

DUCTILITY OF STRENGTHENED R.C BEAMS WITH LAP SPLICES

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Abstract

Studying the ductility of strengthened reinforced concrete beams with varying lap splices is very important for the development of the structural behavior of RC beams. When reinforcement is spliced together within a concrete beam, it is necessary to overlap the bars long enough to transfer the tensile stresses between spliced bars without inducing a pullout failure in the concrete. Most design codes allow the use of bars with lap splice and specify minimum length of the lap as well as the required transverse reinforcement. The objective of this research is to study the behavior of reinforced concrete simply-supported beams with lap splice at tension reinforcement. The tension reinforcement of these beams will be spliced at different locations, with different numbers of lap spliced bars and by using different percentages of reinforcement. Transversal FRP strips will be used to strengthen the RC beams with different lap splice types in order to improve their ductilities. Each of glass and carbon fiber will be used to fabricate the FRP strips. This study concludes that FRP wrapping provided greater ease of application, make beams more ductility.

Arabic Abstract

دراسة ممطولية الكمرات المسلحة ذات وصلات التراكب التي تم تقويتها او اعادة اصلاحها هام جدا لتحسين السلوك الانشائي للكمرات الخرسانية المسلحة. يجب مراعاة طول التداخل المطلوب بين وصلات الحديد بحيث يكون طول التداخل كافي لانتقال اجهادات الشد بين الاسياخ الموصولة دون حدوث انهيار مفاجئ بالخرسانة. كما تم الأخذ في الاعتبار طول الوصلة طبقا للذي ينص عليه الكود. الهدف من هذا البحث هو دراسة سلوك الكمرات الخرسانية المسلحة بسبب الارتكاز ذات وصلات التراكب في منطقه لشد. هذه الكمرات سوف يتم وصل حديد التسليح في منطقة الشد في اماكن مختلفة وسيتم وصل عدد مختلف من اسياخ التسليح وباستخدام نسب مختلفة من حديد التسليح. تم استخدام الالياف المسلحة بالبوليمرات لتقوية واعادة اصلاح هذه الكمرات بغرض تحسين ممطوليتها. كل من الكربون والزجاج سيتم استخدامها لتصنيع شرائح الالياف المسلحة بالبوليمرات.

Keywords: ductility; FRP; lap splices; tensile stresses; transverse reinforcement; tension reinforcement; strengthen.

1. INTRODUCTION

Studying the ductility of strengthened reinforced concrete beams with lap splices is very important for the development of the structural behavior of RC beams. When reinforcement bars are spliced together within a concrete beam, it is necessary to overlap the bars long enough to transfer the tensile stresses between spliced bars without inducing a pullout failure in the concrete. Most design codes allow the use of bars with lap splice. They specify the minimum length of the overlap as well as the required transverse reinforcement. Ductility may be defined as the ability to under-go deformation without a substantial reduction in the capacity of the

member. The curvature ductility factor is a fair more meaningful index for ductility demand, that is because, once plastic hinge has commenced in the structure, the deformation concentrated at the plastic hinge position is caused by the rotation of the plastic hinge. The fundamental information needed by the designer concerns the required member section behavior at the plastic hinge expressed by the curvature ductility factor and its variation with the type of steel used and ratio of compression reinforcement [1].

Fiber reinforced polymer (FRP) materials have been increasingly used in the last two decades to improve various structural characteristics of reinforced concrete

(RC) bridges, buildings and other structures. Ductility of the resulting FRP–concrete system plays an important role in structural performance, especially in certain applications such as earthquake resistant structures, where ductility and energy dissipation play a vital role [2].

Fiber reinforced polymer (FRB) reinforcement has been used over the last few years in the form of laminates, sheets and strips for repair of concrete structures. The non-corrosive characteristics and good fatigue properties of CFRP, significantly, increase the service life of structure. The high strength and low weight of FRB makes it feasible compared to conventional materials used in repair [3].

This research studies the behavior of simply-supported reinforced concrete beams with lap splices at the tension reinforcement. The tension reinforcement of these beams will be spliced at different locations, with different number of lap spliced bars and by using different percentages of reinforcement. Transversal FRP strips will be used to strengthen the RC beams in order to improve their ductility. Both of glass and carbon fiber will be used for the FRP strips.

