Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 9, No. 2, June 2021, pp.1086-1095

Effect of types of fibres on the shear behaviour of deep beam with opening

Mustafa Shareef Zewair[1], Ahid Zuhair Hamoodi[2], Mohammed Farhan Ojaimi[3]
[1,2,3] Department of Civil Engineering, College of Engineering, Basrah University, Basrah, Iraq

ABSTRACT

This paper discusses experiments on the behaviour of deep beams with and without opening in the styles of stainless-steel fibres under a two-point load test. Triple varieties of stainless-steel fibre used constant fibre fraction (1 percent) by volume of concrete, (straight, hooked and corrugated steel fibre)). In this analysis, the key parameters were the fibre forms and the influence of the opening on the behaviour. The results show that the steel fibres raise the first crack and final loads in both groups (first group without opening the second group with opening). Besides, an increase of (20.6 to 40.5) % in first cracking load for the first group and (36.4 to 56.7) % for the second group and an increase of (59.5 to 110.1) % and (20.2 to 28.8) % in ultimate load for first and second groups respectively.

Keywords: Deep beam, Opening, Steel fibres, Crack load, Ultimate load, Deflection

Corresponding Author:

Mustafa shareef zewair
Civil engineering, Basrah University
Basrah, Iraq
Dr.mustafa.shareef.81@gmail.com

1. Introduction

Resistance to shear is a challenging issue for reinforced concrete beams currently under discussion in academia. This is because certain parameters affect the share actions of reinforced concrete beams [1,2], whose interdependence to model is very dynamic. In addition, shear forces interfere with other kinds of loads, including axial load, flexure and torsion, which further complicate the issue. Precisely predicting shear forces is important because, without warning, shear failure occurs. Deep beams of reinforced concrete are deep sections of structural members with a profound portion of the load passed directly to the support by a single strut. Deep beams are also used as bridges, transition girders in buildings and offshore platforms in constructions in structural applications. According to Eurocode 2 (EC2) [3], beams can be classified as deep beams when the ratio of span to depth is smaller than three. On the other hand, ACI 318-14 [4] classifies beams as deep beams which satisfy (a) Clear span does not exceed four times the overall member depth h; or (b) Shear span does not exceed two times the overall member depth. The strength of the deep beams is normally governed by shear and not by flexural [1], and because much of the load is transmitted directly by strut and tie action. [2].

To be accessible to doors or to fit critical services such as ventilation and air conditioning lines, web openings in such beams are also needed. If architectural or mechanical demand were to be increased and the structure of the building changed, the shear capacity of the device would decrease and thus pose a serious safety risk. (El Maaddawy & Sherif, 2009) [5]. Utility pipes and service lines are usually mounted under the beam soffit to form a dead space by a hanging ceiling. The transversal openings between floor beams of the pipes and pipes however reduce the gap that can contribute to a more compact and cost-efficient design. Based on the needs of the architect and mechanical engineer, the openings may have different sizes and forms. In the presence of the Internet openings, the beam and the non-linear stress distribution around the depth of the beam induce geometric discontinuity. The actions of RC deep beams with apertures is different from the behaviour of RC solid beams. Thus, the supply of openings in RC beams reduces beam rigidity and resistance and causes unnecessary cracking and deflection. The behaviour, form and position of the apertures of RC beams with apertures was significantly influenced [6].

As we all know, concrete is a fragile substance that can contribute to reducing breakability and ductility by increasing the mechanical properties of concrete. Fibres are therefore used in concrete to improve the mechanical property of concrete. This form of cement is known as reinforced concrete fibre. (FRC). Many forms of FRC usually use only one kind of fibre in practice, i.e. steel fibres. However, the researchers combine the two separate fibres and applied concrete to get more precise data. We name mixed fibre reinforced concrete this kind of concrete. The conversion of micron crack to microcrack generally results in accelerated fractures and uneven spreading, which increases and joins splits as the external load is added to them. We mixed steel fibres with polypropylene fibres for good performance. Steel fibres can be used to enhance the shear ability of standard RCC depth beam (shear) reinforcement and polypropylene fibres used to manage the micro-pressures of the concrete. Mixed fibres' influence on concrete depends on the fibre forms, the aspect ratio (length/diameter ratio) and the direction of concrete fibres. Shear is commonly used to regulate the intensity of the beam with regular longitudinal reinforcement. The shearing capacity of a mixed fibre deep beam depends on certain factors, including fibre forms and the aspect ratio of fibre. Using small mixed fibres to the concrete mix allows increasing the tensile strength of the concrete after breaking. The principal aim of this work, therefore, is to research the key impact of added mixed fibres with various clear span-to-depth ratios of mixed (crimped steel-polypropylene) [7].

