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Study of the Behavior of Concrete Beams Reinforced with Different lap splice of FRP and conventional steel

Mohamed Atef Ghobashy[1], Amr Mohamed Hilal[2], Mohamed Abdel Razik Ibrahim[3]

[1]Assistant Lecture, Department of Engineering and Construction Technology, of Al-Obour Institute for Engineering and Technology, Kilo 31, Cairo-Ismailia Desert Road

[2]Professor of Structural Engineering, Department Faculty of Engineering, AL-AZHAR University, Egypt

[3]Professor of Structural Engineering, Department Faculty of Engineering, AL-AZHAR University, Egypt

ملخص البحث:

نظرا لوجود العناصر الخرسانية ذات البحور الكبيرة فتعتبير دراسة وصلات الاسياخ من المواضيع الهامة و نظرا لانتاج اسياخ باطوال محدده و ذلك بسبب مشكلة النقل و الطرق فلذلك نلجا لعمل وصلات فكان من الضروري دراسة سلوك تماسك وصلات الاسياخ مع الخرسانة و لانه يوجد دراسات محدوده تناقش هذه المشكلة . فكان من الضروري التركيز عليها و ذلك لانه من الاصعب استخدام القوانين الخاصة باسياخ حديد التسليح التقليدي و ذلك نظرا لاختلاف الخواص الميكانيكية لاسياخ الحديد التقليدي و اسياخ الفيبر . لذلك كان من الضروري دراسة سلوك التماسك بين وصلات اسياخ الفيبر البوليمرية في الكمرات الخرسانة و مقارنتها بوصلات حديد التسليح التقليدي و ذلك لفهم العوامل التي تؤثر علي سلوك قوة التماسك بين وصلات اسياخ الفيبر البوليمرية مع الخرسانة .
و من الملاحظ ان الكمرة الخرسانية المسلحة بحديد تسليح تقليدي و بها وصلة تساوي صفر استطاعت تحقيق 20 % من الحمل الاصلي للكمرة بدون و صلة و كذلك الوصلة 25 سم استطاعت تحقيق 88.4 % من الحمل الاصلي للكمرة بدون وصلة و ايضا الوصلة 40 سم استطاعت تحقيق نسبة من الحمل تكاد مساوية من الحمل الاصلي للكمرة بدون وصلة.و حيث ان الكمر الخرساني المسلحة باسياخ الفيبر(FRP) و بها وصلة تساوي صفر استطاعت تحقيق 17-20 % من الحمل الاصلي للكمر بدون وصلة و كذلك الوصلة 25 سم استطاعت تحقيق 58-66 % من الحمل الاصلي للكمر بدون وصلة و ايضا الوصلة 40 سم استطاعت تحقيق 68-82 % من الحمل الاصلي للكمر بدون وصلة.

Abstract :

Due to the presence of concrete elements with large spans, the study of bars lap splice is considered an important topic, due to the production of bars of specific lengths, due to the problem of transportation and roads, so we resorted to making lap splice. It was necessary to focus on them, because it is more difficult to use the laws of traditional steel bars, due to the different mechanical properties of traditional steel bars and fiber bars. Therefore, it was necessary to study the cohesion behavior between the lap splice of the fiber reinforced polymer in concrete beams and compare them with the lap splice of conventional steel reinforcement in order to understand the factors that affect the behavior of the cohesion strength between the lap splice of the fiber reinforced polymer with concrete.

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It is noted that the reinforced concrete beam with conventional rebar and with a lap splice equal to zero was able to achieve 20% of the original load of the beam without a lap splice, as well as the lap splice equal to 25 cm was able to achieve 88.4% of the original load of the beam without a lap splice, and also the lap splice equal to 40 cm was able to achieve a percentage of the load is almost equal to the original load of the beam without a lap splice. As the concrete beam, reinforced with fiber rods (FRP) and with a lap splice equal to zero, was able to achieve 17-20% of the original load of the beam without a lap splice, as well as the lap splice equal to 25 cm, it was able to achieve 58-66% of the original load of the beam without a lap splice and also a lap splice equal to 40 cm was able to achieve 82-68% of the original load of the beam without a lap splice.

It is noticeable that the behavior of a lap splices in conventional steel was better than that of fiber reinforced polymer. That is, a lap splices that were made in the fiber reinforced polymer need to be greater than the lengths of a lap splices in the conventional steel bars to be able to achieve equivalent ratios of load transfer.

