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Study the Behavior of Beams with Openings and Strengthened by adding Quartz and different types of fiber

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ملخص البحث :

تم إجراء هذا البحث بهدف دراسة تاثير اضافة الياف الحديد للخلطة الخرسانية وذلك علي سلوك الكمرات الخرسانية المسلحة التى بها فتحه دائريه فى منطقه الشير وذلك للحصول على المزيد من الخصائص المرغوبة ، وتحسين العناصر الخرسانية لتحمل أحمال أكبر ولتعزيز أو تحويل السلوك الكلي إلى أكثر ليونة وقوة محسنة للخرسانة. تم اجراء الاختبارات المعملية في معمل الخرسانة – بقسم الهندسة المدنية – كلية الهندسة بالمطرية جامعة حلوان وتم اختبار اربعه كمرات ذات قطاع مستطيل بابعاد) 150*300*1650(مم)عرض*ارتفاع*طول(علي التوالي تم تقسيمهم الي مجموعتين, و تم استخدام ثلاث نسب من الياف الحديد وهما) %5.0 , %1,%5.1(من حجم الخرسانه .المجموعه الاولى كمره واحده لا يوجد بها اى اضافات حيث يوجد بها فتحه دائرية فى منطقه القص. المجموعه الثانيه ثلاث كمرات بها فتحات دائرية فى منطقه القص والخلطه الخرسانيه بها الياف الحديد كاضافه داخليه فى الخلطه الخرسانيه بنسب وهى) %5.0 , %1,%5.1(من حجم الخرسانه . واستنتج من هذه الدراسة إلى أن استخدام ألياف الحديد بنسبة 5.1 ٪ من الحجم له تأثير إيجابي على سلوك الخرسانة المسلحة.

ABSTRACT :

This paper present a study on steel fiber reinforced concrete beams with circular opening in the shear zone “SFRC” that considered relatively as a new method for reinforcing concrete, to gain more desired properties, confine the concrete members to sustain larger loads and to enhance or may convert the total behavior of the member into more ductile one. These tests made in the laboratory of concrete in the faculty of engineering ,mataria branch ,Helwan university. There are four beams with rectangular section with sections 150*300*1650mm. these beams were divided to two groups and were used three percentages of steel fiber which were 0.5%,1.0%,1.5% from volume of concrete. first group has one beam with circular opening in the shear zone without any addition in the concrete. Second group have three beams with circular opening in the shear zone with three percentages 0.5%,1.0%,1.5% from the volume of concrete. From these study ,it was found that 1.5% percentages of steel fiber of beam with circular opening has good effect on the behavior of reinforced concrete.

Keywords: R.C Beam with opening in shear zone, Circular Opening, steel Fiber strengthening *(Shear failure).*

Introduction

For old buildings with solid slab systems, utility pipes and ducts are important to accommodate important services. These services encompass air-conditioning, power supply, telephone line, computer network, sewerage and water supply. In practice pipes and ducts are usually hung beneath the ground beams, and covered by a suspended ceiling for its aesthetics. These openings may be different shapes and sizes such as circular, square or rectangular [1]. The presence of an opening in the web of a reinforced concrete beam results in many troubles in beam behavior such as reduction in beam stiffness, excessive cracking, immoderate deflection and reduction in beam strength [2, 3, 4, and 5]. Furthermore, inclusion of openings leads to a lot of stress concentration around the openings especially at the opening's corners. The reduction of area in the cross sectional dimension of a beam changes the simple beam behavior to a more complex one [2, 3, 4, and 5]. The effect of an opening depends on many factors such as boundary conditions support, tension and compression reinforcement (As, As'), opening location, and load types [6]. It has been noted that the classification of an opening relies upon at the structural response of the beam; when the opening is small enough to maintain the beam-type behavior, then the opening should be classified as a small opening. Otherwise, large openings are those that prevent beam-type behavior from developing [1, 7, and 8]. A circular opening may be considered large when its diameter exceeds 40% of the depth of the web [9, 10], however square openings are considered large when the height exceeds a quarter of the depth of the web [11, 12].

