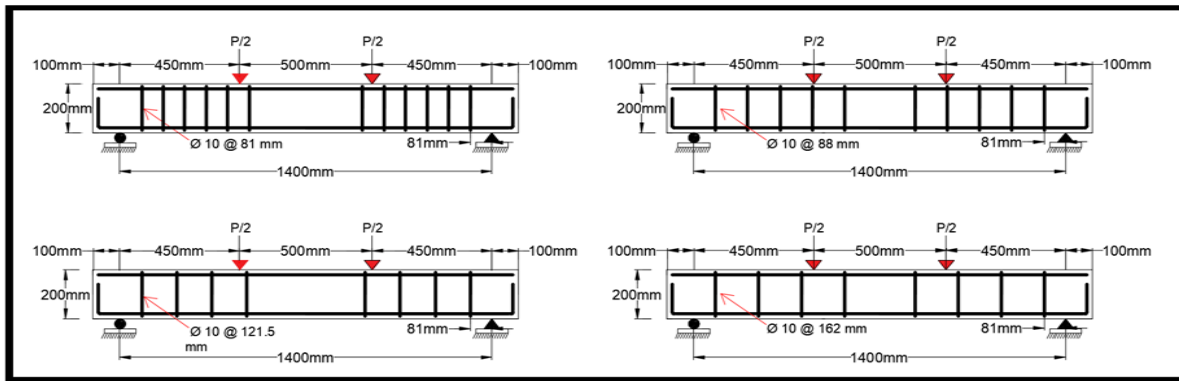


Figure 2. Plate (4-2B): Longitudinal Profile of Wide RC Beams in Group two

3. Results and discussion

Strength characteristics of all specimens (crack, ultimate load and deflection at crack, Failure mode) shown in Table (2).

Table 2. Strength characteristics of specimens tested

group	Beam's Specimens	P-flexural Cracks (kN)	Δ (mm)	P-diagonal cracks (kN)	Δ (mm)	P-Ultimate (kN)	Δ_u (mm)
one	WB1-G1	85	3.8	192	5.5	400	13.1
one	WB2-G1	95	2.2	210	4.65	383	12.2
one	WB3-G1	90	1	215	4	373	10.4
one	WB4-G1	100	1.2	220	4.5	362	10.2
two	WB1-G2	75	1.3	137	2.6	480	16.6
two	WB2-G2	80	1.8	135	2.9	482	17
two	WB3-G2	70	1.9	105	2.8	415	14.8
two	WB4-G2	92	1.4	107	1.9	405	14.4

4.1 Group one

4.1.1 Load of cracking

This can be seen in Table (3) that the measured flexural crack load increased by 11.7 % for all beam (WB2-G1, WB3-G1 and WB4-G1) respectively compared with WB1-G1. Because the lower the Ultimate load, the later the cracks will appear. and the diagonal crack load give same result in WB2-G1 exactly and increased by 14.3% in WB3-G1, but WB4-G1 decreased by 8.3% compared with control beam. All results were close and the differences did not exceed 12% whether they were increased or decreased.

4.1.2 Ultimate load

As shown in the table (3), all beam They gave close results that did not exceed 10%, they beam decreased by (4.25%, 6% and 9.5%) for

WB2-G1, WB3-G1 and WB4-G1 respectively compared with WB1-G1, this descent into the final load is normal due to the increased the shear reinforcement spacing, that means the effect of increasing the distance between stirrups from (d/2 to d) very small for reinforcement concrete wide beam.

4.1.3 Load –Deflection behavior

From Table (3) the deflection in WB1-G1 control beam 13.1mm, the other beams decreased compared with control beam by 6.9%, 20.6% and 22% for WB2-G1, WB3-G1 and WB4-G1 respectively, that means the lower the load, the less deflection. Figure (3) show the Relationship between load and deflection for all beams in this group, from this figure it can be noted All beams have the same behavior, especially up to 300 kN loads.

Table 3. Comparison of the strength characteristics of Group One

Beam Specimens	P-flexural Cracks (kN)	%	P-diagonal cracks (kN)	%	Pu (kN)	%	Δu (mm)	%
WB1-G1	85	--	192	--	400	--	13.1	--
WB2-G1	95	+10.5	210	+8.5	383	-4.25	12.2	-6.9
WB3-G1	90	+5.6	215	+10.7	376	-6	10.4	-20.6
WB4-G1	100	+15	220	+12.7	362	-9.5	10.2	-22

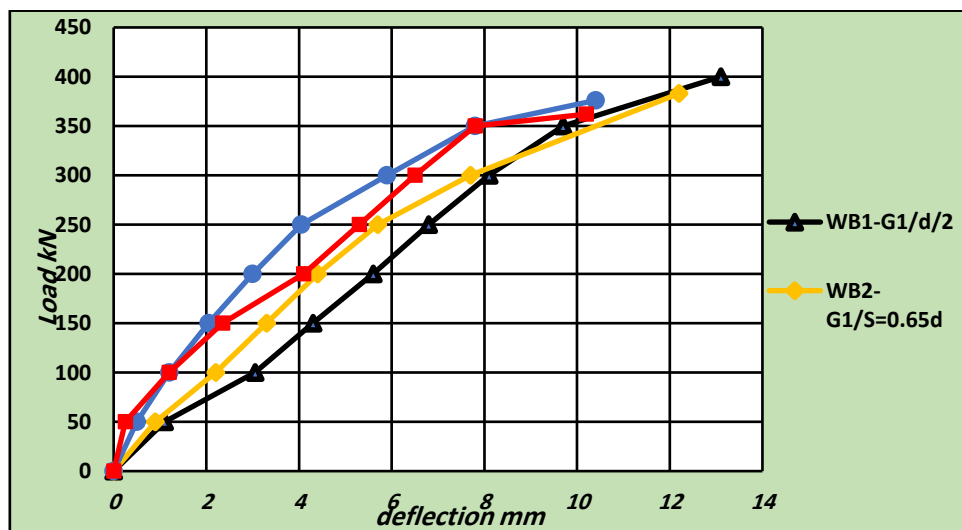


Figure 3. Load- Deflection Curve of wide beams in Group One

4.1.4 Crack pattern

The beams tested at different stages of loading are shown in detail in Figure (4) and plate (1). The numbers in red color inside the diagram represent the development of the cracks at each load, while the black numbers under the cracks represent the sequence of the appearance of the cracks during the test.