2. EXPERIMENTAL PROGRAM

2.1 TESTED SPECIMENS

In this paper test specimens were fabricated to investigate ductility of strengthened RC beams with lap splices with CFRP and GFRP wrapping. The results obtained from an experimental investigation on 18 reinforced concrete beams. The test program includes: Casting of beams (120 x 250 x 3200 mm), strengthening beams specimens by wrapping with CFRP and GFRP strips. Table.1.shows the eighteen simply supported reinforced concrete beams of the test program.

The program included sixteen beams, the internal longitudinal tensile steel reinforcement consisted of four 12mm diameter bars at the bottom ($f_y = 360 \text{ N/mm}^2$), two 10 mm diameter bars at the top of the beam ($f_y = 245 \text{ N/mm}^2$), and 8-mm diameter stirrups at 200 mm ($f_y = 245 \text{ N/mm}^2$). One beam consisted of three 12mm diameter bars at the bottom tensile steel reinforcement. One beam consisted of two 12mm diameter bars at the bottom tensile steel reinforcement.

Fig.1. shows the dimensions and details of beams reinforcement.

2.2 MATERIAL PROPERTIES

The test specimens used in the program were normal strength concrete using local materials. The materials used in casting the reinforced concrete models were clean sand, graded gravel, water, steel reinforcement, and cement. The specified 28-day cube strength was 31 ($f_{cu} = 31 \text{ N/mm}^2$) with a maximum aggregate size of 10 mm. The cement used in all specimens was ordinary Portland cement, while the materials used for repair or strengthening were glass fiber reinforced polymers GFRP and epoxy or carbon fiber reinforced polymers CFRP and epoxy. The properties of these materials were determined from tests carried out according to the standard specifications. The amount of water added was calculated to adjust the water cementing ratio to 0.55. The yield strength and the ultimate strength of the main reinforcing were 360 N/mm^2 . The Glass (GFRP) sheets used in beams had an ultimate strength of 2250 N/mm^2 , an elasticity modulus of 70000 N/mm^2 , and an ultimate elongation of 2.9%. The Carbon (CFRP) sheets used to strengthen the beams had an ultimate strength of 3500 N/mm^2 , an elasticity modulus of 230000 N/mm^2 , an ultimate elongation of 1.6% and had a thickness of 0.13 mm.

2.3 DESIGN OF TEST PROGRAM

The variables of the test program and the symbols will be used to describe the conditions of beams were the following:

The percentage of tension reinforcement:

- a) Four bars with 12 mm diameter (A).
- b) Three bars with 12 mm diameter (B).
- c) Two bars with 12 mm diameter (C).

The number of lap spliced bars which varied from:

- Zero (all bars are continuous) (0).
- One (one spliced bar and others are continuous) (1).
- Two (two spliced bars and others are continuous) (2).
- Three (three spliced bars and one is continuous) (3).
- Four (four bars are spliced) (4).

The number of layers of FRP strips:

- One layer (i).
- Three layers (iii).

Fiber type:

- Glass (G).
- Carbon (C).

Reinforcement lap spliced at different location of the same RC beam (D).

Group (1)

Contains four control beams (A0, A1, A2, and A4) the number of lap spliced bars varied from 0 to 4 bars as reference, and reinforced with four bars in tension zone, as shown in Fig.1.a. The difference between the tested beams was the number of lap spliced bars.

Group (2)

Contains six beams (AGI1, AGI2, AGI4, AGIII1, AGIII2, and AGIII4) with spliced bars varied from 1 to 4, reinforced with four bars in tension zone and strengthened with one or three layers of glass fiber is showed in Fig.1.b. The difference between the tested beams was the number of layers of FRP strips and the number of lap spliced bars. For one layer of glass fiber reinforced polymers the distance between strips was 50 mm and the width of the strip is 50 mm. For the three layers of glass fiber reinforced polymers the distance between the strips was 50 mm and the width of the strip was 50 mm.

