RESEARCH ARTICLE OPEN ACCESS

Study to Compare the Effeciency of Synthetic Fibers Fabrics in Strengthening R.C Beams with Openings

Ibrahim Mohamed Naguib Ismail[1],Khaled S.A. Morsy[2], Tarek Aly Elsayed[3]

[1] (Department of Civil Engineering, The Higher Institute of Engineering, October 6 City, Cairo, Egypt))
[2] Lecture of civil Engineering Structural Engineering Department - The higher institute in 5th settlement.Cairo, Egypt
[3]Professor - Department of Structural Engineering, Faculty of Engineering - Helwan University.Cairo, Egypt

--************************----------------------------------

Abstract:

The Openings in beams are very important in the construction at the present time. the need for concrete openings in reinforced concrete beams has begun to pass through electric wires, special water pipes, firefighting, pipelines, adaptations and many services that must be found mainly in these large buildings. Many researchers exerted great efforts to predict and interpret the behavior of beams with openings. They recommended convenient methods for the design of such beams. But at times the openings are made by unqualified persons or without returning to the designed engineer thus exposing the means to weakness and cracks and may reach to the point of collapse. The researchers have found that the (FRP) sheets have excellent properties in load strength. There are currently many types of (FRP) sheets. But the question arises here, what are the advantages and disadvantages of each type when used to strengthen beams with openings? This question is the gate to estimate the most efficient and the most economic FRP strips type.

The current thesis tries to give an answer for this question, in which GFRP, CFRP and BFRP strips were used to strengthen and improve the behavior of beams with openings. Eight reinforced concrete beams with rectangular cross section (15cm X 30cm) were tested under two-point static loading. Two beams were taken as a control beams without strengthening, one of them was a solid beam without openings. Each one of the other beams was provided with a rectangular web opening of 30cm length and 15cm height. The beams were divided according to the fiber type into three groups, in each group, two beams were tested under two-point loading. Two strengthening schemes with Three different FRP types (GFRP, CFRP and BFRP strips) were considered.

The patterns of cracks, mode of failure, and deformation characteristics (deflection and steel strain tensile) were recorded. Finally, analysis of test results and recommendations were reported.

Keywords: BasaltFiber, Carbon Fiber,GlassFiber, Beam with Openings.

--************************----------------------------------

I. INTRODUCTION

The urgent need to strengthen concrete beams with openings is on the rise. Various motivations lead to the increased demand for strengthening. Deterioration and aging of concrete structure are not the only reasons for strengthening beams, other reasons include upgrading design standards, committing mistakes in design or construction such as creating an opening in existing beams or slabs, exposure to unpredicted loads such as truck hits or powerful earthquakes, and changing the us age of the structure. Recently, the use of advanced composite materials has gained the interest of many researchers withinlast two decades. Recently, many investigators extended the research efforts about using FRP as a strengthening material in both shear and flexure of the beam elements. One of these experimental programs included Tested fifteen reinforced concrete beams with rectangular cross section (10cmx20cm) were tested under uniform static load applied at the middle of the span. The beams were divided, according to the opening location along the beam length, into two groups. In each group, six beams were tested under uniform loading. Two different types of FRP (CFRP and GFRP laminates) were tested.TheStrengthening openings with CFRP and GFRP laminates contribute in reducing number of cracks and cracks widths. Strengthening openings with CFRP and GFRP causes a noticeable reduction in the relative tensile strain ratios**[1].**A total of 13 deep beams with openings were constructed and tested under four-point bending. Test specimen had a cross section of 80 × 500 mm and a total length of 1200 mm. Two square openings, one in each shear span, were placed symmetrically about the mid-point of the beam. The strength gain caused by the CFRP sheets was in the range of 35–73%. A method of analysis for shear strength prediction of RC deep beams containing openings strengthened with CFRP sheets was studied and examined against test results**[2].**Another research studiedFour specimens were tested to study the effect of carbon fiber reinforced plastics (CFRP) wrappings on the shear strength of reinforced concrete deep beam with web openings. Test results indicate that the shear strengths of high-strength concrete deep beam with CFRP wrappings are about 10 % more than that without CFRP wrappings. Test results also indicate that flexural bars of high-strength concrete deep beams with CFRP wrappings are yielded at the ultimate state. An analytical method for determining the shear strengths of reinforced concrete deep beams with web openings and CFRP wrappings is also proposed in this paper. The shear strengths predicted by the proposed method are compared with test results. The comparison shows that the proposed method can conservatively predict the shear strengths of reinforced concrete deep beams with web openings and CFRP wrappings **[3].**Finite elementanalysis has been used in order to study this problem. Fifty-seven beams analysed using finite element program ANSYS V12. Study beams have opening width and height ofdimensions200 × 100 mmand300 × 100 mm.The centreline of the opening is at distance of 225, 300, 350 and 400 mm from the near support. Strengthening of all beams with opening came out to six types of different scheme around the opening using fibre-reinforced polymer (FRP).Thereinforced concrete beams were modelled in 'ANSYS V12' Program under statically load Strengthening beams at opening zone using FRP sheets can significantly improve its overall rigidity and regain part of its stiffness lost as a result of opening creation and the failure loads are mainly affected by strengthening scheme**[4] .**