In the construction sectors in recent years, steel fibre refurbished concrete (SFRC) has become more common. Concrete reinforcement with steel fibres was used in structural elements such as labels to eliminate traditional steel reinforcement. (ACI Committee 544 1996) [8]. SFRC members exhibit enhanced shear strength, more ductile behaviour, and reduced crack widths (Dupont and Vandewalle 2003) [9]. The elimination of shear strengthening in RC systems will theoretically minimize reinforcing bar congestion and building costs. Steel fibres also have multidirectional concrete reinforcement, easy detailed treatment with no congestion, and increased residual strength and ductility after cracking. Past studies (Mansur and Ong 1991) [10] have shown that including discrete fibres enhances the strength and deformation capacities of deep beams and provides better crack control. The results of two deep RC beams with wide openings under singletonically increasing concentrated loading are presented in this article. Ses specimens were compared to the results of a design STM for their ultimate strengths and modes of failure. In addition, two SFRC specimens with a 1,5% fibre volume fraction are geometrically close [7].

2. Experimental program

The key objective of the research program is to provide details on the behaviours of deep reinforced concrete beams with and without opening under two load points and information on the impact of various steel fibre forms. To assess the properties of materials standard testing is carried out by the American Society of Testing and Materials (ASTM), [8,9,10,11] and Iraqi specifications. All these experiments were performed in the College of Engineering Structural Laboratories of the University of Basrah.

2.1. Specimen details

The process included the testing of 8 deep beams of reinforced concrete. Shears with (a/d =1) as deep beams are built to malfunction. The first section consists of (4) open fewer beams of reinforced concrete, and (4) opened reinforced beams of the second section. The first beam (D1) in the first category did not include fibres and served as the reference beam without opening (control beam). There were three distinct forms of fibre, with the remaining three beams (D2, D3 and D4). The first beam (D5) for the second party did not include fibres and an opening for use as a beam of reference (control beam). There were three other deep beams (D6, D7 and D8).

Table 1. Details the description of the tested beams

Beam No.	a/d	Fraction volume (%)	Type of fibre	With or without opening	Beam designation
Beam 1	1	0		Without opening	D1
Beam 2	1	1	Straight steel fiber	Without opening	D2
Beam 3	1	1	Hooked steel fiber	Without opening	D3

Beam No.	a/d	Fraction volume (%)	Type of fibre	With or without opening	Beam designation
Beam 4	1	1	Corrugated steel fiber	Without opening	D4
Beam 5	1	0		With opening	D5
Beam 6	1	1	Straight steel fiber	With opening	D6
Beam 7	1	1	Hooked steel fiber	With opening	D7
Beam 8	1	1	Corrugated steel fiber	With opening	D8

