Effect of Bar Diameter on Shear Capacity of Reinforced Concrete Beams with Flamingo Shear Rein forcing technique

Asmaa Shaker Mahmood[1, a], Suhad M.Abd[2,b]
[1]Department of Civil Engineering College of Engineering
University of Diyala Diyala, Iraq
[2]Department of Highways & Airports EngineeringCollege of Engineering
University of DiyalaDiyala, Iraq
[a]eng_grad_civil051@uodiyala.edu.iq
[b]suhad_abd@uodiyala.edu.iq

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Abstract
An alternative shear reinforcement technique has been proposed which is the flamingo technique, instead of the traditional vertical stirrup, it is made prefabricated. Five reinforced concrete beams were used with dimensions (200 x 300 x 1800) mm, two reference (with stirrups and without stirrups) and three beams using flamingo technique having free ends, constant inclination angle (45°), and fixed length of effective depth were used by (80%, 60%) mm. This study aims to determine how a change in diameter affects the Flamingo technique. The diameters used are (6, 8, 10) mm. According to the results, found that there was a significant improvement in the shearing capacity of the beams by (13.88%,25%and 40.55%)from reference beam, as well as the end cracks, and the behavior of the cracked beam. , when compared with the control (RCWS) beam, the (FD6, FD8 FD10) beams showed deflection decreases of 32.8%, 11.3% and 14.8%, respectively,

Keywords: RC beam, shear failure, and flamingo technique.

Introduction

Despite its high compressive strength, concrete has a low tensile strength. Because of this, it is essential to employ ductile shear reinforcement, which boosts the concrete's capacity for withstanding strain while simultaneously lowering its brittleness. It was common practice to use traditional steel reinforcement in reinforced concrete members as shear reinforcement (stirrups)[1]. Reinforced concrete beams behave very differently when they fail in shear than when they bend, which is considered an unsafe mode of failure by the industry. Excessive shear forces cause diagonal cracks to develop that are much wider than flexural cracks, which usually occur without much advance warning before the beams shear. Reinforced concrete beams were re-examined after shear reinforcement became prohibitively expensive and risky. Beams are supported by internal moments and shears. When designing a reinforced concrete part, flexure is typically taken into account first, which then dictates the size and arrangement of reinforcing bars[2][3]. Mohammed (2015) studied swimmer bars and typical steel stirrups for shear reinforcement. Ten beams (1600 mm long, 150 mm wide, and 250 mm high) were tested for concrete compressive strength, swimmer bar shape, and number of planes. The 10 beams are divided into two groups: the first consists of five standard concrete beams with a constant flexural reinforcement area, and the second consists of five high-strength concrete beams with an identical flexural reinforcement area but higher strength than the first group. One beam from each group employed typical steel stirrups with the same area and spacing, whereas the other four beams were strengthened in shear with swimmer bars with varying numbers of bars, spacing, and number of planes. For both high-strength and conventional concrete, as the number of swimmer bar planes with the same shape increases, so does shear strain. As a result of its increased load-carrying capacity, one of the best forms proposed in this study is the shape one of three swimmer bar planes with 166.67 mm space between them. Crack width, propagation, and quantity were all reduced in comparison to high-strength concrete[4][5][6][7]. BoelVeerle and Corte De Wouter (2013) studied the effect of shear helical rings on reinforced concrete beams under static load and four loading points. The study was conducted on 24 models of concrete beams, 12 with self-compacting concrete and 12 with ordinary compressed concrete. Both types had a vertical rib reference beam and continuous helical ring beams. The beams are designed to ensure shear failure and bending strength. Shear space to depth ratio (2.5-3) Using helical rings increases shear bearing capacity by 5%, increases the shear area-to-depth ratio, and reduces crack width. Due to overlap, this technique is more cost-effective[8].Ahmed (2018) examined the shear behavior of (100*150*1200) mm beams reinforced with standard steel in flexure and with CFRP strips in shear. He studied the effect of adding waste plastic fibers (PET) on beam shear behaviour (0.25, 0.5, 0.75, 1, 1.25, and 1.5 %). This project is intended to reduce stirrup rusting. The insertion of PET fibers into standard steel stirrups boosted the shear strength of beams with CFRP strips. Increased PET fibers enhanced beam shear ductility. FRP materials' brittleness and unidirectionality impede shear reinforcement (stirrup) manufacture [9].Gerald, Yan, and Yannick (2020) examined wire ropes as shear reinforcements. Due to its high flexibility, low weight, and robustness, it's a cheaper alternative to standard rectangular concrete stirrups. This work aims to improve our understanding of the shear behavior of concrete beams reinforced by spiral wire rope. To do this, six beam samples were tested under four loads. DIM technology Examine beam crack formation and spread. According to tests, the strong shear strength of continuous spiral rope favors controlling diagonal cracks. Spiral wire rope samples had a higher serviceability crack width than standard stirrup beam samples[10].By pouring 8 concrete models in 2020,Isam explored carbon textile yarns. All beams (200 * 300 * 1500mm), two as references, one with steel passengers and one without. The rest of the samples used carbon fiber at varying lengths (100, 60 and 30% of the packaging's effective depth). At a 45-degree angle and varying distances, the interference lift extends the final load by 100% by 24.5% and reduces the deviation compared to steel compounds. Reducing distancing between interconnected passengers to 90 mm without further shearing enhancement increased the final load by 26% while reducing deviation by 30.1% compared to ordinary steel passengers. Moreover, the tilting of fabric threads increased the final load by 45 degrees by 55% while reducing deviation by 3% compared to steel passengers. Steel fiber impregnated mortars increased maximum load by 3% and reduced deviation by 13.6%. The last two beams contain flamingo reinforcement with upper limbs and angled bottom. The beams increased shearing capacity, cutting flexibility, final deviation, and breaking behavior. The researcher also studied flamingo technology. Pour four models and study the effect of changing the angle of the free limbs of this technique, as well as the length of these limbs, and discover that they improve the final load and elasticity of the shear capacity when compared to the standard package.[11][12]