II. EXPERIMENTAL WORK

all tested beams have the same total length 1.65m and overall cross section of 15x30 cm, they were simply support at span of 1.5m apart. The steel reinforcement of all beams was: two bars 16mm diameter as tension reinforcement, two bars 12 mm diameter as compression reinforcement, and stirrups 8mm diameter with 28cm spacing. The number of beams that have been prepared for the test is eight beams as a solid single beam without openings reference beam **Fig.1**, And a beam with opening a control specimen is shown in **Fig 2**. The test of beams was provided with one opening of 30cm length, and 15 cm height. These beams were divided according to the type of synthetic fibers and form of strengthening together with the control beams into four main groups is show in **table I:**

1- Group (A) control beams.
2- Group (B) strengthened using glass fiber.
3- Group (C) strengthened using carbon fiber.
4- Group (D) strengthened using basalt fiber.

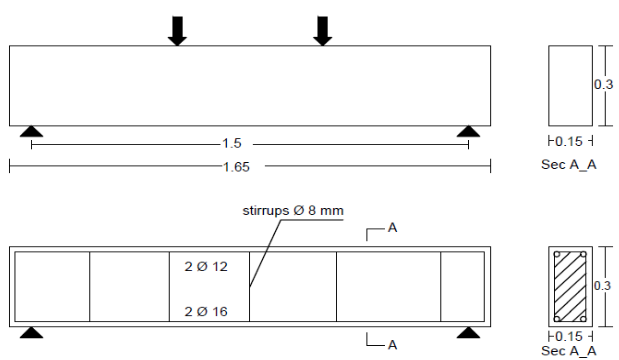


Fig. 1: Details of Typical beam without opening Specimen.

For beams with openings, each group contains two beams strengthened against shear failure, the openings were made in the beams before casting at the position of maximum shear, so that the hole is at a distance of 12 cm for the nearest support and having length of 30 cm and height of 15 cm.

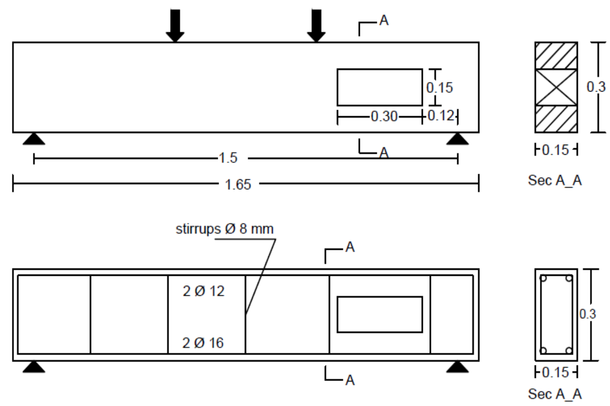
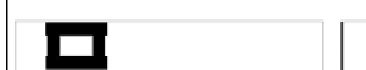
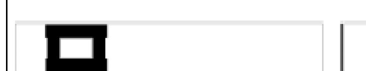
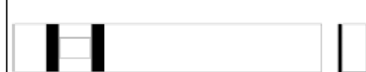
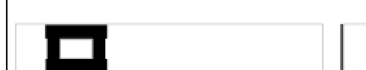


Fig. 2: Details of Typical beam with opening Specimen.

TABLE I
EXPERIMENTAL PROGRAM.

Group	Type strengthening	Beam no	Shape of strengthening
A	Without opening without strengthening	B1	
	With opening without strengthening	B2	- 
B	Glass fiber	B3	
		B4	
C	Carbon fiber	B5	
		B6	
D	Basalt Fiber	B7	
		B8	

Each synthetic fiber type was used to strengthen two beams with two different schemes. The first scheme is to use the fiber around opening, and the second scheme is wrapped the fibers on both sides of the opening (U- Shape).

A. Concrete mix design

The concrete mix was designed to achieve a target compressive strength of 25N/mm² after 28 days. The mix properties are shown in table II.