1- Introduction:

Scientists sought in recent years to search for materials to replace traditional steel reinforcement, and for this reason, composite materials made from the of fibers with resin appeared, and they are called fiber reinforced polymer (FRP), and this research will study a comparison between three types of them, namely, Carbon fiber reinforced polymer (CFRP), basalt fiber reinforced polymer (BFRP) and glass fiber reinforced polymer (GFRP) rods and their comparison with conventional steel bar. And because of the concrete elements with large spans, it was necessary to use a lap splices in the reinforcing bars, and that is due to the production conditions and the method of transportation that force us to produce specific lengths, and because of the lack of research that studies the behavior of the a lap splices in the bars, it was necessary to focus on this study and make a comparison between the most famous Three types of fiber rods, and they are the most widely used at the present time, they are carbon , basalt and glass fibers, and they were compared with conventional steel bars, and three different lengths of a lap splices were studied and they are shown as follows :- (The first a lap splice equal to 0 , second a lap splice equal to 25 cm and the third a lap splice equal to 40 cm) .

2- Experimental program:

All tested specimens had the same cross-sectional dimensions, the beams had a rectangular cross section with a 120 mm width, 250mm height and the length of the beam was chosen to be 2000mm, with distance of 1800mm between the supports were tested in positive bending. The loading system was designed to produce a constant moment region in the middle of the beam specimen. Concrete used in all experimental work has a compressive strength 35N/mm^2 after 28 days.

As shown in table 1 and figure 1 the group (1, 2, 3 and 4) will be cast and experimentally tested in Two-point loading and these beams were tested to measure maximum load capacities and failure modes under static load. Group (1): It consists of four beams and the bars used is conventional steel bars, the first beam without a lap splice, and the remaining three beams with a lap splice of different lengths equal to (zero, 25cm and 40 cm). Group (2): It consists of four beams and the bars used is glass fiber reinforced polymer (GFRP), the first beam without a lap splice, and the remaining three beams with a lap splice of different lengths equal to (zero, 25cm and 40 cm).Group (3): It consists of four beams and the bars used is basalt fiber reinforced polymer (BFRP), the first beam without a lap splice, and the remaining three beams with a lap splice of different lengths equal to (zero, 25cm and 40 cm).Group (4): It consists of four beams and the bars used is carbon fiber reinforced polymer (CFRP), the first beam without a lap splice, and the remaining three beams with a lap splice of different lengths equal to (zero, 25cm and 40 cm).

Table 1: experimental program specimens

Groups	Term	Top RFT	Bottom RFT	Splice length
Group (1)	C-S	2Φ10 – steel bar	2Φ10 – steel bar	Without a lap splice
	(L.S-S-0)			0
	(L.S-S-25)			25
	(L.S-S-40)			40
Group (2)	C-G	2Φ10 – steel bar	2Φ10 – glass fiber	Without a lap splice
	(L.S-G-0)			0
	(L.S-G-25)			25
	(L.S-G-40)			40
Group (3)	C-B	2Φ10 – steel bar	2Φ10 – basalt fiber	Without a lap splice
	(L.S-B-0)			0
	(L.S-B-25)			25
	(L.S-B-40)			40
Group (4)	C-C	2Φ10 – steel bar	2Φ10 – carbon fiber	Without a lap splice
	(L.S-C-0)			0
	(L.S-C-25)			25
	(L.S-C-40)			40

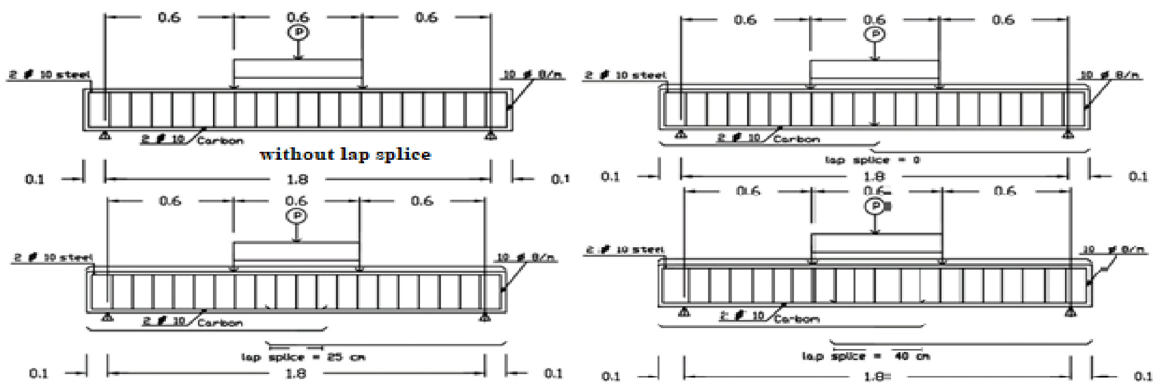

Figure 1: Specimen without lap splice and with lap splice (0,25 and 40 cm)