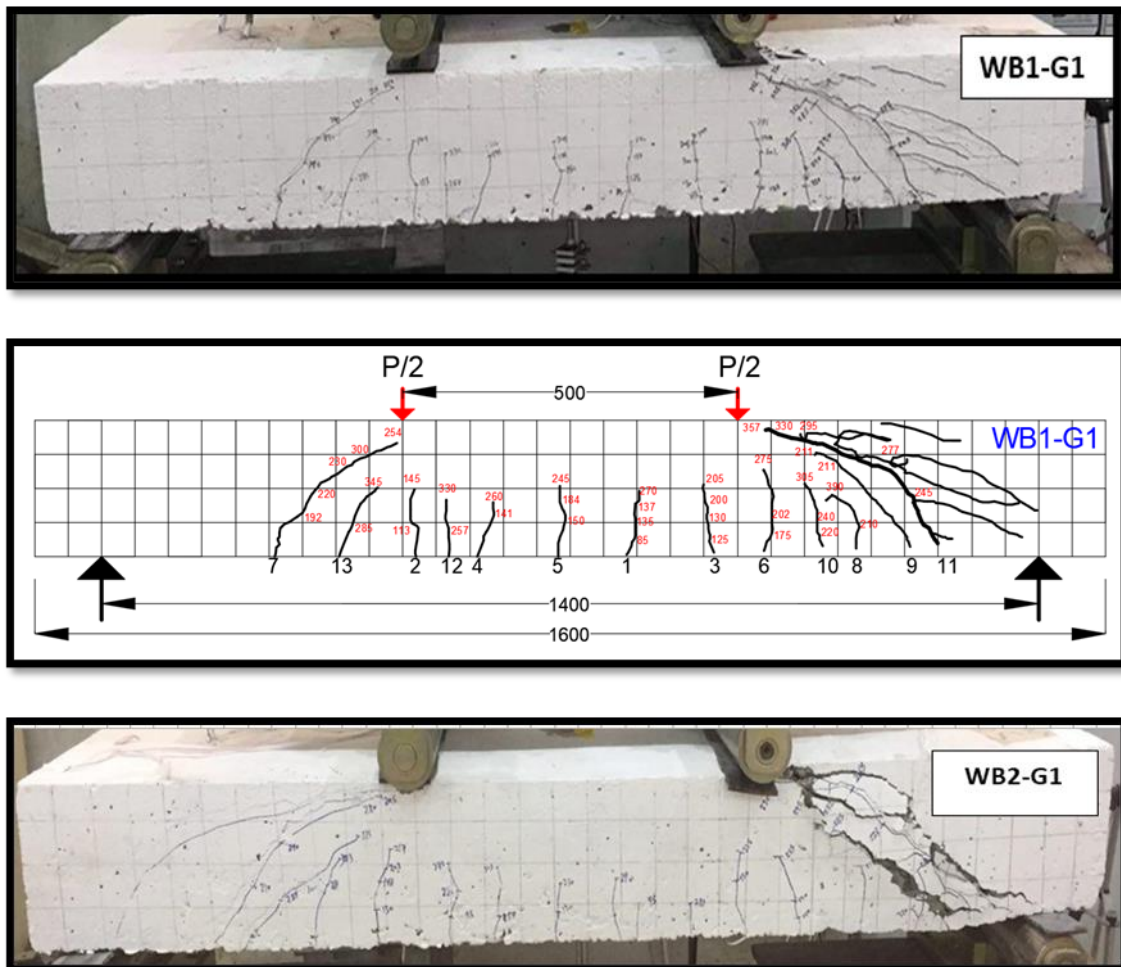
4.1.5 First crack width and number of cracks

The crack width of the first crack at cracking and ultimate load can be seen from Table (4). In the crack load WB3-G1 gave the lowest width among the beams, as it decreased by 33% compared with control beam, While the WB2- G1 gave the highest width as it increased by 25% compared with control beam, but the WB4-G1 give same width with control beam, in ultimate load all beams width increased relation to WB1-G1, the WB2-G1 and WB3-G1 increased with the same increase By 50%, but

WB4-G1 increased by 41.7% compared with control beam, the number of bending cracks is equal across all beams as a result of the same properties of concrete and longitudinal reinforcing , the number of shear cracks increased in WB2-G1 by 8.3% , and decreased by 10% in WB3-G2 and WB4- G2 compared with control beam, The first crack occurred randomly in the middle third of the span it wasn't exactly the widest.

4.1.6 Spacing of shear cracks

It can be seen from Table (4) the shear spacing distance in minimum and average decreased in WB2-G1 and WB4-G1 by (13.6% and 41%) in minimum and (5.7% and 8.6%) in average compared with WB1-G1, but in maximum spacing distance all beams increased compared with the control beam by (5.5% ,16.8% and 9%) for WB2-G1, WB3-G1 and WB4-G1 respectively.