TABLE II
PROPERTIES OF CONCRETE MIX CONSTITUENTS USED IN THE EXPERIMENTAL WORK

Constituents	units	Contents (m³)
Cement	Kg	350
Sand	Kg	720
Water	Liter	175
Water-cement ratio	%	0.5
Coarse aggregate	Kg	1400

B. INSTRUMENTATION

- **Deflection**

The deflection devices were placed at the bottom surface of the tested specimens at mid – span of the beams, and mid – span of openings. As shown in **Fig 3.**

Fig. 3: deflection device

- **Steel tensile strain**

Two strain gauges with 1/100 mm accuracy were used for deflection measurement under the bottom face of the specimens as shown in **Fig 4.** One gauge was placed at edge stirrups of opening at 42.5 cm from near support, and the second gauge was placed at mid – span of beams at main reinforcement steel.

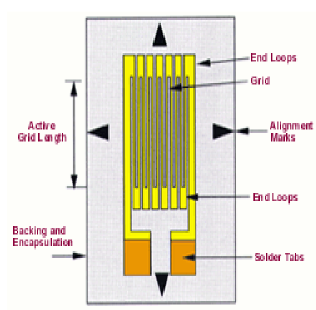


Fig. 4: steel tensile strain device

- **Test Rig and Instrumentation:**

The testing frame in the concrete testing laboratory of the department of civil Engineering of Helwan University was used to test the reinforced concrete beams. **Fig. 5,** shows the test frame. The test beams were mounted on the frame and were adjusted on the supports so that the right and left support acted as hinge. Each support had two side plates with a special lateral bracing system in order to control the verticality of the tested beam during testing.

Fig. 5: Test Setup

III. TEST RESULTS AND ANALYSIS

the control beam "B1" without openings and without any strengthening, the cracks were symmetrically about the vertical axis at shear zone. The major cracks that cause the failure appeared in the form of a diagonal line beginning at point of load and ending at the support. The shape of this cracks is typical as cracks of shear stress.

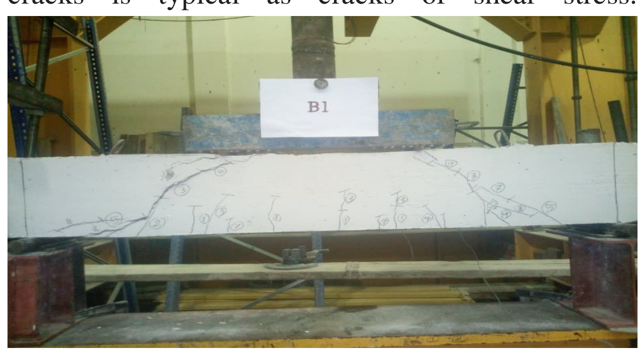


fig. 6: Crack Patterns of Control Beam(B1) Without Opening Without Strengthening.

Control beam “B2”, un-strengthened opening, the first crack was observed at the opening corner near to the support, but the major crack failure took place at the line joining the opposite corner and either the nearest support or the nearest point of load system. Cracks were less compared to control beam (B1), and more focused around opening. In addition, the control beam (B2) failed at lower load compared to control beam (B1). This is because that, the beam has been weakened by opening. Beams having strengthened openings have different cracks behavior.

. fig.7: Crack Patterns of Control Beam(B2) with Opening without Strengthening.

3.1.1 For Beams Using GFRP sheets

Beam “B3” was strengthened using (U-shape). Cracks were initiated first at openings zone. At later stages of loading, minor cracks were observed at mid-span of beam. The mode of failure was due to stirps debonding.

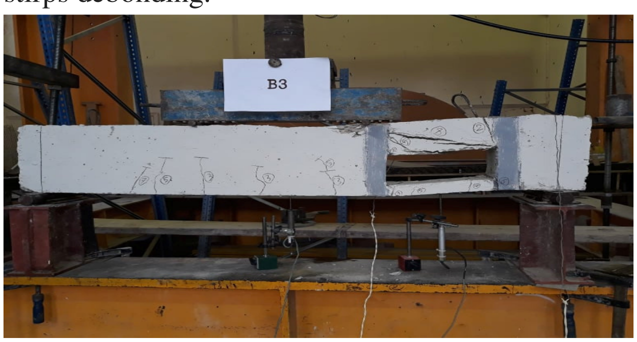


Fig. 8: Crack Patterns of Beam(B3) with GFRP Strengthening, U-Scheme.

Beam “B4” was strengthened using (2-side). Simple cracks were initiated first at openings zone. At later stages of loading, minor cracks were observed at mid-span of beam, at load increased, cracks Increased and widened at mid-span of beam. The mode of failure was due to strips elongation and failure of concrete at the top of opening.