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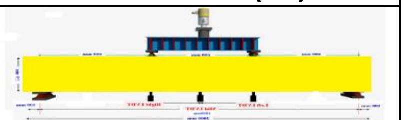
3- Comparison of the Group (1, 2, 3 and 4):

- **Ultimate Load:** According to Table 2 and Figure 2, the beam in which a lap splices were made of conventional steel bars with lengths (0-25-40) cm achieved a load transfer ratio ranging from 21-95% of the load resulting from the beam reinforced with conventional steel bars and without a lap splices. It is also noted that the beams in which a lap splices were made of different fiber bars (carbon - basalt - glass) with lengths (0-25-40) cm achieved a percentage of load transfer ranging from 20-82% of the load resulting from the beams are reinforced with different fiber bars (carbon - basalt - glass) and without a lap splices. It is noted that the length of a lap splice 40 cm in the fiber bars was not sufficient to transfer the entire load, unlike a lap splice of 40 cm in the conventional steel reinforcement. Therefore, it is noticeable that the behavior of a lap splices made of conventional reinforcing steel achieved better ratios in transferring loads than beams with a lap splice made of fiber rods of different types (carbon, basalt and glass).

As shown in Table 2, the beam with a lap splice of 40 cm and reinforced with fiber rods achieved higher loads than the beam reinforced with conventional steel rods and without a lap splice by 10-17%. This indicates the extent of the strength of the beam reinforced with fiber rods, even in the use of a lap splices. However, the lengths of a lap splices in the fiber should not be less than the lengths of a lap splices in steel. Also, the beams with (0-25) cm a lap splices and reinforced with fiber bars achieved loads almost equal to the loads resulting from the beams reinforced with conventional steel rebar with (0-25) cm a lap splices. Therefore, it is noticeable that the beams with a lap splice made of fiber rods or conventional steel rebar with short lengths are almost equal in transferring loads.

Table 2: The values and rates of increase in the values of ultimate load of specimens

Groups	Term	Ultimate load (KN)	Percentage increase of Ultimate capacity (%)
			
Group (1)	**C-S**	77.37	REF
	L.S-S-40	73.34	94.79%
	L.S-S-25	68.39	88.39%
	L.S-S-0	17.01	21.9%
Group (2)	**C-B**	110.6395	REF
	L.S-B-40	87.16	78.77%
	L.S-B-25	73.28	66.23%
	L.S-B-0	22.58	20.4%
Group (3)	**C-C**	133.577	REF
	L.S-C-40	90.94	68.08%
	L.S-C-25	78.331	58.64%
	L.S-C-0	23.3	17.44%
Group (4)	**C-G**	103.713	REF
	L.S-G-40	85.55	82.485
	L.S-G-25	68.86	66.39%
	L.S-G-0	21.49	20.72%

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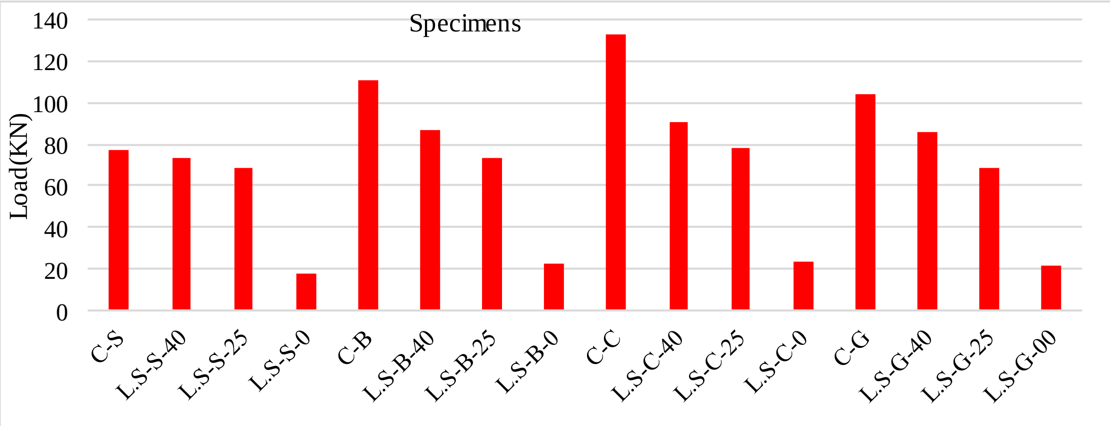