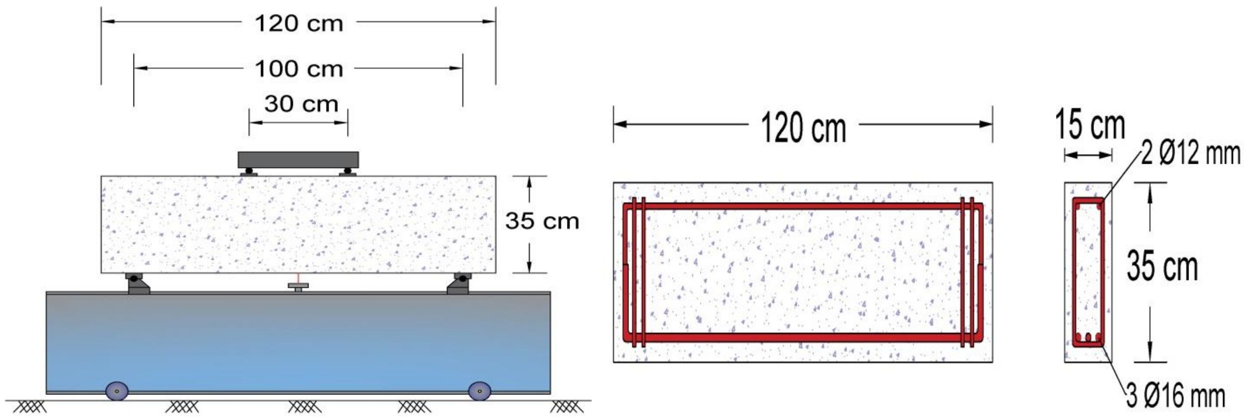

Figure 1. Layout and reinforcement details of tested beams

2.2. Material properties

This study has employed Ordinary Portland cement (Type I) made in Iraq (TASLUJA-CRASTA). It was kept in a dry environment to prevent exposure to various atmosphere environments and used to blend all the specimens of concrete. This cement has tested its chemical and physical properties. A nearby quarry carried the coarse and fine aggregate. The classification of the fine aggregate and the fine aggregate's physical properties were also checked. All these experiments were performed in the College of Engineering Structural Laboratories of the University of Basrah. As longitudinal reinforcements in diameter (12 and 16 mm), two deformed steel reinforcement bars were used while 10 mm deformed steel bars were used as closed stirrups. Sika® Viscocrete® F-180 G is a superplasticizer that has a high-level, high-efficiency water reduction agent plus the stabilizing agent. To investigate the fibre form effect on the deep beam action, three different types of steel fibres were used. Straight, hooked and corrugated steel fibres were used for this work with constant volume fractions of (Vsf = 1%) as shown in Figure (2).

Straight fibres Hooked fibres Corrugated fibres

Figure 2. Type of steel fibres

2.3. Concrete mix proportions

Eight deep beams of reinforced concrete are fitted with normal concrete. A combination of cement, sand, gravel and 0.49 water/cement ratio was chosen for 1:2:3 (by weight). The Sika® Sika® Viscocrete® F-180 G was used as a superplasticizer for a modified polycarboxylate based polymer. Sika® Viscocrete® F-180 G is a high-performance high range water reducing agent plus stabilizing agent. For each mix 3 cubes (150 * 150 * 150) mm, prism beam (500 * 150 * 150) mm and cylinder (300 * 150) mm were prepared and the results are shown in Table (2).

Table 2. Some properties of concrete of the test beam

Specimen	Compression cube test (MPa)	Modulus of rupture (MPa)	Splitting tensile strength (MPa)
Without fiber	35.6	4.19	2.29
Straight steel fiber	44.8	7.00	3.75
Hooked steel fibre	43.5	8.14	4.30
Corrugated steel fibre	44.0	7.78	4.16

2.4. Test setup

All of the specimens were measured using a two-point load of a shear range to an acceptable depth ratio of 1.0 as supporting beams. The two concentrated loads were produced using a steel distribution beam. The descriptions and the devices used to examine beam specimens are shown in Figure (3). The beams were measured with a balanced electro-hydraulic tester with a maximum capacity of 2000 kN. The mid-span of the beam was measured with a linear variable displacement dial gauge. At the measurement unit, the original deflexed and load values were zeroed, the loading mechanism installed. The first state of the beams was then assumed to be these states. One of the eight beams is the control beam, which after 28 days of curing is measured for load power. The crack amplitude was observed after the failure of all the beams.