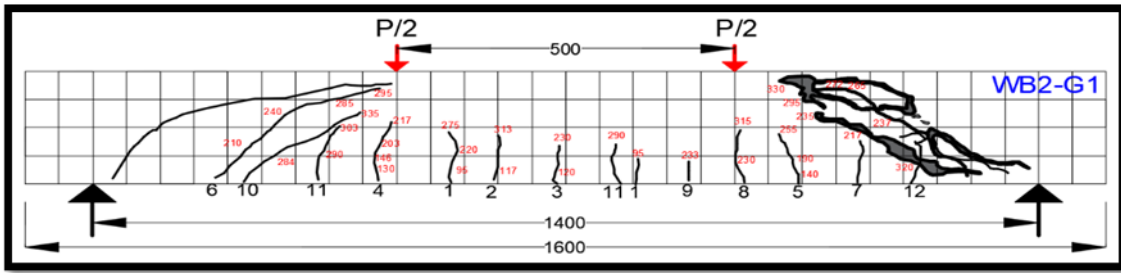


Figure 4. Plate (1) cracking patterns of specimens of Group One

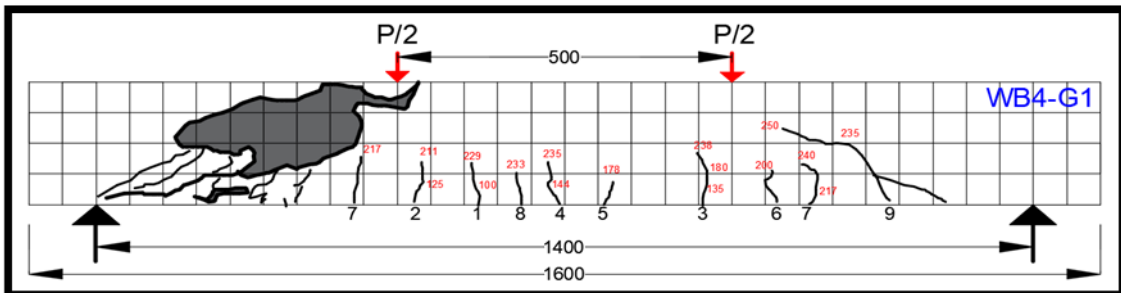
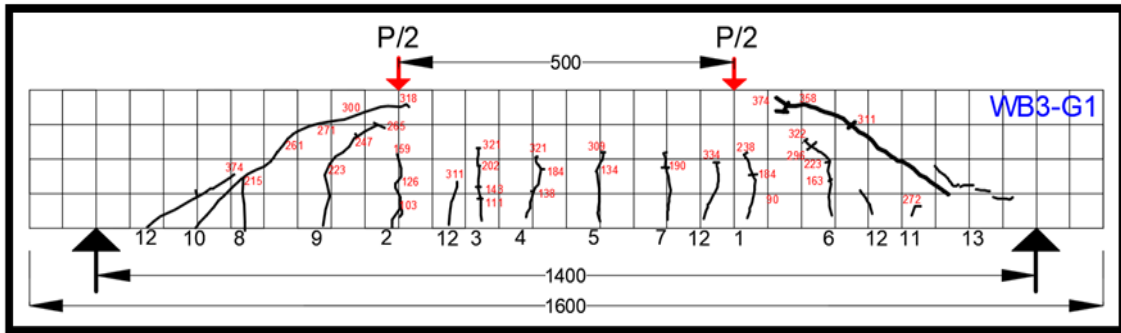


Figure 2. Plate (1) cracking patterns of specimens of Group One

Table 4. First crack width, number and spacing of cracks for Group One

Beam Specimens	1st crack at cracking		1st crack at ultimate load		no. of cracks		spacing of shear cracks(mm)		
	Load (kN)	Width (mm)	Load (kN)	Width (mm)	flexural	shear	min	max	average
WB1-G1	85	0.03	400	0.14	6	11	22	104	70
WB2-G1	95	0.04	383	0.28	6	12	19	110	66
WB3-G1	90	0.02	376	0.028	6	10	51	125	81
WB4-G1	100	0.03	362	0.24	6	10	13	121	64

4.2 Group two

4.2.1 Load of cracking

It can be seen from the table (5) in flexural crack load WB2-G2 and WB4- G2 increased by 5.9% and 13% respectively Comparison with control beam, but WB3-G2 decreased by 12.5%. In diagonal crack load all beams decreased compared with control beam by 1.5% ,23.3% and 21.9% for WB2-G2, WB3- G2 and WB4-G2 respectively.

4.2.2 Ultimate load

The main objective of this study is to determine the effect of the ultimate load of concrete reinforced wide beams when increase

spacing of shear from $(d/2)$ to $(3/4d, S$ and $d)$, and to compare it with the references RC beam specimens. The ultimate load of the tested beams in this group was shown table (5). The results show that the (WB2, WB3 and WB4) give Very close values Not exceed 16% compared with (WB1) (control beam).

4.2.3 Load –Deflection Behavior

From Table (5) the deflection in WB1-G2 control beam 16.6mm, the WB3- G2 and WB4-G2 decreased compared with control beam by 22.9% and 31.3%, but WB2-G2 give close increasing with WB1-G2 by 2.4, Figure (5) Show the relationship between load and deflection for all beams in this group.