Figure 2: values of ultimate load of specimens

- **Deflection Behavior:**

It is noticeable that the use of FRP rods significantly increases the deflection of the samples. According to Table 3 and Figure 3, the beam in which a lap splices were made of conventional steel bars with lengths (0-25-40) cm achieved a deflection ratio ranging from 4.9-57.12% of the deflection resulting from the beam reinforced with conventional steel bars and without a lap splices. It is also noted that the beams in which a lap splices were made of different fiber bars (carbon - basalt - glass) with lengths (0-25-40) cm achieved a percentage of deflection ranging from 3-75% of the deflection resulting from the beams are reinforced with different fiber bars (carbon - basalt - glass) and without a lap splices. Figures 4, 5, 6 and 7 shows the failure shapes of all specimens.

Table 3: The values and rates of increase in the values of deflection at three points in the specimen's

Term	Deflection-left		Deflection-mid		Deflection-right	
	Value(mm)	Rate %	Value (mm)	Rate %	Value (mm)	Rate %
C-S	15.9462	Ref	20.70158	Ref	15.3083	Ref
L.S-S-40	9.11	57.12%	9.889	47.75	8.645	56.47%
L.S-S-25	6.892	43.22%	7.5414	36.425	6.6473	43.42%
L.S-S-0	.7841	4.91%	.8978	4.335	.76881	5.025%
C-B	41.126	Ref	48.037	Ref	40.298	Ref
L.S-B-40	23.98	58.30%	25.97	54.065	23.21	57.595
L.S-B-25	17.71	43.06%	19.26	40.09%	17.18	42.635
L.S-B-0	1.253	3.04%	1.5045	3.13%	1.228	3.047%
C-C	26.4727	Ref	30.1206	Ref	25.7636	Ref
L.S-C-40	13.05	49.29%	14.369	47.70%	12.645	49.08%
L.S-C-25	11.269	42.565	12.742	42.30%	10.959	42.53%
L.S-C-0	1.3708	5.17%	1.698	5.63%	1.343	5.21%
C-G	35.19	Ref	41.71	Ref	34.43	Ref
L.S-G-40	26.276	74.66%	28.606	68.58%	25.622	74.415
L.S-G-25	18.294	51.98%	20.578	49.335	17.804	51.71%
L.S-G-0	1.1028	3.13%	1.2676	3.03%	1.08088	3.13%

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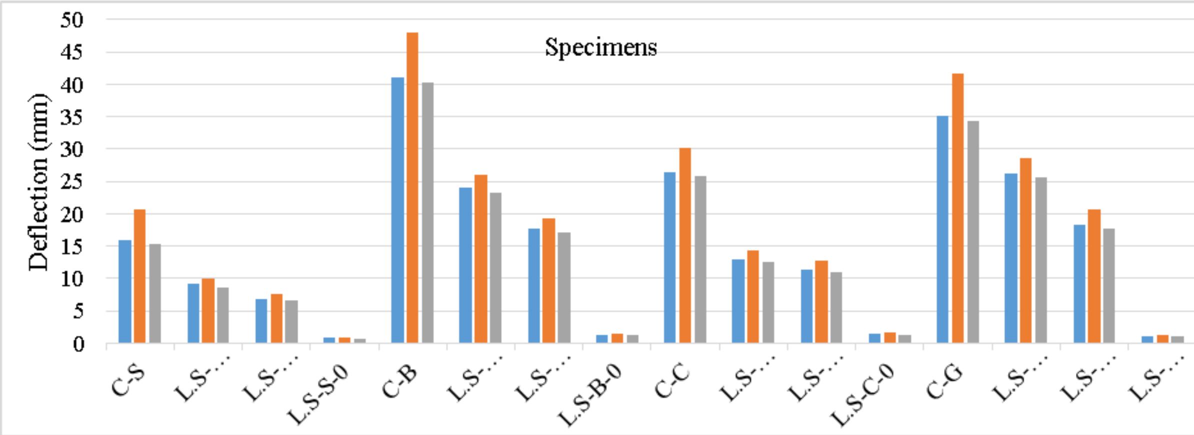