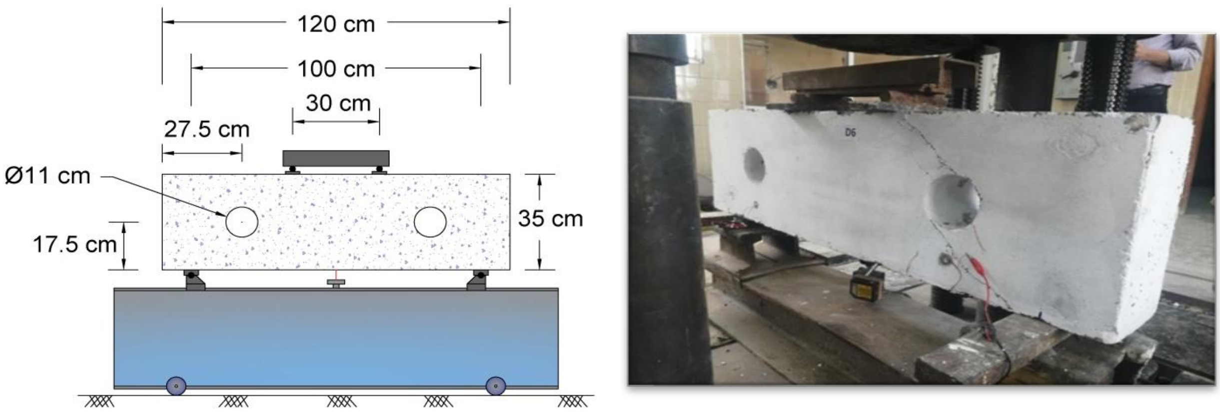

Figure 3. Testing machine and load measurement

3. Experimental results & discussion

3.1. First cracking and failure modes

All beams measured were elastically conducted at low levels of load. In the early stages of packing, the beams were crack-free, the deflects were minimal and proportionate to the load applied, the stresses were strong and the whole cross-section was involved. The first diagonal shear break occurs abruptly on the net and spreads to the top and bottom at 20.7 percent to 40.5 percent for the first group and at 36.4 percent to 56.7 percent (for the second group) of failure load. This load, however, was not failing. This suggests that after shear crack appears, there is the reserve power of these deep beams. With increasing load, the inclined crack steadily became wider. They have the same behaviour as the steel beam for beams containing steel fibre, as steel fibres slow the starting of cracks to stop their spread. The volume of steel fibre affects the start and expansion of cracks significantly. For opening beams, the fault mode is much the same as for without opening beams. The opening created less fragile actions over the same beams under static loading in beams without opening. The deflection for the (D1) beam, for example, is (2.15 mm) at load 225.6 kN, while for the (D5) deflector, it is at load level (2.97 mm).

The explanation may be that there were more deflections in the opening beam. Table (4) provides summary information on the performance of the two-point loading testing of deep fibre reinforced concrete beams (first and second groups) and the shear crack patterns of these deep beams after a breakdown in figure (4) to (11).

Table 3. The ultimate load capacities and first crack load

Beam designation	First crack load (kN)	Ultimate applied load (kN)	Percentage increase in ultimate load w.r.t. reference beam
Reinforced concrete deep beams without opening			
D1	127.5	315.2	----
D2	176.6	522.4	65.7%
D3	176.6	502.8	59.5%
D4	137.3	662.2	110.1%
Reinforced concrete deep beams with opening			
D5	107.9	230.5	----
D6	107.9	296.8	28.8%
D7	157.0	277.1	20.2%
D8	127.5	279.6	21.3%