Experimental Program

❖ Material

•Cement

This study employs standard Portland cement (type I) supplied by the Tasluja factory in Iraq. The chemical makeup and physical attributes adhere to the Iraqi Standard Specification (I.Q.S. No.5, 1984) (I.Q.S. No.5, 1984[13].

• Finer Aggregates

The natural sand used for this project's fine aggregate was found in the Al-Sidor area. It has a 2.38 fineness modulus. Conformity of the fine aggregate's grading and physical characteristics to the Iraqi Specification's limitations (I.Q.S. No.45, 1984.)[14]

• Coarse aggregate

In this investigation, coarse aggregates consist of natural gravel with a maximum particle size of (12.5mm). The natural gravel came from the Al-Sidor area. After being cleaned, the gravel was dried by air. The physical properties and grading of the aggregates met the requirements (Iraqi standard No. 45, 1984).[14]

• Steel Reinforcement

Deformed steel bars are used to reinforce beams in shear and bending, as shown in Table(1) 6mm,8mm and 10 mm stirrups were used in the Flamingo technique, as well as 2 ϕ12 in the compression zone to stabilize steel and 4 ϕ 16 for flexural reinforcement whereas ϕ8 @130mm were used as traditional vertical stirrups

Table (1) Properties of Reinforcing Steel Bar

Type	**diameter (mm)**	**Yield Stress fy(MPa)**	**Ultimate Strength fu (MPa)**	**Elongation (%)**
Main reinforcement	16	580	683	10.24
	12	635	728	9.04
Shear reinforcement	10	495.5	597.7	11.25
	8	330	528.1	21.52
	6	336.6	696.5	19.72

• head stud

They are attached at the head of free endings by welding (double head) as shown in Figure 1 where they interfere with concrete and prevent slipping.

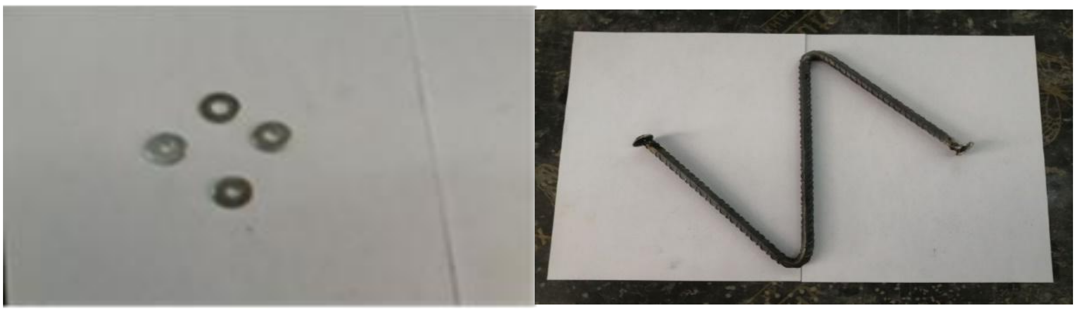


Fig (1)