Figure 3: Effect of deflection on the beams

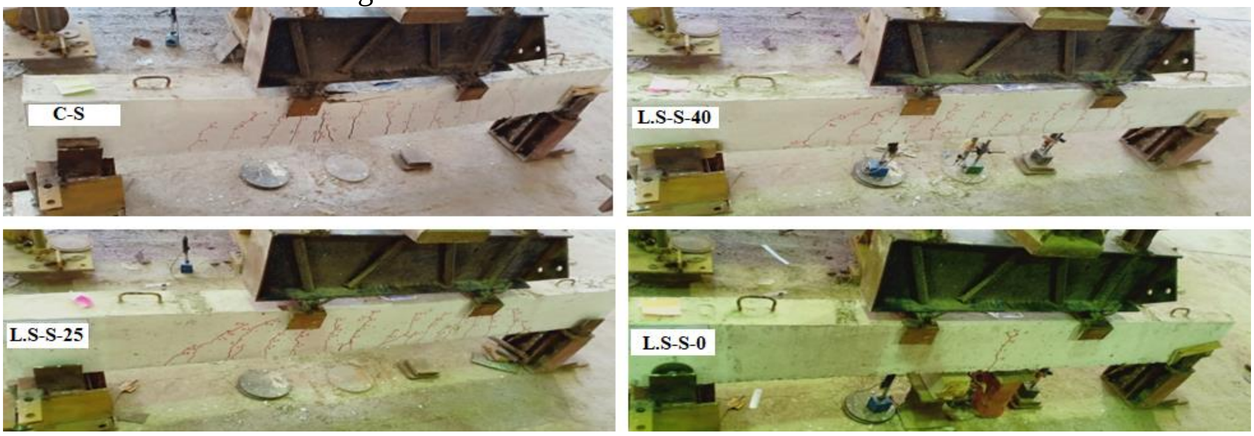

Figure 4: Cracks pattern and failure mode of the beam reinforced conventional steel without lap splice and with lap splices (0,25 and 40)

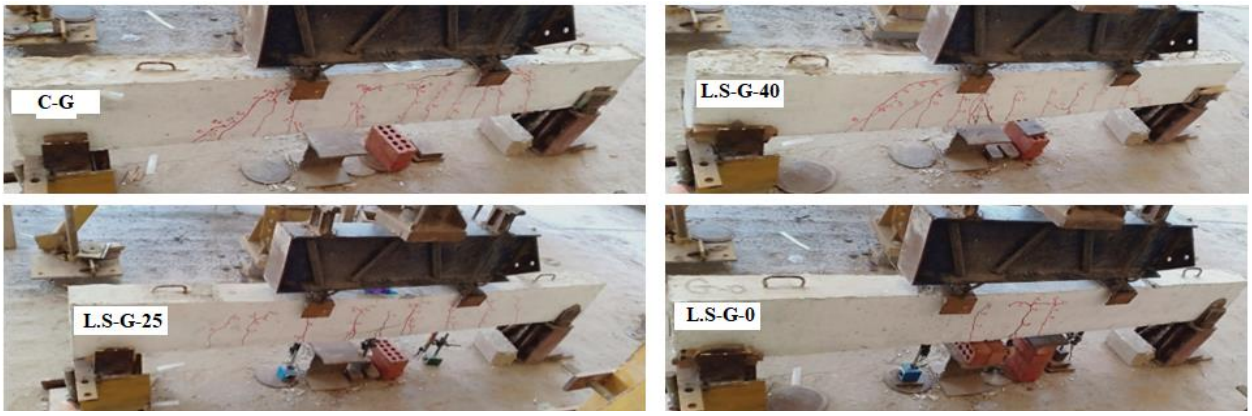

Figure 5: Cracks pattern and failure mode of the beam reinforced GFRP without lap splice and with lap splices (0,25 and 40)

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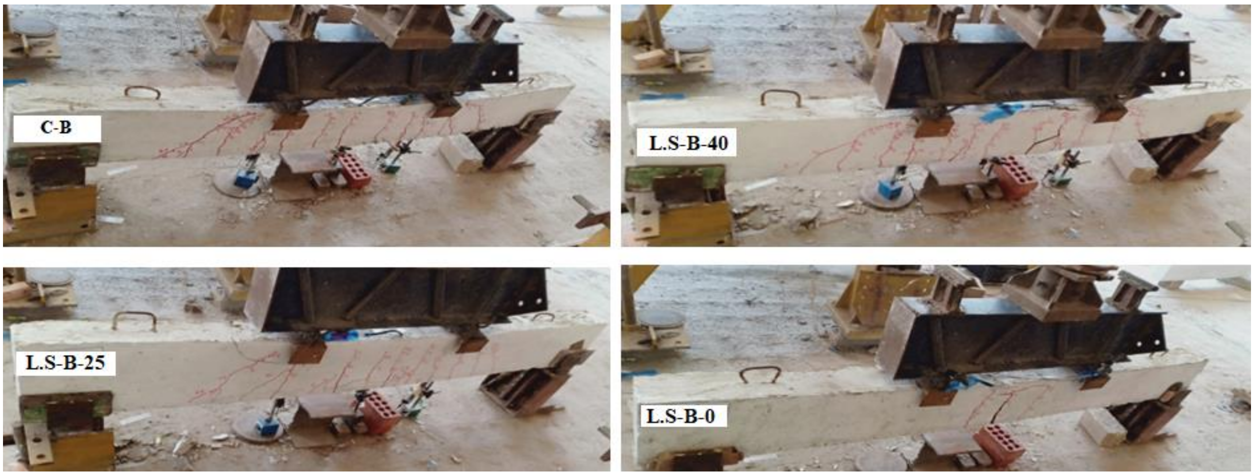