Table 5. Comparison of the strength characteristics of Group Two

Beam Specimens	P-flexural Cracks (kN)	%	P-diagonal cracks (kN)	%	Pu (kN)	%	Δu (mm)	%
WB1-G2	75	--	137	--	480	--	16.6	--
WB2-G2	80	+5.9	135	-1.5	482	+0.4	17	+2.4
WB3-G2	70	-12.5	105	-23.3	415	-13.5	14.8	-10.8
WB4-G2	92	+13	107	-21.9	405	-15.6	14.4	-13.25

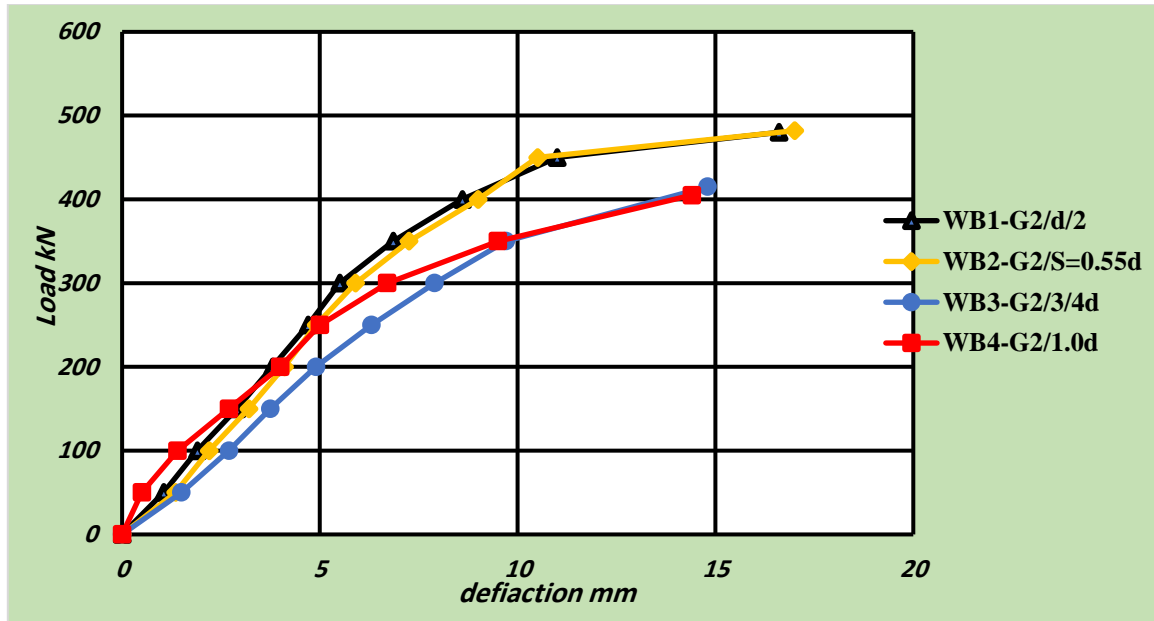


Figure 5. Load- Deflection Curve of wide beams in Group Two

4.2.4 Crack pattern