A. Concrete Mix

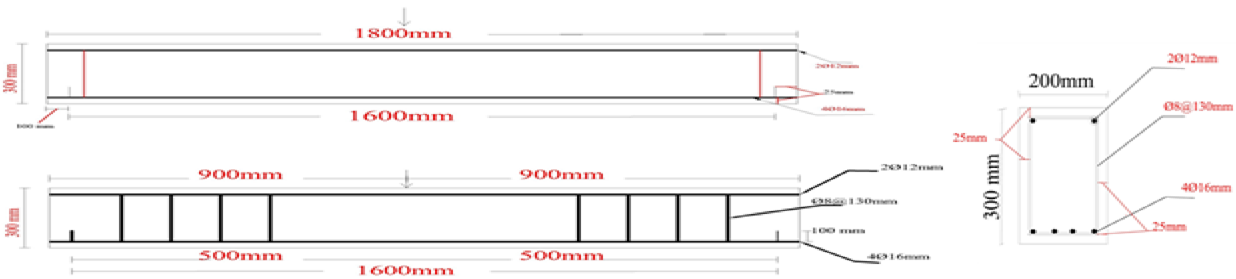
A concrete mix with 39MPa and mix constituents shown in Table (2) was used through this. Cylinders of 300mm heights and 150mm diameters were used to obtain compressive strength of concrete at (7 and 28) days. After demanding the samples were cured in water tanks for 28 days[15].

TABLE 2Concrete mix constituents

Cement (kg/m3)	450
Sand (kg/m3)	860
Gravel (kg/m3)	860
Water (kg/m3)	207
S.P	0.46%
w/c	46%
Slump (mm)	140mm

B. Specimens Descript

The samples in this study used molds with dimensions (200 × 300 × 1800 mm), the first control beam (RCWS) (see Fig. 2.a,b) was reinforced with conventionally vertical steel stirrups in the shear zone, second reference beam without stirrup and other beams with flamingo technique with different diameters of steel bars (6, 8, and 10) mm (as a main variable to study their effect on shear capacity) ,the angle of inclination was fixed at 45 degrees ,and free ends are fixed with an actual depth value of 80% for the long ends and 60% for the short ends. The shape of a flamingo is roughly Z-shaped with legs (see Figures 3a, b,c), and its surface area is equivalent to that of vertical stirrup. They were tested in one-point load at mid beams in order to determine the shear capacity and other properties as shown in Table 3.

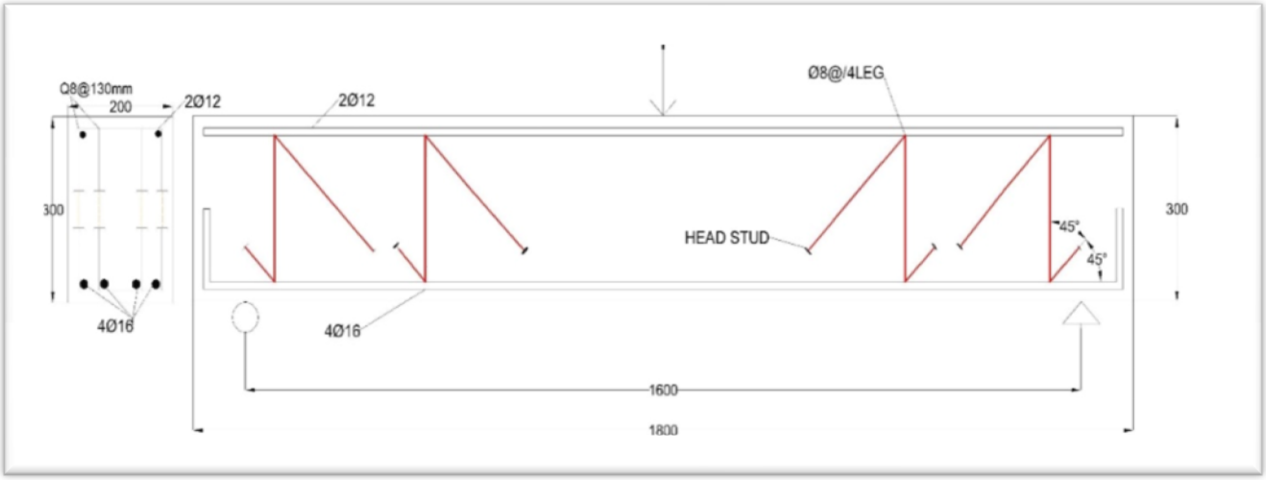


(a)