Group (3)

Contains three beams (ACIII1, ACIII2, and ACIII4) with lap splices, varying from 1 to 4 bars, reinforced with four bars in tension zone and strengthened with three layer of carbon fiber , the distance between the strips was 50 mm and the width of the strip was 50 mm as shows in Fig.1.c. The difference between the tested beams was the number of lap spliced bars.

Group (4)

Contains three beams (AD4, AGID4, and AGIIID4) with lap splices at different places, reinforced with four bars in the tension zone and strengthened with GFRP strips is showed in Fig.1.d. The difference between the tested beams was the number of layers of FRP strips.

Group (5)

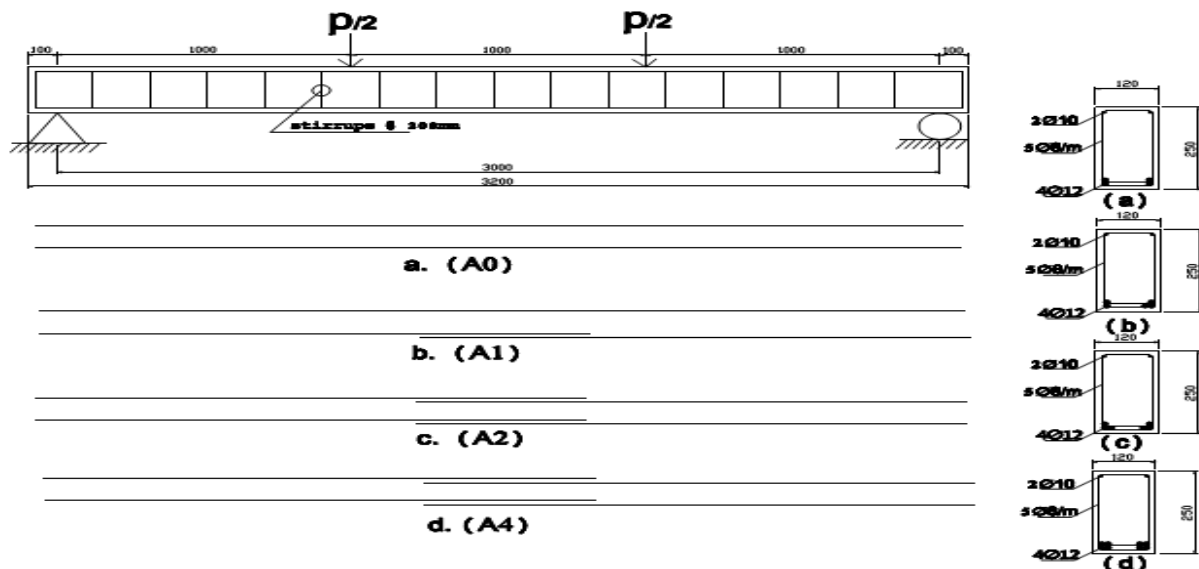
Contains two beams (BGIII3 and CGIII2) with lap splices, strengthened with three layers of GFRP strips , the distance between strips was 50 mm and the width of the strip was 50 mm, spliced 100% of the reinforce-

ment, as shows in Fig.1.e. The difference between the tested beams was the reinforcement ratio.