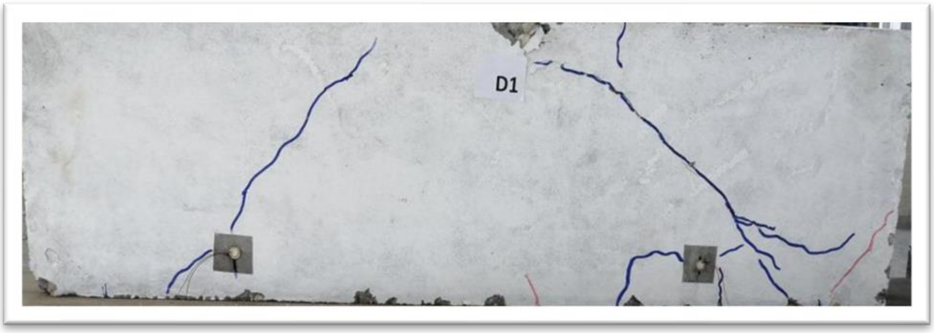

Figure 4. Shear cracks pattern of D1

Figure 5. Shear cracks pattern of D2

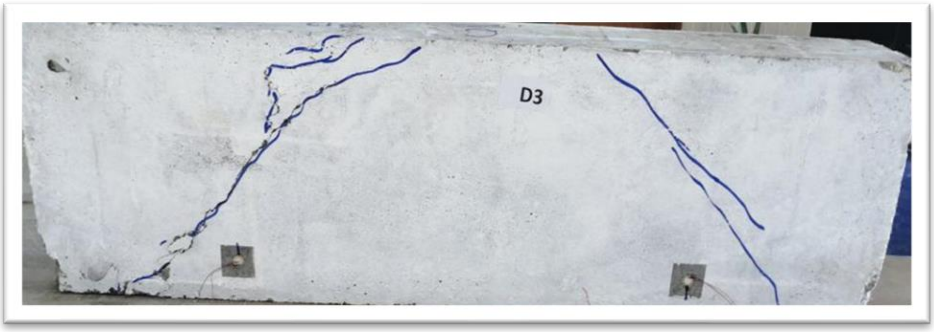

Figure 6. Shear cracks pattern of D3

Figure 7. Shear cracks pattern of D4

Figure 8. Shear cracks pattern of D5

Figure 9. Shear cracks pattern of D6

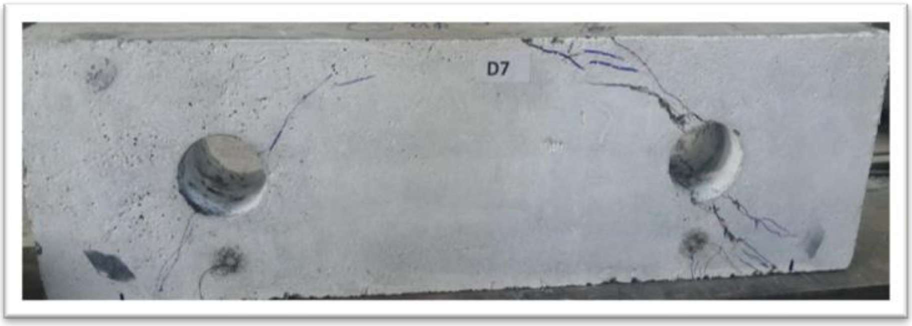

Figure 10. Shear cracks pattern of D7

Figure 11. Shear cracks pattern of D8

3.2. Cracking and ultimate loads

In the shear span, the load at which the first major diagonal shear crack occurs is considered a shear cracking load. The crack is abrupt and normally occurs in the centre of the shear period and propagates in the resulting rise of the applied load into the support and loading points. At about the middle point of the beam, the highest crack diameter occurred in the main inclined shear pit. The first group was managed by a strengthened deep concrete beam, referred to as D1. With D1, a shear crack spontaneously emerged in the shear span as the applied load crossed roughly (127.5 kN). The shear crack grew as load rose and worsened until a breakdown took place, due to a width of the diagonal crack (the main shear crack), with an overall load of 315.2 kN applied. The D2, D3 and D4 fibre beams have the same behaviour as the beams except that the angular crack has been delayed more than the control beam. For D2, after the load was reached (176.6 kN), the crack diameter increased until the complete load of 522.4 kN was added. The load loss was 502.8 kN in the D3 beam containing hooked steel fibre, the first crack started at 176.6 kN. The decrease in deflection is due to the high rigidity feature of the fibre by compared the D4 beam with on-cast steel fibre with straight steel fibre. For the second part, the deep beam of control (D5) failed at an ultimate load equal to 230,5 kN with an opening and not containing fibres. The beam deflections were initially in the elastic range at the early loading steps and the load applied was then raised until the crack was detected in the shear area 107.9 kN at load. The width of the tilted crack is increasing until it fails (shear failure). The deep beams (D6 and D7) included steel fibres straight and hooked. Both types of fibre lead to a 28.8 and 20.2% improvement in the ultimate load power of the deep beam D5, and a first crack (107.9 kN and 157 kN) respectively. Concerning the final load of control Deep Beam D5, the first crack hit the applied load (127.5 kN) and the last load rise was 21.3%, it can be seen that for example the inclined cracking load was decreased by the load of the corrugated steel (D8).