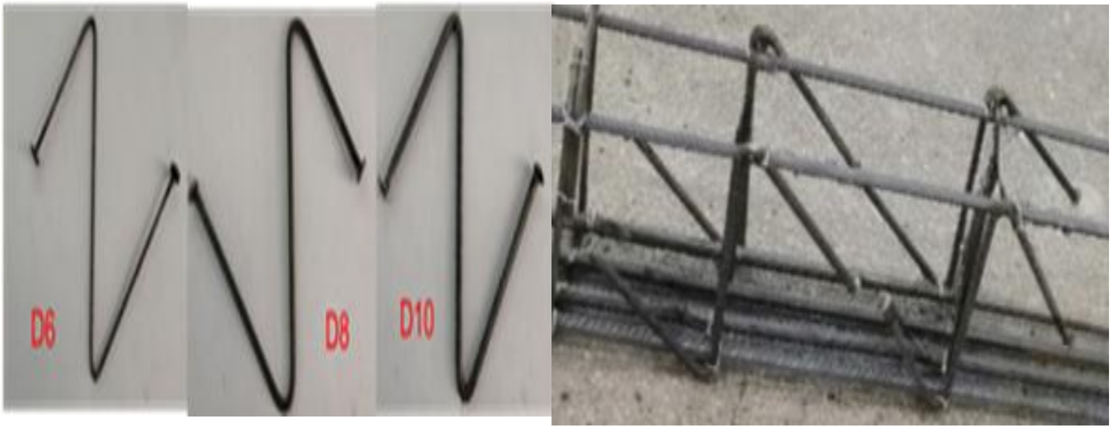
(b)

Fig. 2. (a,b) (Reference beams)

This pre-fabrication is installed using normal splicing as in normal stirrup , thereby reducing manual work on site and easing of application.



(a)



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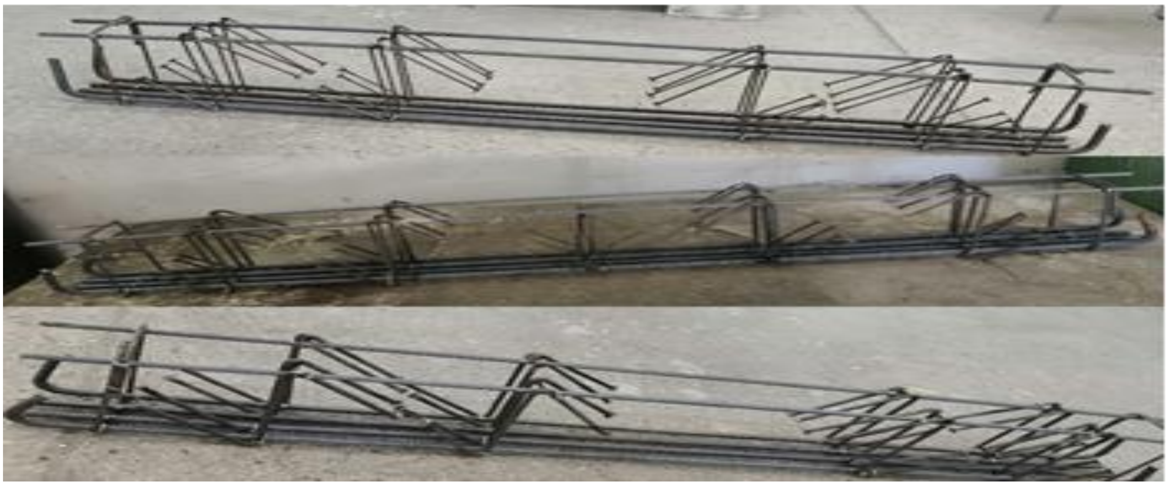

(c)

Fig. 3(a,b,c) Flamingo reinforcing technique

Specimen	Description
RCWOS	With out stirrup
RCWS	Have used 8 steel stirrups mm at 130 mm
FD6	With a diameter of 6mm and a lower end length of 60% and an upper end length of 80% and a 45° angle of inclination.
FD8	With a diameter of 8mm and a lower end length of 60% and an upper end length of 80% and a 45° angle of inclination.
FD10	With a diameter of 10mm and a lower end length of 60% and an upper end length of 80% and a 45° angle of inclination.

TABLE 3 Details of the tested beams

Conclusion and Discussion

This section compares the load-bearing capacity, load deflection, shear ductility index, and crushing behaviour of the flamingo and control beams. The comparison focuses on the most efficient usage of steel stirrups or flamingo technique which is done by using the same area steel in the control beam. Table 1 results of beams after tested.