Figure 6: Cracks pattern and failure mode of the beam reinforced BFRP without lap splice and with lap splices (0,25 and 40)

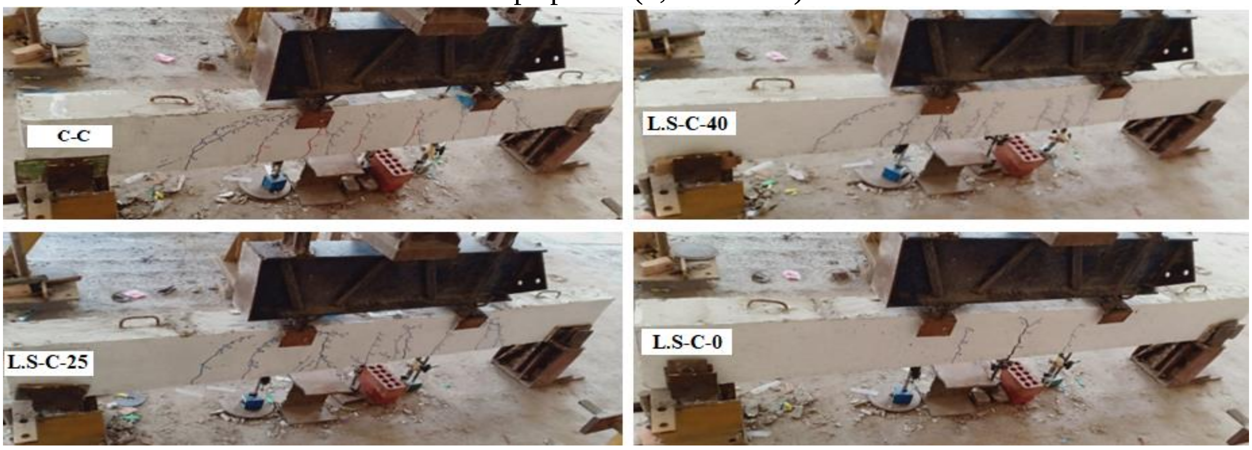

Figure 7: Cracks pattern and failure mode of the beam reinforced CFRP without lap splice and with lap splices (0,25 and 40)

- **Strain behavior**

Strain of bars

The values of strain in tensile reinforcement as shown in figure 8 and table 4 for specimens' groups (1,2,3,4). beams (C-B and C-G) the maximum strain in tensile reinforcement. And that the least strain occurred in the beams reinforced with carbon-fiber rods. As the strain produced in the beams in the beams with a lap splices, whether they were made of fiber rods or conventional steel, achieved a percentage that did not exceed 70% of the strain produced in the bars in the beams without a lap splice.

Strain of concrete.

The values of strain in concrete as shown in figure 9 and table 4 for specimens' groups (1,2,3,4). beams (C-B and C-C) the maximum strain in concrete. And since the strain produced in the concrete in the beam with a lap splices, whether it was made of fiber rods or conventional steel reinforcement, it achieved a percentage that did not exceed 55% of the strain produced in the concrete in the beam without a lap splices.

Table 4: values and rates of increase for strain in bars of specimens

Groups	Term	Strain of bars	Strain of concrete	Ratio of strain bars	Ratio of strain concrete
Group (1)	**C-S**	.017708	.002395	Ref	
	L.S-S-40	.011816	.001209	66.72%	50.48%
	L.S-S-25	.0096610	.001191	54.55%	49.72%
	L.S-S-0	.0004639	.000292	2.61%	12.19%
Group (2)	**C-B**	.0196759	.002871	Ref	
	L.S-B-40	.014096	.001601	71.64%	55.76%
	L.S-B-25	.0113619	.00145	57.74%	50.50%
	L.S-B-0	.0008490	.000474	4.31%	16.50%
Group (3)	**C-C**	.01321	.0028998	Ref	
	L.S-C-40	.00672	.001346	50.87%	46.41%
	L.S-C-25	.005586	.001175	42.28%	40.52%
	L.S-C-0	.0005076	.000571	3.84%	19.69%
Group (4)	**C-G**	.0196759	.002713	Ref	
	L.S-G-40	.0131886	.001348	67.02%	49.68%
	L.S-G-25	.011714	.001275	59.53%	46.99%
	L.S-G-0	.0007871	.000405	4.005	14.92%