Fig.9: Crack Patterns of Beam(B4) with GFRP Strengthening Two-Side scheme

3.1.2 For Beams Using CFRP sheets

Beam “B5” was strengthened using (U-shape). Showed similar performance to beam “B3” but with less cracks at mid-span of beam.

Fig. 10: Crack Patterns of Beam(B5) with CFRP Strengthening, U-Scheme.

Beam “B6” was strengthened using (2-side). Showed similar performance to beam “B4” but, the cracks were more around the opening.

Fig.11: Crack Patterns of Beam(B6) with CFRP Strengthening Two-Side scheme

3.1.3 For Beams Using BFRP sheets

Beam "B7" was strengthened using (U-shape). Cracks were more regular and more extensive compared with beam (B3) and beam (B5). BFRP sheets were characterized by higher stresses, improved cracking behavior and good cohesion between them and the surface of beam.

Fig. 12: Crack Patterns of Beam(B7) with BFRP Strengthening, U-Scheme.

Beam "B8" was strengthened using (2-side). The cracks pattern was more extensive and increased at the mid-span of beam comparing beams "B4" and "B6".

Fig.13: Crack Patterns of Beam(B8) with BFRP Strengthening Two-Side scheme

3.1.4 Effect of Strengthening Scheme on The Crack Pattern and The Mode of Failure

The cracks behavior was more regularly distributed, as well, the cracks movement from opening zone to mid-span of beam for beam strengthened using (Two-Side) strengthening scheme proved that strengthened using (Two – Side) scheme was better compare the beams strengthened using (U – Shape) scheme.

3.2 CRACKING AND ULTIMATE LOADS:

The control beam "B1" without openings and without strengthening was the best compared to the other beams with openings. The cracking load of beam "B1" was 66.69KN. and the ultimate load was 168.68KN.The cracking load of the control beam "B2" with opening without strengthening was 17.16KN with a decrease of about 75% from the control beam "B1", and the ultimate load was 68.95KN, with a decrease of about 60% of the control beam "B1". This is due to the opening in the shear zone, which weakened the ability of the beam to carry the exposed loads and change the behavior of cracks.It's clear that the cracking and ultimate loads values for control beam (B2) were less that the values for beams that strengthened using FRP sheets.

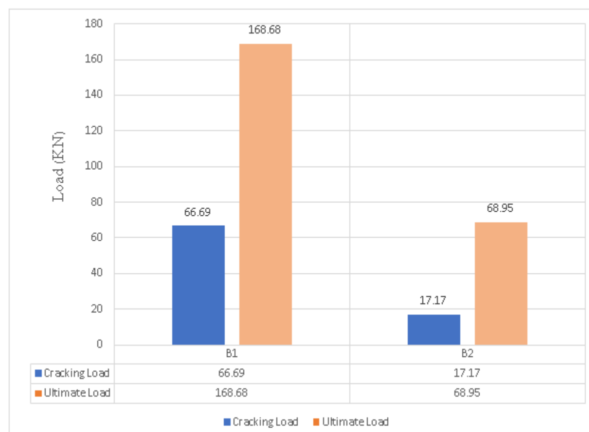


Fig.14: Compare Between Cracking and Ultimate Loads for Control Beams (B1) and (B2)

3.2.1 For Beams Strengthened Using GFRP sheets:

For beam "B3" strengthened using (U-shape), the cracking and ultimate load are 38.60%, 17.80% higher than those for control beam (B2) respectively. For beam "B4" strengthened using (Two-Side), the cracking and ultimate load are

30.86%, 16.30% higher than those for control beam (B2) respectively

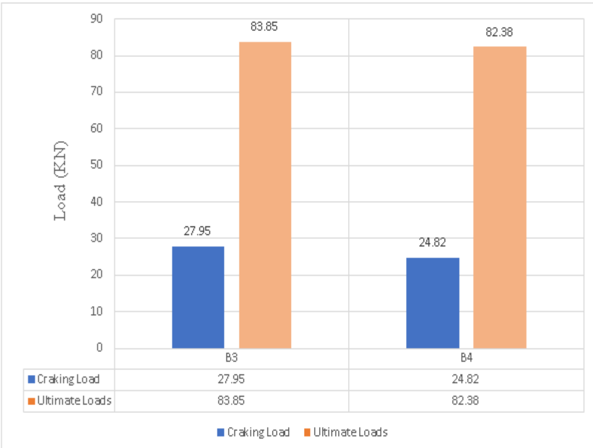


Fig.15: Comparing Between Cracking and Ultimate Loads for Beams (B3&B4) Strengthened Using GFRP Laminates