Previous Research

Various research had been carried out the usage of FRP laminates as external strengthening at shear in RC beams and the resistance force has been calculated ignoring the effect of existing stirrups besides openings and in the top and bottom cord of the opening [13-17]. However, the creation of a new opening in RC beams for existing homes and the effect of existing stirrups besides the opening are not taken into consideration. In this work, we experimentally assess the effect of the opening in the loaded RC beam by measuring the strain in the adjacent existing stirrups. Additionally, the reduction in shear strength as a result of the added opening in existing RC beams is calculated. The external strength around the opening is evaluated. The effect of creating the opening in the existing building is studied taking following the three items into account; 1) Opening dimensions and shape. 2) The time needed to create an opening; examining three cases before casting (case A), after casting and before loading (case B) and under loading by approximately 30kN (case C). 3) External strengthening using CFRP sheets and internal strengthening using discrete steel fibers added to concrete.

Experimental Programme

Materials Characteristics

The materials used to cast the specimens were (sand, dolomite, ordinary Portland cement and drinking water). Concrete mix designed to get target cubic compressive strength of 25 kN/m^2 after 28 days.

Coarse Aggregate: Dolomite used from natural sources with nominal maximum size of 10 mm. This nominal size was chosen taking into consideration the dimension of the tested beams as well as the spacing between the reinforcing bars. Batches used were all of good quality, clean and free from organic material.

Fine Aggregates: Natural sand composed of siliceous materials, clean and free from impurities.

Cement: Locally produced high quality ordinary Portland cement (CEM I 42.5 R).
Mixing Water: Drinking water used for mixing and curing for all specimens

Reinforcement Steel: Different reinforcement diameters and types used in this study. High tensile deformed steel bars of 10, 12 and 16 mm diameter were used as top and bottom steel for beams and denoted by (Y), While mild smooth steel 8 mm diameter was used as stirrups in all beams and denoted by (Φ).

steel Fibrers: The discrete steel fibers used was purchased from "sika" Company with properties as listed in Table 1.

Table (1): Properties of discrete steel Fiber.

Properties	**Value**
Density	2670 kg/m^3
fiber length	25 mm
Filament diameter	0.9 µm
E- Modulus	200 GPa
Appearance	

Mixing

The proportions of these mixes are listed in the Table 2. Sand, coarse aggregate and half amount of fibres added to the mechanical mixer and mixed for about one minute. Cement and the rest amount of fibres were added without adding of water for another one minute to insure better dispersion of the fibers throughout the mix, then water is added gradually to the mixer and continued in mixing for about 5 minutes to obtain homogenous mix for all constituents. It was observed that mixes with different fibres content was less workable than those without fibres, this may be due to the absorption of certain amount of moisture by the fibres. Therefore, super Plastizer additive was added to the mix to enhance with 0.3 by water volume for enhancing the workability of the mix

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Table (2): Quantities by Weight for 1m^3 Concrete.

Mix No.	% of steel fiber	Cement Content (kg/m^3)	Coarse Aggregates (kg/m^3)	Fine Aggregates (kg/m^3)	Steel (kg/m^3)	Water (kg/m^3)
1	0.0%	350	1320	660	0.0	175
2	0.5%	350	1320	660	2.9	175
3	1%	350	1320	660	5.8	175
4	1.5%	350	1320	660	8.7	175

Test Specimens

Experimental work consists of four beams, six cubes and six cylinders. The beams with dimensions 150 mm width, 300 mm depth, 1650 mm length and 1500 mm centre-right support to centre-left support. The four beams classified into two groups as listed in Table 3. First group consists of one concrete beam with circular opening in the shear zone classified as control beam (shear failure), beam with 3Y16 bottom, 2Y10 top reinforcement and 10Φ6/m stirrups. The second group consists of three concrete beams with circular opening in the shear zone (shear failure), beams with 3Y16 bottom, 2Y10 top reinforcement and 10Φ6/m stirrups, first beam is with adding 0.5 % of concrete volume steel fiber, the second beam is with adding 1.0 % of concrete volume steel fiber, the third beam is with adding 1.5 % of concrete volume steel fiber as shown in Fig. (1). All beams tested under two point shear test.