The beams tested at different stages of loading are shown in detail in Fig. (6) and plate (2), The numbers in red color inside the diagram represent the development of the cracks at each load, while the black numbers under the cracks represent the sequence of the appearance of the cracks during the test, New in this group is the increase in the width to depth ratio from 2.5 to 3.

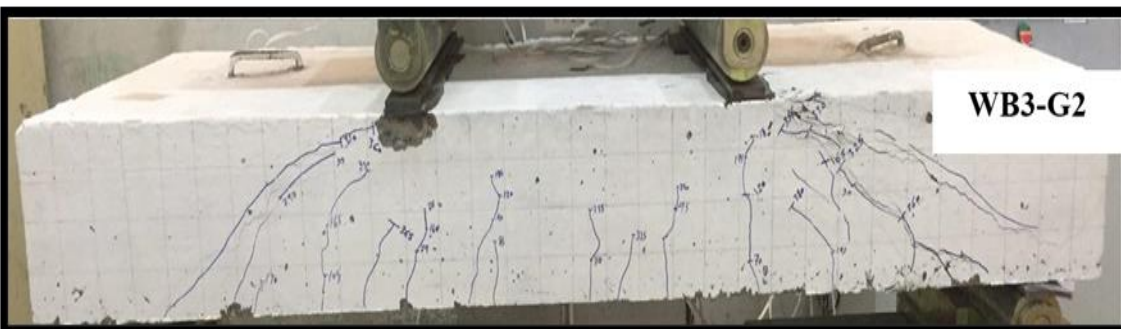
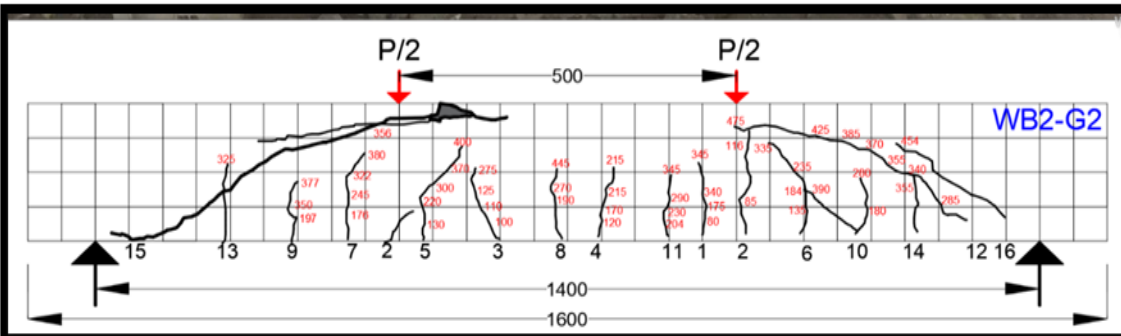
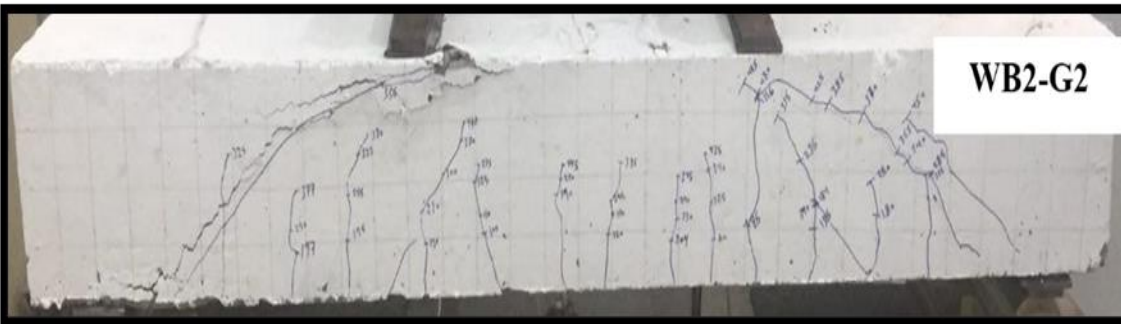
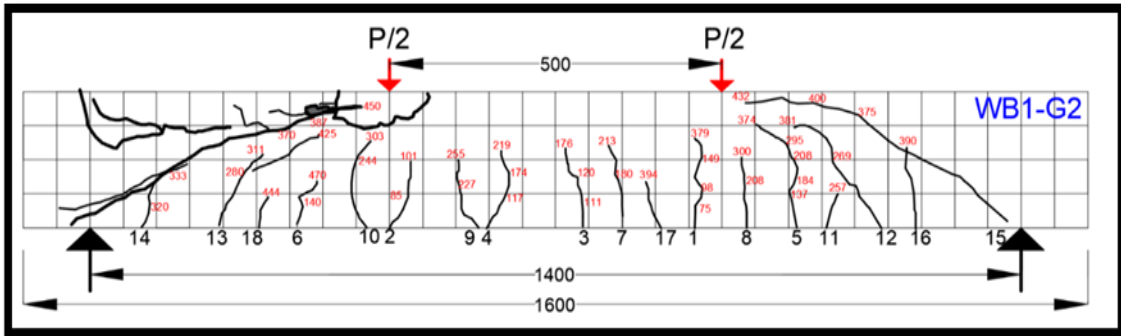
4.2.5 First crack width and number of cracks