Table (4) Test results of the beam

Specimen	**Py* kN**	**% diff in Py**	**Pu kN**	**% Diff in Pu**	**y**(mm) Δ**	**% diff in Δy**	**Δu(mm)**	**Diff. of Δu %**	**Ductility Δ**	**in .diff% ductility**
RCWOS	**….**	**..**	**108**	**-40%**		**..**	**6.5**	**…..**		
RCWS	**126**	**..**	**180**	**…**	**5.5**	**…**	**12.8**	**……**	**2.33**	**…**
FD6	**145**	**15.1%**	**205**	**13.88%**	**5.7**	**3.62%**	**8.6**	**-32.8%**	**1.5**	**-35.6%**
FD8	**160**	**26.98%**	**225**	**25%**	**6.9**	**25.4%**	**8.95**	**-30%**	**1.3**	**-44.2%**
FD10	**180**	**42.8%**	**253**	**40.55%**	**7.35**	**33.6%**	**10.8**	**-15.6%**	**1.43**	**-38.6%**

*Py: Yield load of longitudinal reinforcement when it reached its yield strain.
** Δy: Deflection at yield load

A. Load Carrying Capacity

Form Table (4) notes that yield load of beams has been increased with increase diameter of bar in Flamingo technique by(15.1%,26.98%,and42.8%) for (FD6,FD8,and FD10) respectively, compared with (RCWS) ,while the ultimate load (the load at which shear failure occurs) and mid-span deflection at this load, the test results for the beams are summarized in Figure (4). The load carrying capacity of the(FD6, FD8, FD10 and RCWS) beams increased by (89.8%, 108.3%, 134.3% and 66.67%), respectively, compared with(RCWOS),but when compared flamingo reinforcement technique with (RCWS)at ultimate load found it has been increased by(13.88%,25%and 40.55%) for (FD6, FD8, and FD10) respectively. All (FD6, FD8, and FD10), the amount of reinforcement in the shear zone is nearly identical to that in the control beam. The flamingo shape of the steel reinforcement is ideal because it creates frequent shear junctions at the points where the system's legs meet. Free ends with a lower and upper inclination, respectively, provide higher and deep bond with surrounded concrete shear zone which limit crack propagation and raise the capacity of beams to the applied load.