Table (3): Specimens Details.

Group	**Beams**	**As**	**As**	**Stirrups**	**Type of Section**	**Fibre Ratio %**
Group (1)	BC	3Y16	2Y10	10 ϕ 6/m\\	shear failure	0
Group (2)	BS1	3Y16	2Y10	10 ϕ 6/m\\	Shear failure.	0.50
	BS2	3Y16	2Y10	10 ϕ 6/m\\	Shear failure.	1.00
	BS3	3Y16	2Y10	10 ϕ 6/m\\	Shear failure.	1.50

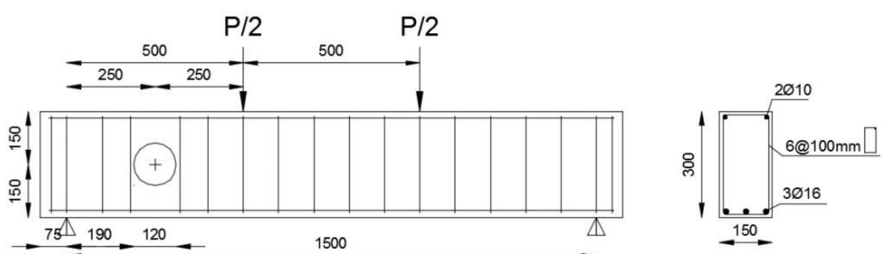

Fig. (1): Details of tested Beams Group 1 (shear failure beams) in mm.

TEST SETUP

Specimen setup is as shown in Fig.2, all specimens subjected to concentrated load using hydraulic jack at the middle of a distribution beam (I-sec). The distribution beam was supported on the tip of two bars that were fixed with the beam specimen at its ends. Three dial gauges for measuring deflections were located at mid span of the beam, 375mm apart from each other. The first one was at the mid span, the second was at 375 mm from the right support and the third was at 375mm from the left support.

Fig. (2): Beam under two Point Load.

RESULTS OF EXPERMENTAL PROGREM

Test values for beams are summarized in Table 4 and will be discussed below.

General Behavior and Cracking Patterns

Fig. (3,4,5 and 6) shows the cracking patterns for beams (BC, BS1, BS2 and BS3) after failure. Comparing the crack patterns between specimens found that they were close. Circular Openings were located at the left side of the beam, in the center between the concentrated load and the support. The Circular openings had diameter eqaul to 125 mm at mid of beam height and it was equal 0.4 t (total height of beam) . By comparing the specimens (BC) and (BS1), (BS1) which strengthened with 0.5% percentage of steel fiber in mixture had cracks around the opening as shear carcks but BC had cracks around the opening and along the beam as flexural cracks and shear cracks. One crack appeared at top cord above the opening and another one crack appeared at bottom cord below the opening between the support and the corners of opening and the crack reached to support but the width of crack is smaller than the crack at beam (BC). By comparing the specimens (BC) and (BS2), (BS2) which strengthened with 1.0% percentage of steel fiber in mixture had cracks around the opening as shear cracks. one crack appeared at top cord above the opening and another one crack appeared at bottom cord below the opening between the support and the corners of opening and the crack reached to support but the width of crack is smaller than the crack at beam (BC). By comparing the specimens (BC) and (BS3), (BS3) which strengthened with 1.5% percentage of steel fiber in mixture had cracks around the opening and along the beam as flexural cracks and shear cracks. One crack appeared at top cord above the opening and another one crack appeared at bottom cord below the opening between the support and the corners of opening but the width of crack is smaller than the crack at beam (BC). The steel fiber had a little improvement on the behavior and have controled the crack width.

Fig. (3).Cracking Pattern for Beam (BC).

Fig. (4).Cracking Pattern for Beam (BS1).

Fig. (5).Cracking Pattern for Beam (BS2).

Fig. (6).Cracking Pattern for Beam (BS3).