3.3. Load versus mid-span deflection results

An experimental study into the load compared to mid-span deflection curves is proposed for the measured deep beams at various loading levels. Maximum deflections were not achieved in case of failure to prevent damage to the dial gauge. Figure (12) shows the load-deflection curves of the deep beam of the first group (without opening). The fibre has decreased in deflection which makes the first big crack smaller relative to fibreless beams in the load-deflection curves of the measured deep beams. The following can be explaining the load versus the mid-span of the D1 beam deflection response (control beam). The applied load (applied shear force) was borne in the first phase of loading by the concrete and remained the same for all beams until the first diagonal crack appeared. It should be noted that a shift in the curve slope has taken place since the forming of a sloping crack, because of the considerable reduction in the stiffness of the beam of the formation of the first major slope crack. Due to the shear crack appeared, the deflection curve drop at 127.5 kN after that beam D1 continued in carrying the load with the new slope (stiffness) till failure. Finally, the rate of increase in deflection far increases the rate of increase in value of the applied loads when the load is approaching its final value. The fibre beams behaved in the earlier loading stage with the reference beams. With increased load, shear cracks were created and extended which reduced the rigidity of fibre beam specimens with fewer inclinations than the reference beams. After that, the fibre resisted the applied shear force. This was obvious because the curve went the same way. The first- and second-class behaviour can be seen in figures (12 & 13). As compared with the first category (beams without opening) and the second one (beam with opening), the opening raises the deflection, with the deflection (2.15 mm) of the D1 beam on load (225.6 kN), but the deflection of the D5 beam (2.97 mm) is the same. For other beams as seen in figures, this disparity is shown (14, 15, 16 and 17).