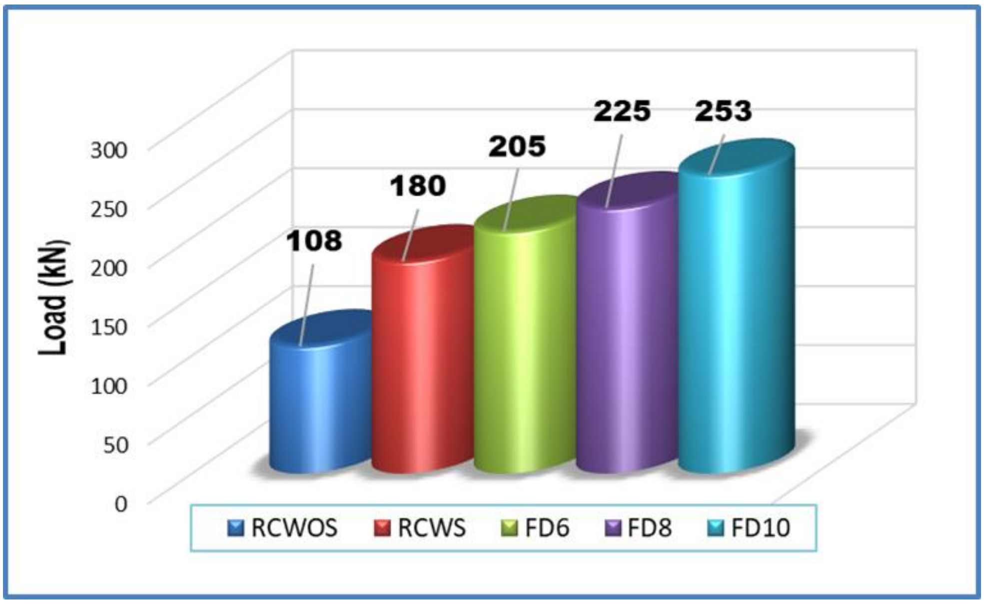

Fig. 4 Ultimate Load Capacity of Tested beams

B. Load Deflection Behavior

Table (4) illustrated the test results for the five beams. At yield load ,deflection of beams with different bar increased by (3.62%,25.4%, and 33.6%) for FD6, FD8 and FD10 from RCWS Deflection of the beams with different diameter when compared to beams without stirrup RCWOS , the beams (FD6, FD8, FD10, and RCWS) show increased by (30.8%,37.7%,66.15% and 96.9%) respectively, As a result of increasing the final load of the beams and their ductility as a result of the use of steel reinforcement, thus avoid the sudden failure that occurred when the beam without steel reinforcement. but when compared to a control beam with traditional stirrup RCWS, the beams (FD6, FD8 and FD10) show a decrease in deflection of about)32.8 %, 11.3%, and 14.8 % (, respectively. The geometric shape of the flamingo technique improved the deflection because of the free ends were inclined in addition to the vertical reinforcement intercept of the shear force spread from the support to the mid span of beam by certain angle. Figures (5) all models show an increase in deformation with increasing applied load, and all samples correspond to each other when the load is set at 55 kN. Then, as a result of the increased in the diameter of the bar used, deflection increased because the bond strength decreased with this increase.

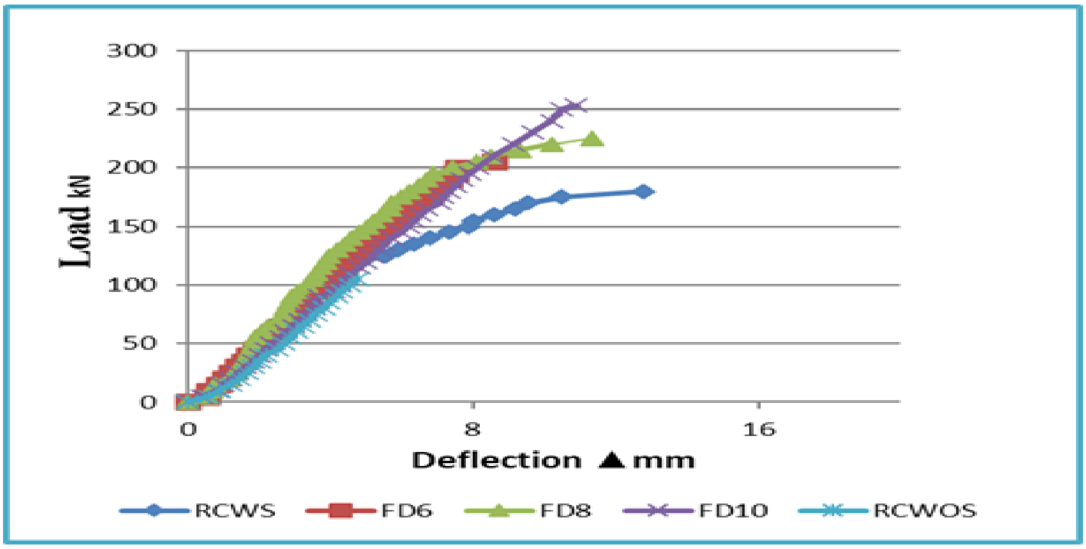

Fig. 5 Load deflection curves for the flamingo specimens

C. Shear Ductility

The capacity of a material to deform without considerably lowering its bending strength is referred to as that the ductility (Δ_u / Δ_y) in beams. Table (4)shows the shear ductility index for beams, and note that using the flamingo technique, the shear ductility index decreased by (35.6%, 44.2%, 38.6%) for (FD6, FD8 and FD10) compared to RCWS, when the diameter bar of the reinforcement was increased ,shear ductility becalmed lower due to lack of bonding between concrete and steel reinforcement because of this increase.

D. Crack Behaviour

The first crack load is observed to show by 64.8%, 38.9%, 31.7%,62.2%, and 58.5% from the ultimate load for samples (RCWOS, RCWS, FD8,FD6,and FD10), respectively. but when Compared to reference beam without stirrup (RCWOS), the ratio was (83.3%, 25%, and 14.66%) and was (7.15%,36.4%,52.7%) when compared to beam with normal stirrup (RCWS) reinforced models with the flamingo technique (FD6, FD8, and FD10). According to Table (5), the percentage of cracks at load 160 kN visible during service decreases by (50%, 66.6% and 73.33%) when using the FD8, FD6, and FD10 samples instead of the reference beam (RCWS), respectively. It was discovered that the crack width becomes narrower as the diameter increases as a result of the increased area of bar as result occurs used large diameter when carrying the constant. From Plate (1) notice that crack path in beams (RCWOS and RCWS) mode failure was shear but in beams (FD6, FD8) flexure shear failure and in beam (FD10) was dowel actionfailure. TABLE 5Details about all of the cracks.