Table (6) displays the crack width of the first crack at cracking and the ultimate load which was considered to be the maximum crack width compared to other cracks. The crack width at first crack increase in WB2-G2, WB3-G2 and WB4-G2 by 27% at Average. And the crack width at ultimate load increase by 14.6% at Average in WB2-G2 and WB3-G2 compared with control beam, but WB4-G2 decreased by

8.5%. The number of flexural cracks Equal in all beams except WB2-2 increase by 14%. While number of shear cracks increased in wide beam WB2-G2 and WB3-G2 by 10% and the WB4-G2 are given the same number of cracks cumbered with WB1-G2.

4.2.6 Spacing of shear cracks

From Table (6) it can be seen the effect the increase maximum spacing of shear reinforcement, minimum, maximum and average crack spacing increased in WB2-G2 and decreased in WB3-G2 and WB4-G2, minimum spacing increased by (21% and maximum spacing increased by 17.8%, and average spacing increased by 5.5% for WB2-G2 compared with control beam, for WB3- G3 and WB4-G2 at minimum, maximum and average spacing decreased by (50%), (20.6%) and (18.8%) respectively compared with the control beam.



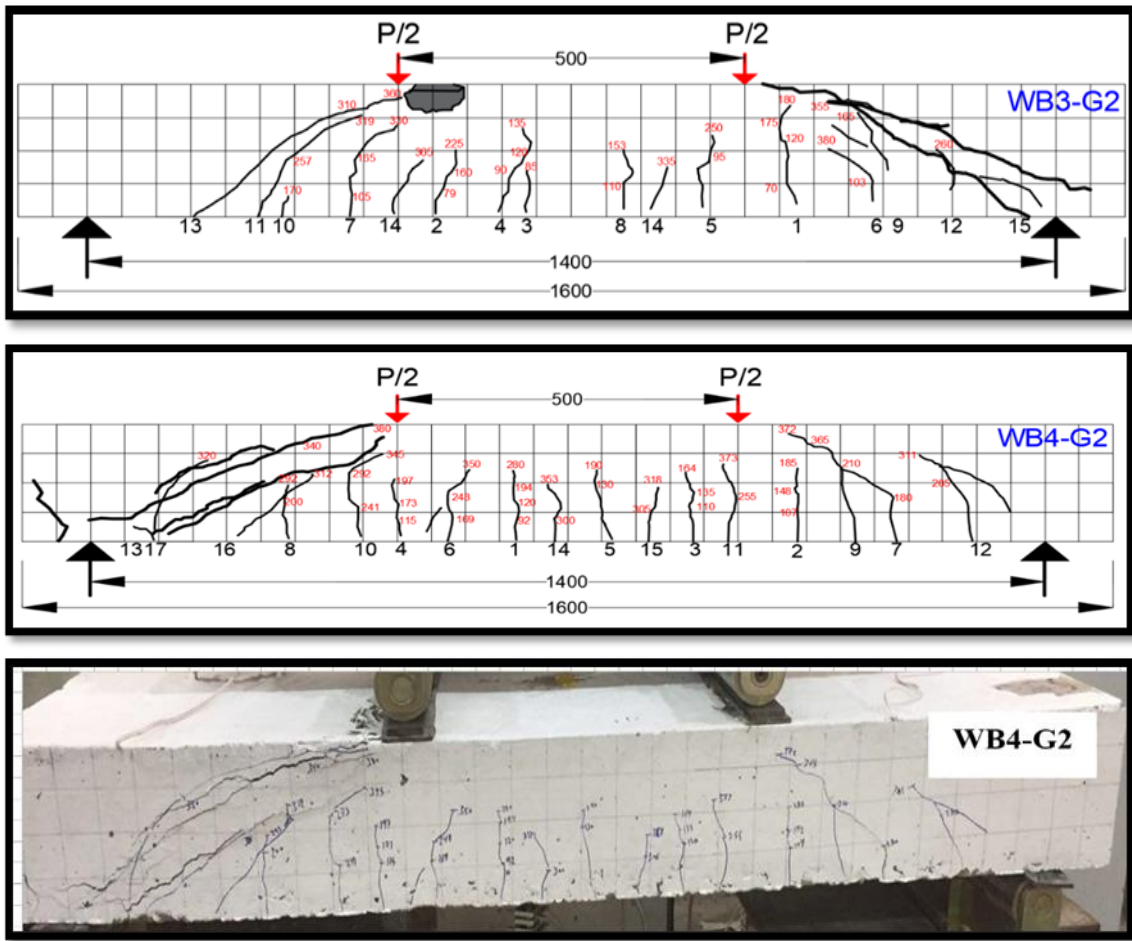


Figure 6. Plate (2) cracking patterns of specimens of group Two

Table 6. First crack width, number and spacing of cracks for group two

Beam Specimens	1st crack at cracking		1st crack at ultimate load		no. of cracks		spacing of shear cracks(mm)		
	Load (kN)	Width (mm)	Load (kN)	Width (mm)	flexural	shear	min	max	average
WB1-G2	75	0.03	480	0.26	8	13	44	138	85
WB2-G2	80	0.0675	482	0.32	8	11	56	168	90
WB3-G2	70	0.035	415	0.327	7	11	22	114	64
WB4-G2	92	0.0345	405	0.238	9	13	22	105	74

4.3 Comparison the results of the groups one and two

In fact, the main difference between Group One and Two was related to the increase

in beam width from 500mm in group One (the width to depth ratio 2.5) to 600mm in group Two (the width to depth ratio 3), Tables (7) Explain the comparison between the strength characteristics of Groups One and Two.

Table 7. Comparison between the strength characteristics of groups one and two

Beam Specimens	P-flexural Cracks (kN)	%	P-diagonal cracks (kN)	%	Pu (kN)	%	Δu (mm)	%
WB1-G1	85	--	192	--	400	--	13.1	--
WB1-G1	75	-11.8	137	-28.6	480	+16.7	16.6	+21
WB2-G1	95	--	210	--	383	--	12.2	--
WB1-G1	80	-15.8	135	-35.7	482	+20	17	+28.2
WB3-G1	90	--	215	--	376	--	10.4	--
WB1-G1	70	-22.2	107	-51	415	+9.4	14.8	+29.7
WB4-G1	100	--	220	--	362	--	10.2	--
WB1-G1	92	-8	105	-51.4	405	+10.6	14.8	+31

From table (7) noted the first flexural and diagonal crack decreased in all beams of group two by (11.8,15.8,22.2,8) % in flexural and by (28.6,35.7,51,51.4) % in diagonal for (WB1-G2, WB2-G2, WB3-G2and WB4-G2) respectively compared with group one, the ultimate load and ultimate deflection increased

in all beams in group two by (16.7, 20, 9.4, and 10.6) % in ultimate load and by (21, 28.2, 18.7, 16.7)% in ultimate deflection for (WB1-G2, WB2-G2, WB3-G2and WB4-G2) respectively compared with group one, as shown in figure (7,8,9and 10).