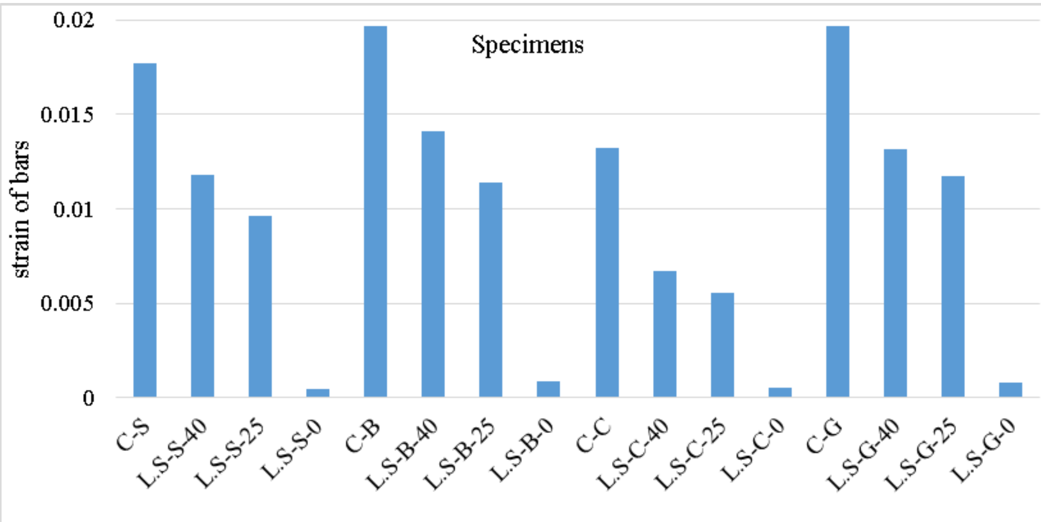

Figure 8:Strain of bars in all specimens

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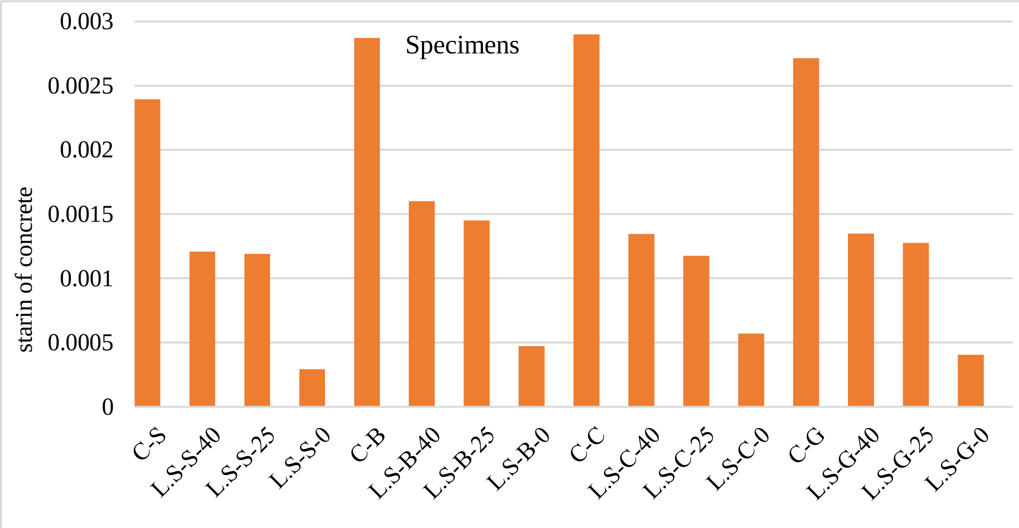

Figure 9: Strain of concrete in all specimens

4- CONCLUSIONS:

- **Group (1):** Where it was found that the maximum load in the beam with a lap splice equal to 0 cm was able to reach 21% of the maximum load of the control beam. Also, the maximum load in the beam with a lap splice equal to 25 cm was able to reach 88.4% of the maximum load of the control beam. As for the maximum load in the beam with a lap splice equal to 40 cm, it is almost the equal of the maximum load of the control beam. Also, there was a loss in deflection with a rate ranging from 52.24-95.5%.