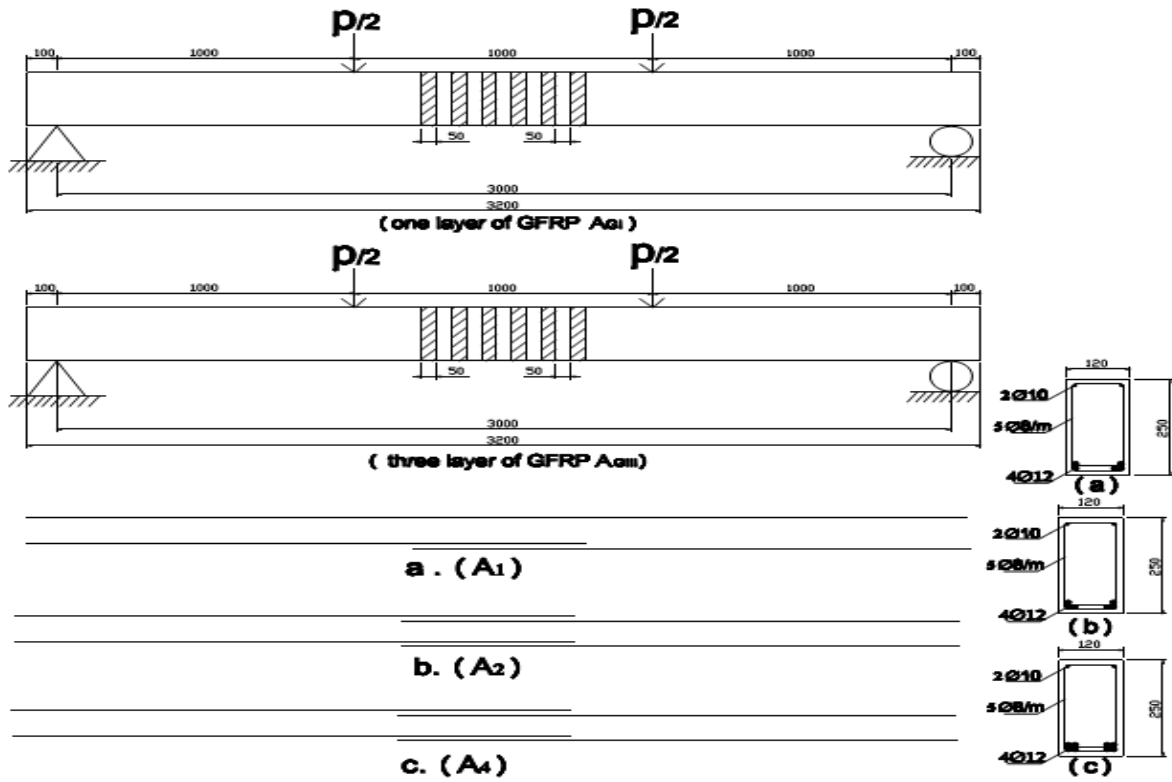
2.4 THE TECHNIQUE OF REPAIR AND STRENGTHENING OF REINFORCED CONCRETE BEAMS

The CFRP sheets, GFRP sheets used in the study were from Sika Company. The epoxy resin used had two components A and B that were mixed in 4:1 ratio by weight for wrapping the carbon and glass fiber sheets onto the concrete. The samples are air dried prior to the application of FRP wraps. The concrete surface was grinded and cleaned to expose the aggregates for proper application of FRP sheets. A grinder was used for rounding off the sharp corners and removing local unevenness from the surfaces. Once the concrete surface was prepared, epoxy resin was placed on the concrete surface. Then the FRP strips were placed using a steel roller, as shown in Fig. 2.

Five control beams were considered (A0, A1, A2, A4, and AD4), these beams were not strengthened. Beam specimen AD4 had lap splice in different location. The studied parameters are given in Table.1. Four beams were strengthened with one layer of fiber reinforced polymers, the distance between strips was 50 mm and the width of the strip was 50 mm. nine beams were strengthened by three layers of fiber reinforced polymers the distance between strips was 50 mm and the width of the strip was 50 mm.



(a) Group. 1.



(b) Group 2.

(c) Group 3.