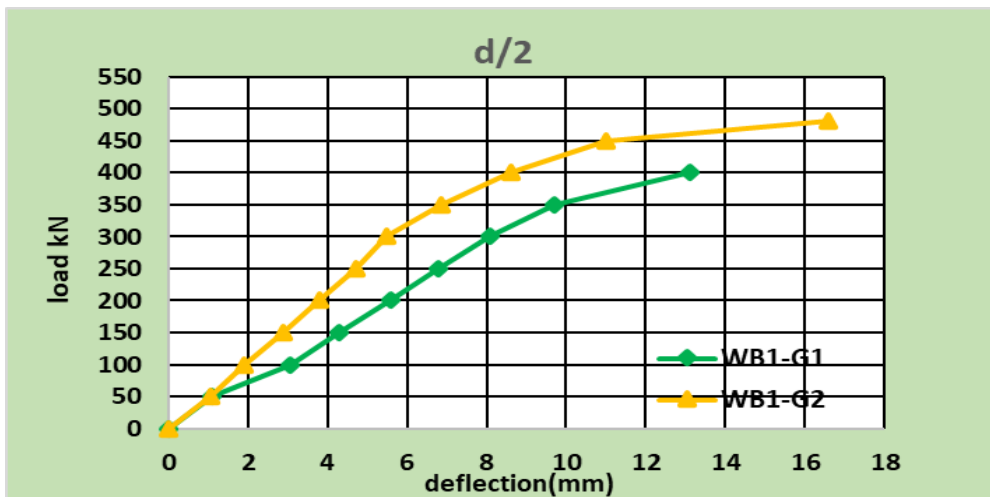


Figure 7. Load deflection curve for WB1-G1 and WB1-G2

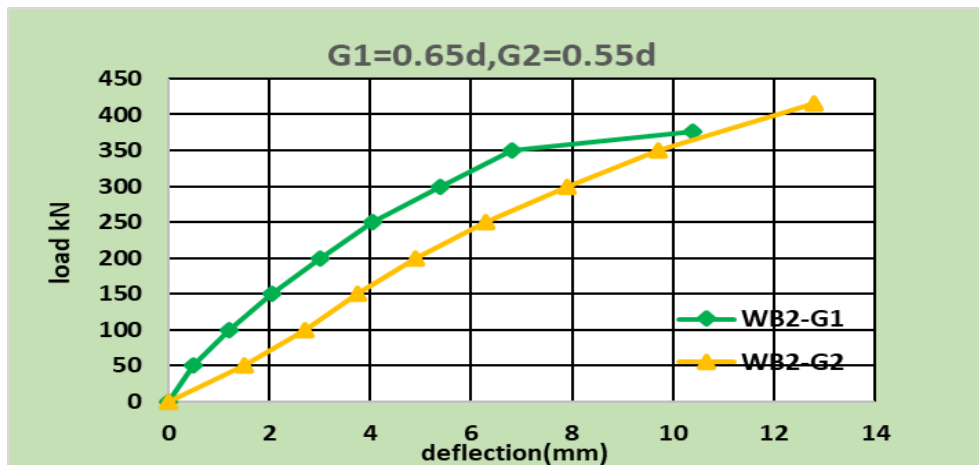


Figure 8. Load deflection curve for WB2-G1 and WB2-G2

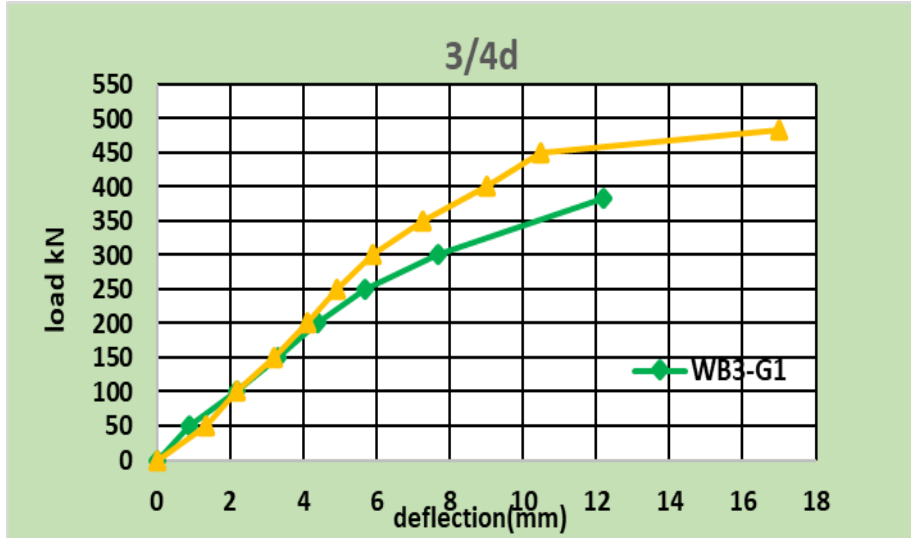


Figure 9. Load deflection curve for WB3-G1 and WB3-G2

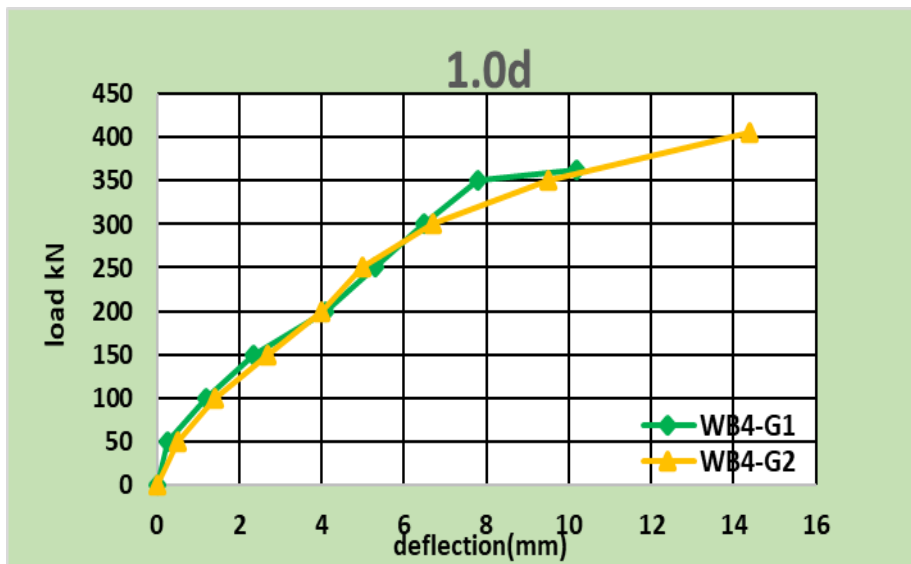


Figure 10. Load deflection curve for WB4-G1 and WB4-G2

4.3.1 First crack width and number of cracks:

From table (8) noted the width of flexural cracks increased in all beams in group Two by (40, 42, 13) % for WB2-G2, WB3-G2 and WB4-G2 respectively compared with group one except WB1-G2 give same crack width WB1-G1. In first diagonal cracks load, all beams increased in group Two by (46, 12.5, 14) % for WB1-G2, WB2-G2 and WB3-G2 respectively compared with group one except WB4-G2 give same crack width WB4-G1. The number of

flexural cracks increased in all beams of group Two by (25, 25, 14 and 33) % for WB1-G2, WB2-G2, WB3-G2 and WB4-G2 respectively compared with group one. The number of diagonal cracks load increased in all beam of group Two by (15, 10 and 30) % for WB1-G2, WB3-G2 and WB4-G2 respectively compared with group one except WB2-G2 decreased by 9% compared with WB2-G1, as shown in table (8).