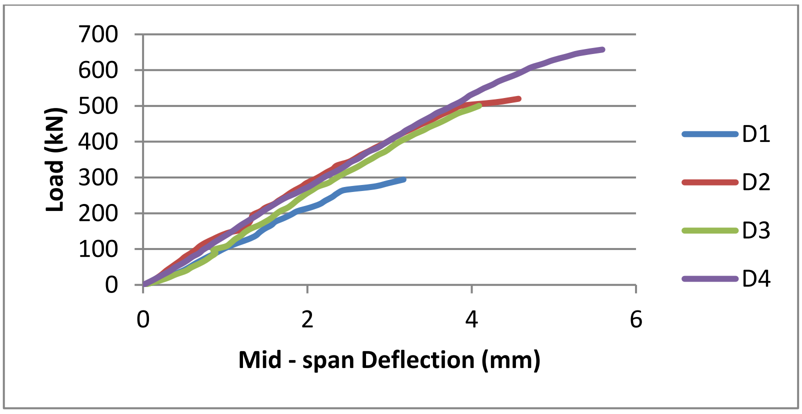

Figure 12. Deflection behaviour of tested beams for the first group

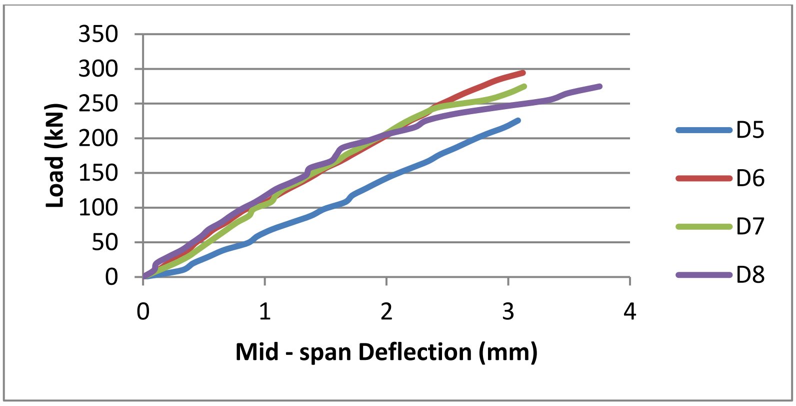

Figure 13. Deflection behaviour of tested beams for the second group

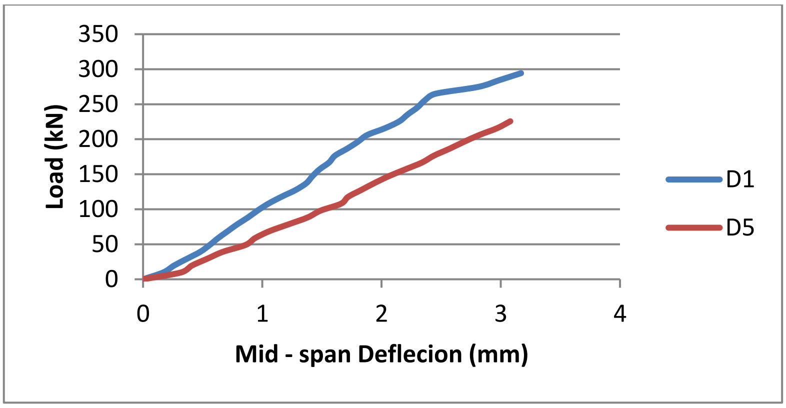

Figure 14. deflection behaviour of tested beams for D1 & D5

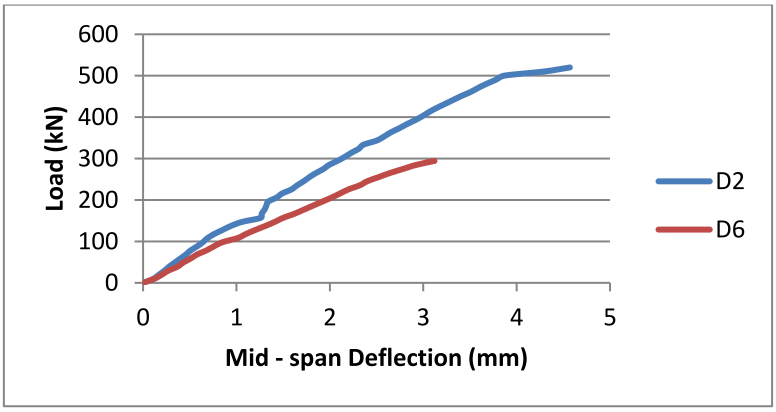

Figure 15. Deflection behaviour of tested beams for D2 & D6

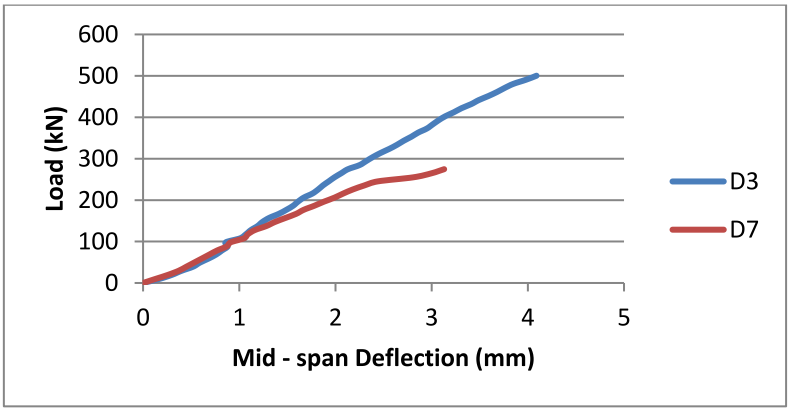

Figure 16. Deflection behaviour of tested beams for D3 & D7

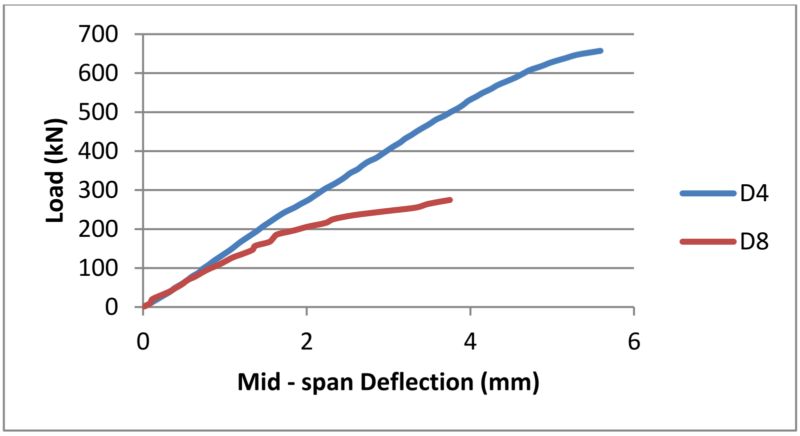

Figure 17. Deflection behaviour of tested beams for D4 & D8

4. Conclusions

The tests will draw the following findings that apply to the set of variables presently mentioned