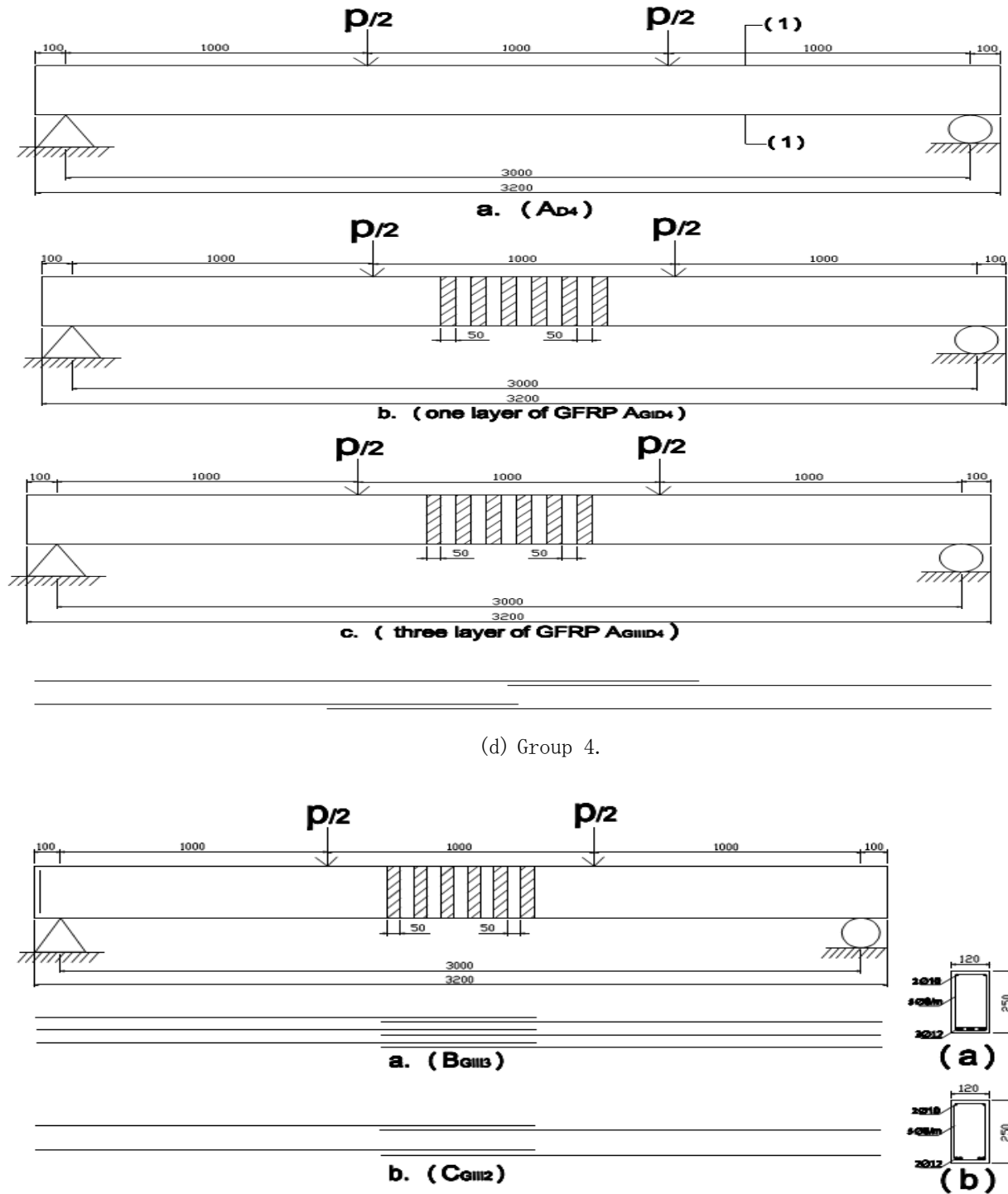


Fig.1: Dimensions and details of reinforcement of the beams specimens.



Fig. 2: Beams after strengthening.

Table (1): The experimental test program and strengthening technique.

Group	Beam	Main reinforcement	No. of lap spliced bars	Lap spliced bars	Strengthening technique	
1	Group 1	A ₀	4 ϕ 12	0		—————
2		A ₁	4 ϕ 12	1		—————
3		A ₂	4 ϕ 12	2		—————
4		A ₄	4 ϕ 12	4		—————
5	Group 2	A _{G1}	4 ϕ 12	1		 One layer of GFRP strips
6		A _{G2}	4 ϕ 12	2		 One layer of GFRP strips
7		A _{G4}	4 ϕ 12	4		 One layer of GFRP strips

8		A_{GIII1}	4 ϕ 12	1		
9		A_{GIII2}	4 ϕ 12	2		
10		A_{GIII4}	4 ϕ 12	4		
11	Group 3	A_{CIII1}	4 ϕ 12	1		
12		A_{CIII2}	4 ϕ 12	2		
13		A_{CIII4}	4 ϕ 12	4		
14	Group 4	A_{D4}	4 ϕ 12	4	0.35 L, 0.65 L	
15		A_{GID4}	4 ϕ 12	4	0.35 L, 0.65 L	 One layer of GFRP strips
16		A_{GIID4}	4 ϕ 12	4	0.35 L, 0.65 L	
17	Group 5	B_{GIII3}	3 ϕ 12	3		
18		C_{GIII2}	2 ϕ 12	2		

Note: lap splice length 550 mm, bars spliced at 0.5 L otherwise mentioned.