Specimen	Crack load Pcr (kN)	Ultimate load Pu (kN)	Pcr/Pu (%)	%Increase in cracking load	crack width @	%decrease crack width @
RCWOS	**60**	**108**	**64.80%**	…..	….	…..
RCWS	**70**	**180**	**38.90%**	…..	**0.6**	…
FD6	**75**	**205**	**31.70%**	**7.15%**	**0.3**	**-50%**

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FD8	**110**	**225**	**62.20%**	**36.40%**	**0.2**	**- 66.60%**
FD10	**148**	**253**	**58.50%**	**52.70%**	**0.16**	**- 73.33%**

Table (5) detail of load crack and crack width

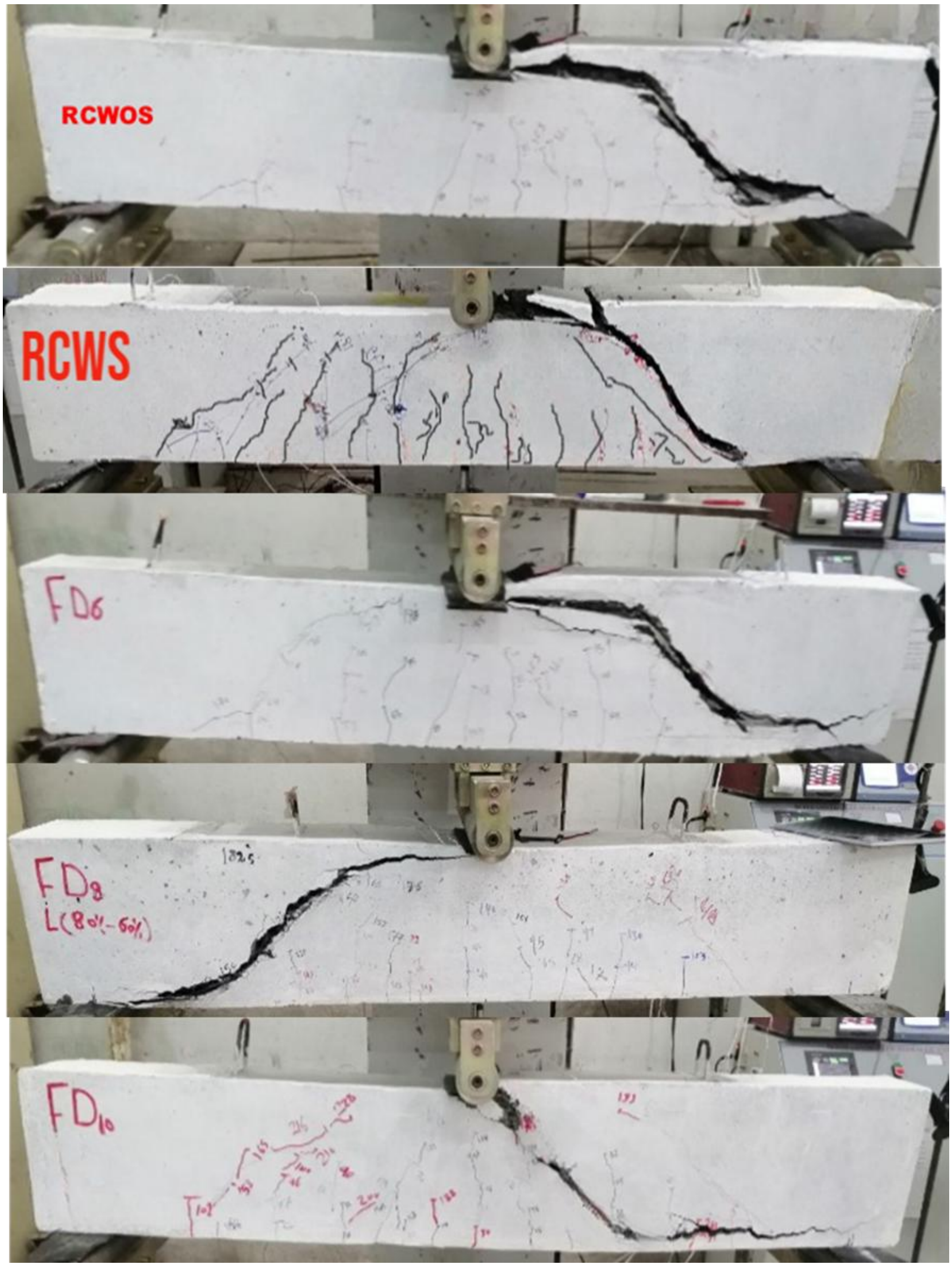

Plate (1) Crack patter of variable diameter

CONCLUSIONS

As a result of this research, it was discovered that:

•Beams with the flamingo technique, the load-deflection, stiffness and cracking behavior were all superior to the traditional steel stirrups.