3.2.2 For Beams Strengthened Using CFRP sheets:

For beam "B5" strengthened using (U-shape), the cracking and ultimate load are 43.46%, 14.980% higher than those for control beam (B2) respectively. For beam "B6" strengthened using (Two-Side), the cracking and ultimate load are 52.97%, 18.63% higher than those for control beam (B2) respectively

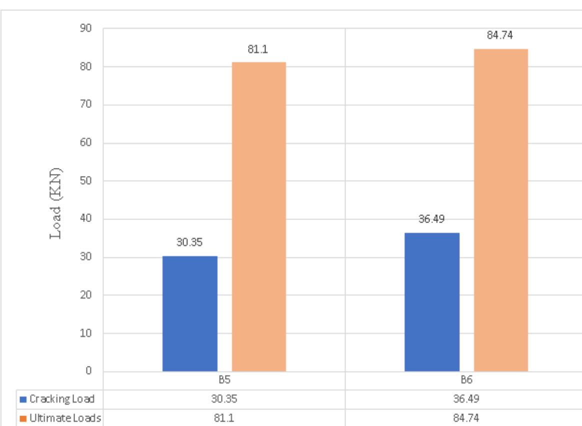


Fig.16: Comparing Between Cracking and Ultimate Loads for Beams (B5&B6) Strengthened Using CFRP Laminates

3.2.3 For Beams Strengthened Using BFRP sheets:

For beam "B7" strengthened using (U-shape), the cracking and ultimate load are 24.60%, 18.74% higher than those for control beam (B2) respectively. For beam "B8" strengthened using (Two-Side), the cracking and ultimate load are 47.77%, 26.76% higher than those for control beam (B2) respectively.

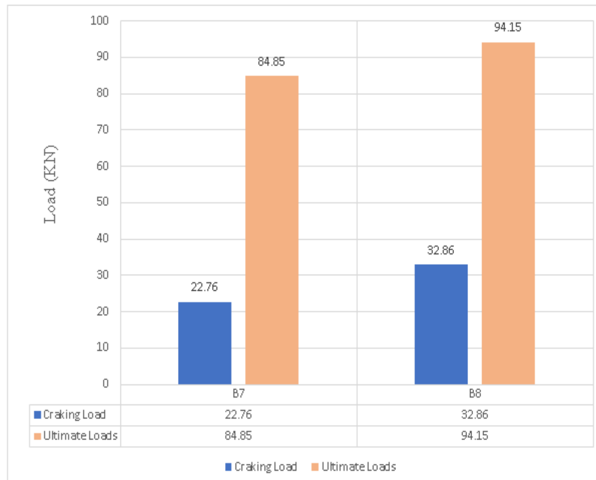


Fig.17: Comparing Between Cracking and Ultimate Loads for Beams (B7&B8) Strengthened Using BFRP Laminates

3.2.4 Effect of Strengthening Scheme on The Cracking and The Ultimate Load

Beams strengthened GFRP strips using (U – Shape) scheme was higher about 11.20% at cracking load and 1.75% at ultimate load compare other beam using (Two – Side) scheme. But the beams strengthened CFRP, BFRP strips using (Two – Side) scheme was higher about 16.83%, 30.74% at cracking load, and about 4.30%,9.9% at ultimate load respectively compare (U – Shape) scheme.

3.3 DEFLECTIONS:

It is clear from the results of the values of the deflection at cracking and ultimate loads of control beam (B1) that without strengthening without openings were higher than those for control beam (B2) with opening without strengthening as shown at **Fig.18.**

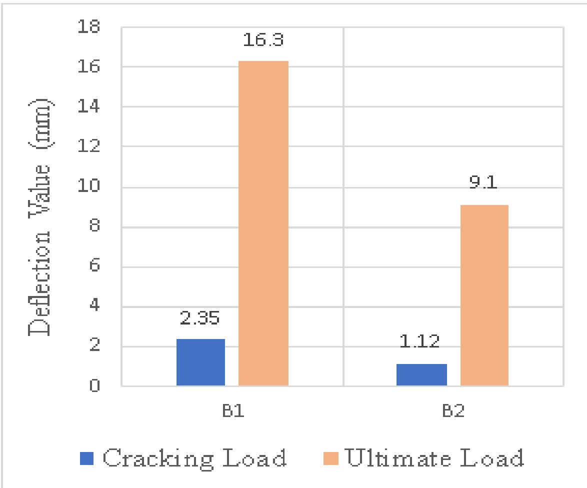


Fig.18: Deflection Values for B1, B2 At Mid – Span of Beams

3.3.1 For Beams Using GFRP Sheets

Comparing with control beam with opening “B2” without any strengthening, at cracking load, the deflection at mid-span of beam was increased about 13.85% for beam “B3” and about 18.25% for beam “B4”. But at ultimate load, the deflection was increased about 2.67% for “B3” and decreased about 3.85% for “B4”, as shown at **Fig.19.**