Failure Load

The experimental maximum load showen in Fig. (7). Maximum capacity load for beam (BC) was 166 KN, while maximum capacity load for beam (BS1) was 155 KN, maximum capacity load for beam (BS2) was 188 KN and maximum capacity load for beam (BS3) was 219 KN. By comparing results, it obvious that the steel fiber had little effect on beams with small percentage(0.5%) from steel fiber at failure load and high effect on large percentage at 1% and 1.5% from steel fiber. Beam (BS1) reduced by 6.63% of the beam capacity, while beam (BS2) increased by 13.25% of the capacity of beam and beam (BS3) increased by 31.93% of the capacity of beam. with higher percentages of fibers BS3(1.5%) has lower cracking load than control beam.

Crack Load to Failure Load Ratio

The experimental crack load to failure load ratio showed in Fig. (8). crack load to failure load ratio of (BC) was 54.52%, for BS1 was 67.10%, for BS2 was 51.33% and for BS3 was 29.09% . By comparing results, it was clear that the crack load to failure load ratio of beam

(BS1) increased by 12.58% when compared with BC and that mean BS1 more brittle than BC**.** BS2 decreased by 3.19% when compared with BC and that mean BC more brittle than BS2. finally, BS3 decreased by 25.43% when compared with BC and that mean BC more brittle than BS3. So putting high percentage of steel fiber is better than putting low percentage of steel fiber to achieve a good warning time before failure.

Table 4: Results of Tested Specimens

Beam No.	**Cracking Stage**	**Failure Stage**		
	P_{CR} (Kn)	**P_F (Kn)**	Δ_f at opening **(mm)**	Δ_f at midsapn **(mm)**
BC	90.5	166	5.74	6.9
BS1	104	155	6.65	8.42
BS2	96.5	188	5.92	7.13
BS3	63.7	219	3.51	4.64

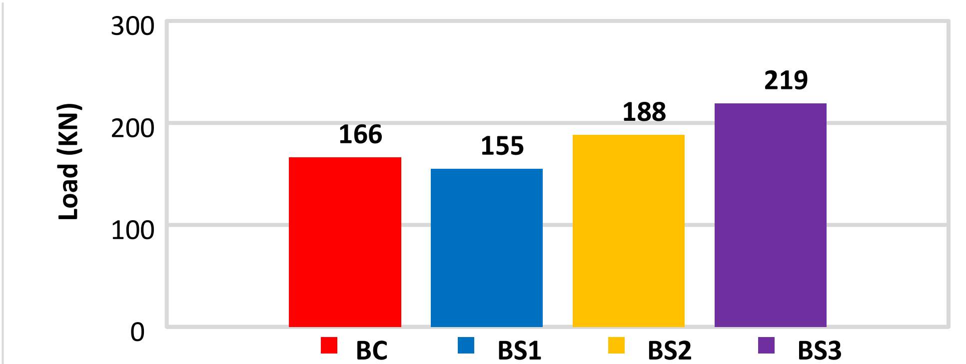

Fig.(7): Failure Load for Specimens

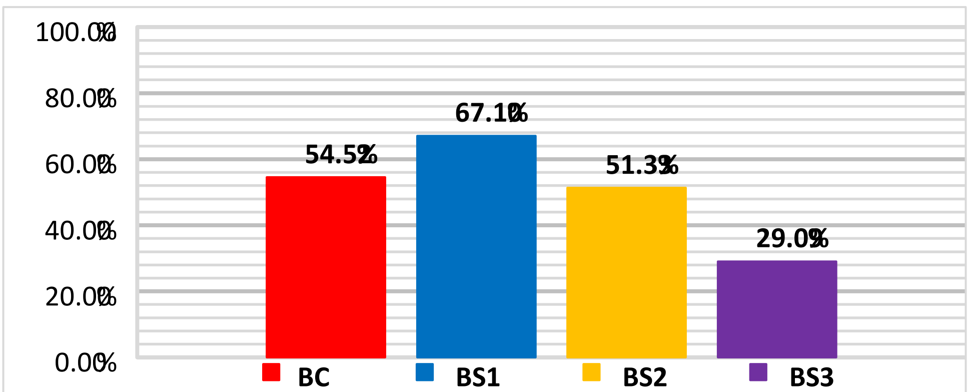

Fig. (8): Crack Load to Failure Load Ratio for Specimens.