•Beam with flamingo technique with a diameter of 10 mm a greater load capacity was achieved, and smaller crack width of reference beam, and other beams with flamingo

• The mode of failure of reference beam (RCWS) was shear failure and beams with flamingo was shear failure and dowel action.

•It has been observed that the crack width is decreasing, and the reason for this is the increase in the diameter of the steel used in Flamingo Techniques production.

REFRENCE

[1] B. Abdulsalam, "BEHAVIOUR OF SHEAR CRITICAL FRP REINFORCED CONCRETE ONE-WAY SLABS," 2014, doi: 10.13140/RG.2.1.2783.1844.

[2] Z. P. Bazant and H.-H. Sun, "Size effect in diagonal shear failure: influence of aggregate size and stirrups," *ACI Mater. J.*, vol. 84, no. 4, pp. 259–272, 1987.

[3] A. C. I. Committee, "ACI 318-19: Building Code Requirements for Structural Concrete and Commentary," *Am. Concr. Inst. Farmingt. Hills, MI, USA*, 2019.

[4] H. A. Mohamed, "Effect of using swimmer bars on the behavior of normal and high strength reinforced concrete beams," *Ain Shams Eng. J.*, vol. 8, no. 1, pp. 29–37, Mar. 2017, doi: 10.1016/J.ASEJ.2015.07.007.

[5] M. Hemanthkumar, "Effect of Swimmer Bars on Reinforced Concrete Beams," *Int. J. Emerg. Technol. Eng. Res.*, vol. 4, 2016, [Online]. Available: www.ijeter.everscience.org

[6] M. M. Al-Nasra, N. M. Asha, and A. S. Najmi, "Investigating the Use of Swimmer Bars as Shear Reinforcement in Reinforced Concrete Beams," 2013. [Online]. Available: www.irjes.comwww.irjes.com

[7] M. Al-Nasra, "The use of Swimmer Bars as Shear Reinforcement in Reinforced Concrete Structures," *J. Eng. Appl. Sci.*, vol. 14, no. 9, pp. 2775–2782, Dec. 2019, doi: 10.36478/jeasci.2019.2775.2782.

[8] W. De Corte and V. Boel, "Effectiveness of spirally shaped stirrups in reinforced concrete beams," *Eng. Struct.*, vol. 52, pp. 667–675, Jul. 2013, doi: 10.1016/J.ENGSTRUCT.2013.03.032.

[9] b Abdulkader Ismail Al-Hadithia and Mustafa Ahmed Abbasa, "Innovative technique of using carbon fibre reinforced polymer strips for shear reinforcement of reinforced concrete beams with waste plastic fibres," *http://www.tandfonline.com/loi/tece20*, 2018.

[10] K. H. Yang, G. H. Kim, and H. S. Yang, "Shear behavior of continuous reinforced concrete T-beams using wire rope as internal shear reinforcement," *Constr. Build. Mater.*, vol. 25, no. 2, pp. 911–918, 2011, doi: 10.1016/j.conbuildmat.2010.06.093.

[11] I. S. Mhaimeed and S. M. Abd, "Shear Capacity of Concrete Beams Reinforced with Textile Carbon Yarns and Flamingo Reinforcing System," *2021 4th Int. Iraqi Conf. Eng. Technol. Their Appl. (IICETA), 2021, pp. 212-217*, 2021, doi: doi: 10.1109/IICETA51758.2021.9717950.

[12] Isam S.Mhaimeed and Suhad M.Abd, "Improved shearing capacity of reinforced concrete

thresholds using arming techniques using new proposed steel arming techniques," *Republic of Iraq Ministry of Planning Central Organization for Standardization and Quality Contro*, Diyala, Jul. 04, 2021.

[13] I. S. No, "Portland Cement, the Iraqi Central Organization for Standardization and Quality Control." Baghdad-Iraq, 1984.

[14] I. S. No, "45, Natural Sources for Gravel that is Used in Concrete and Construction." Baghdad, 1984.

[15] "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens 1", doi: 10.1520/C0039_C0039M-16.