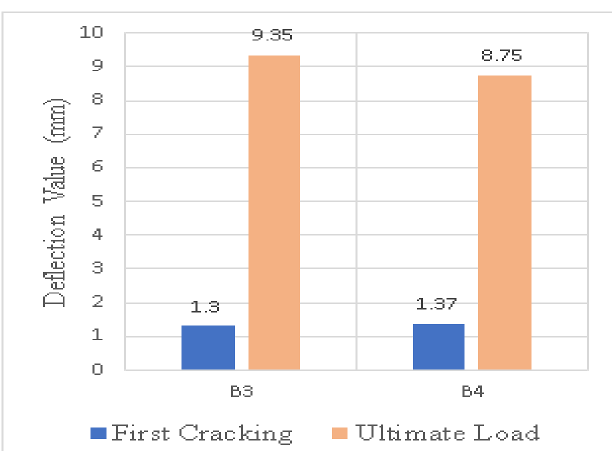


Fig.19: Deflection Values for Beams (B3, B4) At Mid – Span of Beams

3.3.2 For Beams Using CFRP Sheets

The deflection at mid-span of beam at cracking loads was increased about 21.13% for beam “B5” using (U-shape) scheme, and about 13.85% for beam “B6” using (Two-Side) scheme. But at ultimate loads, the deflection increased about 2.15% for “B5”, and decreased about 7.15% for “B6”, comparing with control beam (B2) as shown at **Fig.20.**

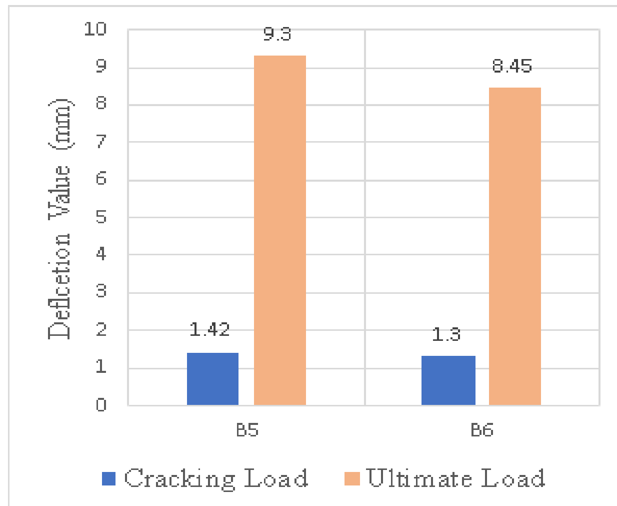


Fig.20: Deflection Values for Beams (B5, B6) At Mid – Span of Beams

3.3.3 For Beams Using BFRP Sheets

The increase of deflection at mid-span of beam at cracking loads was about 17.04% for beam “B7”, and about 6.67% for beam “B8”. But the deflection values at ultimate loads was increased about 3.20% for “B7”, and decreased about 17.92% for “B8”, comparing control beam (B2), as shown at **Fig.21.**

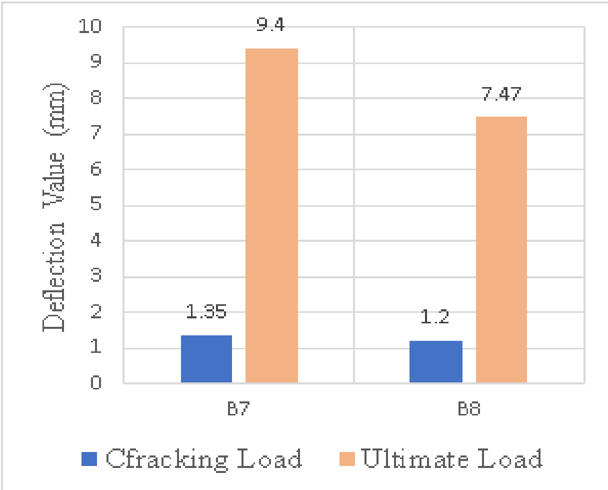


Fig.21: Deflection Values for Beams (B7, B8) At Mid – Span of Beams

3.3.4 Effect of Strengthening Scheme on The Deflection

From results it was found that the beams that using (Two – side) scheme gave better results comparing beams that strengthening using (U-shape) scheme. The decrease of deflection values at mid-span of beam at ultimate loads for beams using (Two -side) scheme was about 6.42% for beams using GFRP strips, and about 9.14% for beams using CFRP strips, and about 20.50% for beams using BFRP strips.