Load-Deflection Curves

Two points of deflection for each specimen were measured, one at the mid span (at 750 mm from support) and the other under the center of opening (at 250 mm from support). Fig. (9) shows the deflection curve at mid span for beams (BC2, BS1, BS2 and BS3). The deflection of beam (BC) at mid span was 6.9 mm at peak load of 166 KN, the deflection of beam (BS1) at mid span was 8.42 mm at peak load of 155 KN, the deflection of beam (BS2) at mid span was 7.13 mm at peak load of 188 KN and the deflection of beam (BS3) at mid span was 4.64 mm at peak load of 219 KN. By comparing the results between (BC) and (BS1), it was found that the value of deflection at failure load at mid span for beam (BS1) increased by 22 % although the peak load for beam (BS1) was less than beam (BC). By comparing the results between (BC) and (BS2), it was found that the value of deflection at mid span for beam (BS2) about the same to the beam (BC2) although the peak load for beam (BS2) was bigger than (BC). By comparing the results between (BC) and (BS3), it was found that the value of deflection at mid span for beam (BS3) decreased by 32.75% but the peak load for beam (BS3) was bigger than (BC). From this results it found that high percentage (1.5%) was more effective than the other percentages (0.5% and 1%) for failure load and deflection as beam BS3 had a higher failure load and minimum deflection.

While the Fig. (10) shows the deflection under the center of the opening for beams (BC, BS1, BS2 and BS3). The deflection of beam (BC) under opening was 5.74 mm at peak load of 166 KN, the deflection of beam (BS1) under opening was 6.65 mm at peak load of 155 KN, the deflection of beam (BS2) under opening was 5.92 mm at peak load of 188 KN and the deflection of beam (BS3) under opening was 3.51 mm at peak load of 219 KN. By comparing the results between (BC) and (BS1), it was found that the value of deflection at peak load under opening for beam (BS1) increased by 15.85 %although the failure load was too close. By comparing the results between (BC) and (BS2), it was found that the value of deflection under opening for beam (BS2) increased by 3.14% and too close to beam (BS2) although the failure load for beam (BS2) was different and larger than BC. By comparing the results between (BC) and (BS3), it was found that the value of deflection under opening for beam (BS3) decreased by 38.85% although the failure load for beam (BS3) was different and larger than BC.

The steel fiber in mixture had a high effect on beams with circular opening which improved the behavior of beams for deflection and load, while the higher steel fiber in mixture ,the higher of load for failure load and lower deflection as steel fiber make strong bond between him and concrete .