- For beams with opening compared with non-opening beams, lower carriage potential exists between 18–30 percent.
- Adding steel fibre increased the first crack load in the specimens.
- In terms of compression and tensile strength, the hardened concrete features of the fibre-reinforced concrete are mildly affected by fibres' presence. Added steel fibres enhance HSC's strength of tensile. The compressive and bending forces of plain HSC, like steel fibres, have been increased.
- The addition of 1.0% steel fibres resulted in an HSC beam deflection-hardening reaction and met ACI 318 Code [10] shear resistance residual strength requirement.
- The addition of stainless-steel fibres effectively blocked crack growth and created a greater amount of initial bending cracks and diffused them than simple HSC. The increased tension intensification also produces higher post cracking rigidity of strengthened SFR-HSC beams than for those without fibres.
- The test results affirm the application of steel fibre and the sheer ability of the RC beams can be increased. In this analysis, for the first group, the beams were able to carry between 38% and 18% of the beam load and for the second group between 11% and 26% of the beam load over the ultimate beam load.
- The existence of the fibres of the measured beams is based on measurements via the beam examination. For fibre beams, the presence of delayed, restrained fibres, leads to increased load-bearing capacitance, and the occurrence of the original shear breaks at higher loads, before and after the first cracking.
- Compared with the reaction of deep control beams, deep fibre reinforced concrete beams show a stronger response to load deflection.

5. References

[1] K. Smith and A. Vantsiotis, "Shear strength of deep beams," ACI Journal Proceedings, vol. 79, no. 3, pp. 429-437, 1982.

[2] M.P. Collins, D. Mitchell, and E.C. Bentz, "Shear design of concrete structures," The Structural Engineer Journal, vol,86 no, 10, pp. 32-39, 2008.

[3] British Standards Institution, Eurocode 2: Design of Concrete Structures: Part General Rules and Rules for Buildings, British Standards Institution, 2004.

[4] ACI Committee, American Concrete Institute and International Organization for Standardization, Building Code Requirements for Structural Concrete (ACI 318M-14) and Commentary, American Concrete Institute, 2014.

[5] T. El Maaddawy, and S. Sherif, "FRP composites for shear strengthening of reinforced concrete deep beams with openings," Composite Structures. vol. 89, no. 1, pp. 60– 69, 2009.

[6] S. C. Chinl and S.I. Doh, “Behaviour of reinforced concrete deep beams with opening in the shear zone,” Journal of Engineering and Technology, vol. 6, no. 1, 2015.

[7] A. N. Kumbhar and S. S. Kadam, “Experimental Investigation Of Mixed Fiber Reinforced Concrete Deep Beam In Shear,” International Journal of Engineering Research and General Science, vol. 3, no 3, pp. 2091-2730, 2015.

[8] ACI Committee 544, “Report on Fiber Reinforced Concrete (ACI 544.1R-96) (Reapproved 2009),” American Concrete Institute, Farmington Hills, MI, 63 pp., 1996.

[9] D. Dupont, and L. Vandewalle, 2003, “Shear Capacity of Concrete Beams Containing Longitudinal Reinforcement and Steel Fibers,” Innovations in Fiber-Reinforced Concrete for Value, SP-216, N. Banthia, M, 2003.

[10] M. A. Mansur, and K.C.G. Ong, 1991, “Behavior of Reinforced Fiber Concrete Deep Beams in Shear,” ACI Structural Journal, vol. 88, No. 1, pp. 98-105, 1991.

[11] C. Basyigit, M. H. Alkayis, and M. I. Kartli, “Environmental effects of utilization of sustainable building materials”, Heritage and Sustainable Development, vol. 3, no. 1, pp. 64–70, May 2021.