3.4 STEEL TENSILE STRAIN:

From test results, control beam "B1" was the highest results in steel tensile strain because it has without any openings. But the steel tensile strain values for control beam "B2" Significantly decreased compared to control beam "B1" This is because the opening has been reduced the strengthening of beam especially it's not strengthening by any type of fibers. where the steel tensile strain value at mid-span of beam decreases at cracking load by about 86.22%, and the steel tensile strain values decrease at ultimate load by about 62.75%.

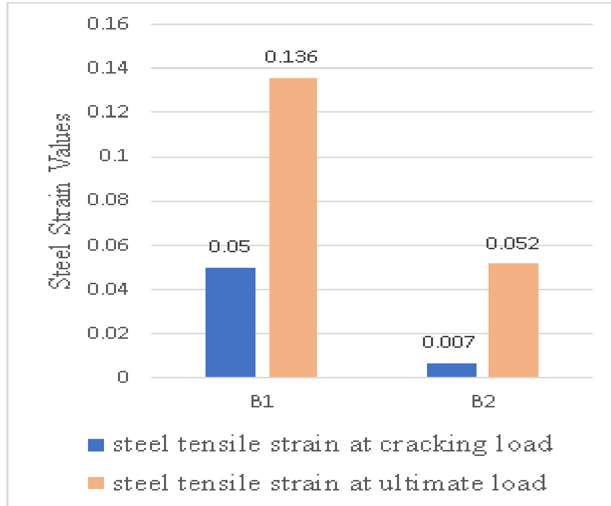


Fig.22: Steel Tensile Strain Values for Control Beams at Mid – Span of Beams

3.4.1 For beams strengthened using GFRP strips

For beam "B3", the value of steel tensile strain at mid-span of beam increased at cracking load compare to the control beam "B2" by about 30%, but at ultimate load, the value increased by about 14.44%.The steel tensile strain values of beam "B4" at cracking load at mid – span of beam was higher about 61.12%, and at ultimate load about 36.70%.

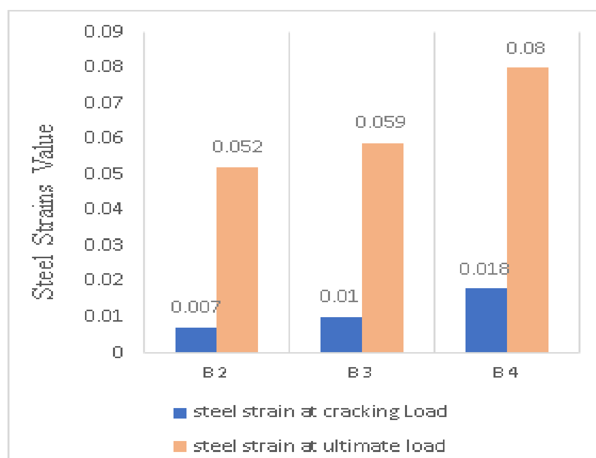


Fig.23: steel tensile strain values for beamsUsing GFRP strips at Mid – Span of Beams

3.4.2 For beams strengthened using CFRP strips

For beam “B5”, the value of steel tensile strain was higher at first cracking load compared to the control beam “B2” at mid – span of beam by about 67.15%, but at ultimate load, the value increased about 24.25%. at beam (B6), the steel strain values at first cracking higher about 78.22%, and at ultimate load was increased about 34.22%,

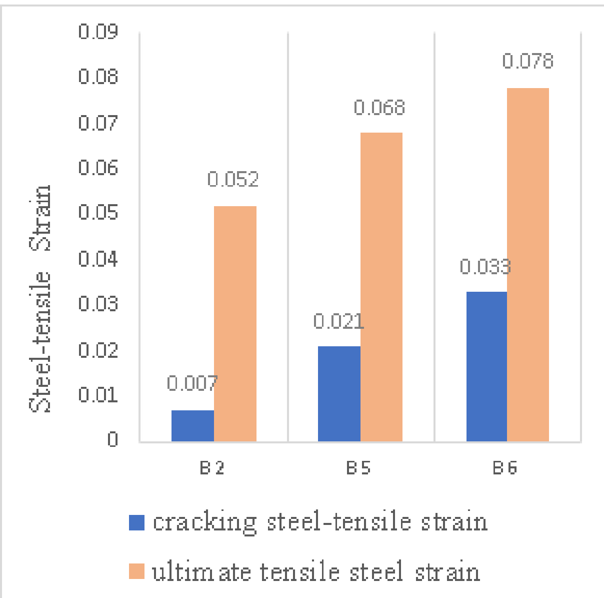


Fig.24: steel tensile strain values for beamsUsing CFRP strips at Mid – Span of Beams