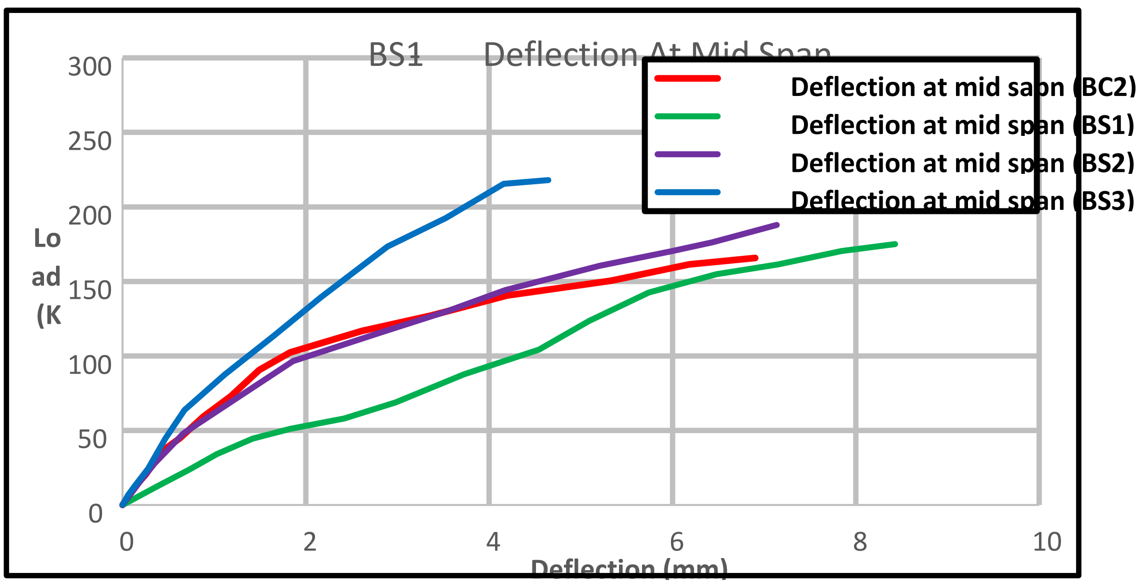

Fig. (9): Deflection at mid span for specimens (BC, BS1, BS2 and BS3)

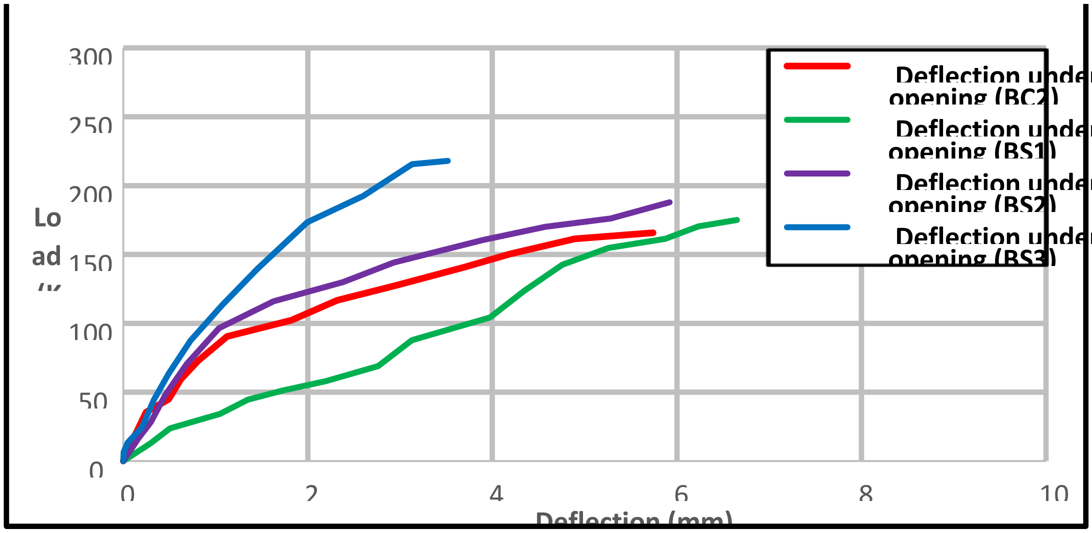

Fig. (10): Deflection under opening for specimens (BC, BS1, BS2 and BS3)

CONCLUSION

Effect of strengthening RC beams with steel fiber

1-The strengthening beams with steel fiber and having circular opening with dimension (D = 0.4t) with different percentage (0.5 % - 1.0 % - 1.50 %) of volume of concrete in mixture, decreasing in the capacity by 6.63 % for percentage equal 0.5%, increasing in the capacity by 13.25 % and 31.93 % for percentages 1.0% and 1.5% from the control beam with circular opening respectively.

2-Having steel fiber in mixture of tested beam with 1.5% percentage of volume made the beam carry a large amount of stress but didn't reached to the yield value of stress of steel. 3-Steel fiber in mixture improve the capacity of beams for deflection and failure load which had a higher failure load and minimum deflection at mid span and under opening. 4-Having steel fiber in mixture of tested beam with 1.5% percentage of volume made the stiffness of beam more better than other beams

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