- **Group (2):** Where it was found that the maximum load in the beam with a lap splice equal to 0 cm was able to reach 20.4% of the maximum load of the control beam. Also, the maximum load in the beam with a lap splice equal to 25 cm was able to reach 66.23% of the maximum load of the control beam. As for the maximum load in the beam with a lap splice equal to 40 cm, it was able to reach 78.88% of the maximum load of the control beam. Also, there was a loss in deflection with a rate ranging from 45-96 %.

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- **Group (3):** Where it was found that the maximum load in the beam with a lap splice equal to 0 cm was able to reach 17.74% of the maximum load of the control beam. Also, the maximum load in the beam with a lap splice equal to 25 cm was able to reach 58.64% of the maximum load of the control beam. As for the maximum load in the beam with a lap splice equal to 40 cm, it was able to reach 68.08% of the maximum load of the control beam. Also, there was a loss in deflection with a rate ranging from 40-94 %.

- **Group (4):** Where it was found that the maximum load in the beam with a lap splice equal to 0 cm was able to reach 20% of the maximum load of the control beam. Also, the maximum load in the beam with a lap splice equal to 25 cm was able to reach 66.3% of the maximum load of the control beam. As for the maximum load in the beam with a lap splice equal to 40 cm, it was able to reach 82.49% of the maximum load of the control beam. Also, there was a loss in deflection with a rate ranging from 30-96 %.

- It is noted that the ability of the conventional steel bars in a lap splice was more efficient than the different fiber rods (FRP), as it achieved a percentage of load transfer ranging from 21-95%, unlike the fiber rods (FRP), which managed to achieve a percentage ranging from 17.74-82.49%.

- It is noted that the maximum strain on the reinforcing bars occurred in the beam C-B and C-G, and the lowest strain in the reinforcing bars occurred in the beam C-C. And a lap splice in the reinforcing bars significantly affected the values of the resulting strain in the reinforcing bars, as it did not exceed 70% of the actual values. And since the strain produced in the concrete in the beam with a lap splices, whether it was made of fiber rods or conventional steel reinforcement, it achieved a percentage that did not exceed 55% of the strain produced in the concrete in the beam without a lap splices.

- In the beam with a lap splices, it was noticed that the failure occurs at a lap splice location.

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5- REFERENCES:

[1] Grace NF, Sayed GA, Soliman AK, Saleh KR. Strengthening reinforced concrete beams under fiber-reinforced polymer (FRP) laminates. ACI Struct J 1996; 96(5):865–75.

[2] Triantafillou TC. Shear strengthening of reinforced concrete beams using epoxy-bonded FRP composites. ACI Struct J 1998;95(2):107–15.

[3] Deniaud C, Cheng JJR. Reinforced concrete T-beams strengthened in shear with fiber-reinforced polymer sheets. J Compos Constr, ASCE 2003;7(4): 302–310.

[4] Buyukozturk O, Gunes O, Karaca E. Progress in understanding debonding problems in reinforced concrete and steel members strengthened using FRP composites. Const Build Mater 2004;18:9–19.

[5] Greco F, Nevone Blasi P, Lonetti P. An analytical investigation of debonding problems in beams strengthened using composite plates. Eng Fract Mech 2007;74(3):346–72.

[6] Bruno D, Carpino R, Greco F. Modelling of mixed mode debonding in FRP reinforced beams. Compos Sci Technol 2007;67:1459–74.

[7] Hollaway L. Glass reinforced plastics in construction: engineering aspects. John Wiley & Sons; 1978.

[8] Aiello MA, Ombres L. Load-deflection analysis of FRP-reinforced concrete flexural members. J Compos Constr, ASCE 2000;4(4):164–71.

[9] Peece M, Manfredi G, Cosenza E. Experimental response and code models of GFRP RC beams in bending. J Compos Constr, ASCE 2000;4(4):182–90.

[10] Rizkalla SH, Nanni A. Field applications of FRP reinforcement: case studies. American Concrete Institute (ACI) special publication SP-215; 2003.

[11] Kamal M, Safaan M, Al-Gazzar M. Ductility of concrete beams reinforced with hybrid FRP rebars. HBRC J, Hous & Build Res Cent 2006;2(3):1–12.

[12] Ashour AF. Flexural and shear capacities of concrete beams reinforced with GFRP bars. Constr Build Mater 2006;20:1005–15.

[13] Naaman AE, Jeong SM. Structural ductility of concrete beams prestressed with FRP tendons. In: Proceedings, 2nd int. RILEM symp. FRPRXS-2. Non-metric (FRP) Rienforcement for concrete structures. RILEM. 1995. p. 379–86.

[14] Militky, J.K., 1996. Ultimate Mechanical Properties of Basalt Filaments.