4.3.2 Cracks spacing

Based on table (8) the minimum spacing between shear cracks increased in WB1-G2,

WB2-G2, WB4-G2 by (50%, 66%,41%) respectively compared with group one except WB3-G2 decreased by 57% compared with WB3-G1, as shown in table (8). The maximum spacing of shear cracks increased in WB1-G2 and WB2-G2 but decreased in WB3-G2 and WB4-G2 b (+24% and +34%) respectively compared with group one, and decreasing by (-

9% and -12%) respectively compared with group one, as shown in table (8).

The average spacing of shear cracks increased in WB1-G2 and WB4-G2 by (17% and 11%) and decreased in WB2-G2 and WB3-G2 by (6% and 21%) respectively compared with group one, as shown in table (8).

Table 8. First crack width, number and spacing of cracks for Groups One and Two

Beam Specimens	1st crack at cracking		1st crack at ultimate load		no. of cracks		spacing of shear cracks(mm)		
	Load (kN)	Width (mm)	Load (kN)	Width (mm)	flexural	shear	min	max	average
WB1-G1	85	0.03	400	0.14	6	11	22	104	70
WB1-G2	75	0.03	480	0.26	8	13	44	138	85
WB2-G1	95	0.04	383	0.28	6	12	19	110	96
WB2-G2	80	0.0675	482	0.32	8	11	56	168	90
WB3-G1	90	0.02	376	0.28	6	10	51	125	81
WB3-G2	70	0.035	415	0.327	7	11	22	114	64
WB4-G1	100	0.03	362	0.24	6	10	13	121	
WB4-G2	92	0.0345	405	0.238	9	13	22	105	74

5. Conclusions

Increasing the spacing of shear reinforcement from ($d/2$ in WB1-G1) control beam to ($0.65d$, $3/4d$ and $1.0d$) in WB2-G1, WB3-G1 and WB4-G1 gives close results in RC wide beam when use width to depth ratio 2.5 (width of beam 500mm) (group one) in all the following tests:

1. The ultimate shear load gives very close value with control beam (spacing $d/2$), all beams decreased by 4.25%, 6% and 9.5% respectively
2. the first flexural crack increased by 10.5%, 5.6% and 15% respectively, the first diagonal crack too increased in all beams by 8.5%, 10.7% and 12.7% for respectively.
3. The ultimate deflection decreased in all beams by average 16.5%.
4. The width of first flexural crack increased in WB2-G1 by 25% and decreased in WB3-G1 by 33%, and the WB4-G1 give same width with WB1-G1.
5. The number of flexural cracks was equal in all beams, the number of shear cracks increased in WB2-G1 by one crack and

decreased by one crack in WB3-G1 and WB4-G1.

6. The average spacing between shear cracks increased in WB3-G1 by 13.6% and decreased by 5.7% and 8.5% for WB2-G1 and WB4-G1 respectively compared with WB1-G1 control beam.

When increase the width to depth ratio from 2.5 to 3 (the width from 500mm to 600mm) (group two) notice the following:

1. The increase width in group two give increase ultimate load by average 14.25% for all beams compared with group one, when increasing the spacing between stirrups in this group WB2-G2 give same ultimate load with WB1-G2 and the WB3-G2, WB4-G2 decreased by 13.5% and 16.6% respectively compared with WB1-G2 control beam.
2. The increase width in group two It led to the emergence of the first flexural cracks early by average 14.25% for all beams compared with group one, increasing the shear

spacing in this group give increased in WB2-G2 and WB4-G2 by 5.9% and 13% respectively and decreased in WB3-G2 by 12.5% compared with WB1-G2, The first diagonal crack in beams of width 600 mm (group two) decreased in all beams by average 41.7% compared with beams of width 500 mm (group one), but when increasing the shear spacing in this group give decreased in all beams by 1.5%, 23% and 22% for WB2-G2, WB3-G2 and WB4-G2 respectively compared with WB1-G2 control beam.

3. The increase width in group two give increase ultimate deflection in all beam by average 22.6% except WB4-G2 (spacing 1.0d) decreased by 16.7% compared with beams in group one (width 500mm), increasing the shear spacing in this group give decreasing in ultimate deflection by 27% compared with WB1-G2 control beam.
4. The increase width in group two give increase in width of first flexural crack by average 32% compared with beams in group one (width 500mm), increasing the shear spacing in this group gives increased for all beams by average 27.3 % compared with WB1-G2 control beam.
5. The increase width in group two give increase in number of flexural cracks by average 2 cracks, the diagonal cracks increased too by average 2 cracks, increasing the shear spacing in this group gives decreased by 1 crack in WB3-G2 and increased by 1 crack in WB4-G2 and WB2-G2 give same number of crack compared with WB1-G2 control beam and the number of diagonal cracks decreased in WB2-G2 and WB3-G2 by 2 cracks and the WB4-G2 gives same number of diagonal cracks compared with WB1-G2 control beam.
6. The increase width in group two give increase in average spacing between shear cracks by 14% in WB1-G2 and WB4-G2 and decreased by 13.5% in WB2-G2 and WB3-G2 compared with beams in group one (width 500mm), increasing the shear spacing in this group gives increased by 5% in WB2-G2 and decreased by 25% and 13%

for WB3-G2 and W4-G2 respectively compared with WB1-G2 control beam.

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