3.4.3 For beams strengthened using BFRP sheets

For beam “B7”, the value of steel tensile strain higher at mid – span of beam at cracking load compared to the control beam “B2” about 62.03%, and at ultimate load, the value increased about 45.28%. The steel tensile values of beam “B8” at cracking load higher by about 49.09%, and at ultimate load was increased about 47.37%

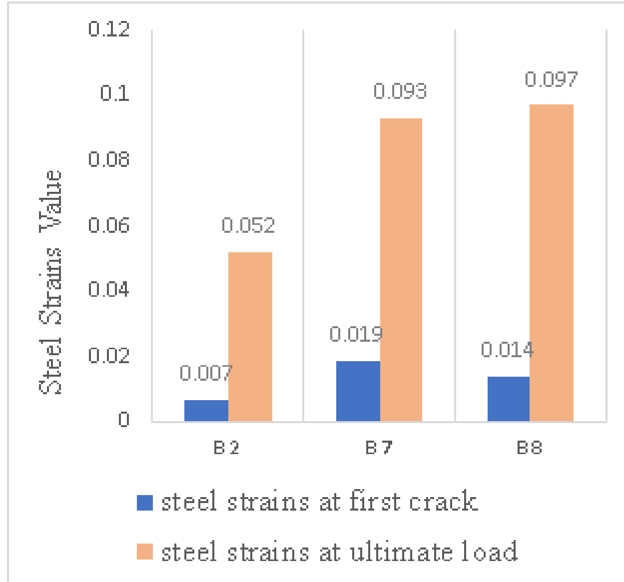


Fig.24: steel tensile strain values for beamsUsing BFRP strips at Mid – Span of Beams

IV. CONCLUSIONS

1. The high value of the tensile strength and modulus of elasticity of CFRP strips resulted in delaying the initiation of cracks. For beam strengthened with (Two – Side) scheme, CFRP strips were cutoff in the same direction as the major crack. For beam strengthened with (U – Shape) scheme, the end of CFRP strips were separated from surface of beam resulting in cracks increased and failure.

2. Strengthening the beams with BFRP strips gave more strength around opening zone. BFRP strips characterized by good elongation, which gives the beams flexibility of load distribution, and this is shown at increase of cracks along the beams. Also, BFRP strips is characterized by high modulus of elasticity, which gave the beams an extra ability to strength the

load specially around opening zone. It was also good in its coherence with the surface of the beams.

3. For beams strengthened with CFRP strips, the cracking load for strengthening using (U – Shape) and (Two – Side) schemes are higher compared to the control beam (B2) by 43.54%, 52.97%, and the ultimate loads by 15%, 18.63% respectively.

4. For beams strengthened with BFRP strips, the cracking load for strengthening using (U – Shape) and (Two – Side) schemes are higher compared to the control beam (B2) by 24.60%, 32.86%, and the ultimate loads by 18.75%, 26.70% respectively.
5. Strengthening openings with CFRP is more effective in controlling the beams deflection at cracking loads.

6. Strengthening openings with BFRP is more effective in controlling the beams deflection at ultimate loads.

7. Strengthening openings with GFRP or CFRP causes a noticeable reduction in the relative tensile strain ratios.

8. Strengthening with (Two – Side) scheme is the best in reducing tensile strain values than strengthening with (U – Shape) scheme.

V. References

[1] Venice Fayed Ibrahim, Sherif M. Helmy, Nagy F. Hanna, And Nasr Z. Hassan, "Strengthening RC Beams with Openings That Created After Casting Using Synthetic Fibers. Helwan University, Cairo, Egypt 2007.

[2] Tamer El-Maadawy and Sayed Sherif ,Composite Structures, Volume 89, Issue 1, June 2009, Pages 60-69

[3] Lu, W.-Y., Yu, H.-W., Chen, C.-L., Liu, S.-L., Chen, T.-C., "High-Strength Concrete Deep Beams with Web Openings Strengthened by Carbon Fiber Reinforced Plastics", Computers and Concrete, 15 (1), Pp. 21-35. Cited 4 Times. 2015.

[4] Nasr Z.Hassan, Alaa G.Sherif, Amal H.Zamarawy, Finite element analysis of reinforced concrete beams with opening strengthened using FRP, Ain Shams Engineering JournalVolume 8, Issue 4, December 2015.

[5] Thabet, S.M., Osman, S.A., "Simulation Behavior of Flexure in Reinforced Concrete Beam with Opening Reinforced with Glass Fiber Reinforced Polymer (GFRP)", Materials Science Forum, 857, Pp. 421-425., 2016.