All beams strengthened by three layers of FRP otherwise mentioned.

2.5 TEST SETUP AND TESTING PROCEDURE

The test set-up used in this research consisted of rigid steel frames supported by the laboratory's rigid floor in the Reinforced Concrete Laboratory at the Faculty of Engineering, Banha University as shown in Fig.3. All the beams were tested under positive bending.

The load was applied through a mechanical screw jack and was transferred to the tested beam through a steel spreader beam which was supported on two steel rollers covering the entire width of the beam to provide 2 concentrated load, as shown in Figs 3,4. The load was measured using electrical load cell under the screw

jack, of maximum capacity 1000 KN, as shown in Fig.3. The distance between the two applied loads was 1000 mm.

The deflections were measured by three linear variable differential transformers (LVDTs). Two of the LVDTs were placed under the two load points and the third one was under the beam at mid span. The strain on the lap spliced bar was measured. The rotation was measured by two LVDTs. This was done by subtracting the two readings of these LVDTs and dividing the result by the distance between the two LVDTs, as shown in Fig.3.

The load cell and the six LVDTs were connected to a data system for recording.



Fig.3: The test set-up.



(a) Steel spreader beam and electrical load cell.



(b) Mechanical screw jack.

Fig.4: Loading system

3. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results including ultimate loads, corresponding deflection at mid-point, corresponding Final Ductility Factor and failure modes for the beam specimens are summarized in Table 2. The results obtained from these tests are analyzed in the following.

3.1 ULTIMATE LOAD

The ultimate capacity (P_u) of each beam was determined by the peak load attained during loading test. The data collected to determine the increasing of the ultimate capacity of beams due to strengthening beams with CFRP and GFRP.

3.1.1 THE EFFECT OF NUMBER OF LAP SPICED BARS

Fig.5 shows the relation between the ultimate load and the percentage of spliced bars for the tested beam specimens A0, A1, A2, and A4. The ultimate load of the beam specimens A0, A1, A2, and A4 were 81 KN, 80 KN, 79 KN, and 72 KN respectively. This means that the beam specimens A1, A2, and A4 achieved an ultimate load of 98.76%, 97.5 %, and 88.89% respectively of that of the control beam specimen A0. It is clear that as the number of lap spliced bars increased the ultimate load decreased.

3.1.2 COMPARE BETWEEN STRENGTHENING BY ONE LAYER OF GFRP AND THREE LAYERS OF GFRP

Fig.6 shows the ultimate load for the different strengthened beam specimens with different number of glass fiber reinforced polymer strips in lap splice zone with different number of lap spliced bars.

It is clear that as the number of lap spliced bars increased the ultimate load decreased. The ultimate load of beam specimens AGIII1, AGIII2, and AGIII4 strengthened with three layers of glass fiber strips were higher than that of beam specimens AGI1, AGI2, and AGI4 strengthened with one layer of glass fiber strips by 104.76%, 102.44%, and 102.6% respectively. The ultimate load of beam specimens AGIII1, AGIII2, and AGIII4 strengthened with three layers of glass fiber strips were higher than that of beam specimens A1, A2, and A4 by 110%, 106.33%, and 109.7% respectively. The ultimate load of beam specimens AGI1, AGI2, and AGI4 strengthened with one layer of glass fiber strips were higher than that of beam specimens A1, A2, and A4 by 105%, 103.8%, and 106.94% respectively.

3.1.3 COMPARE BETWEEN STRENGTHENING BY GFRP AND CFRP

Fig.7 shows the ultimate loads for the different strengthened beam specimens with different type of fiber reinforced polymer in lap splice zone with different number of lap spliced bars. The ultimate load of beam specimens ACIII1, ACIII2, and ACIII4 were 86 KN, 81 KN, 77 KN respectively. Beam specimens ACIII2, and ACIII4 achieved an ultimate load of 94.2 % and 89.4% of that of beam specimen ACIII1 respectively.

It is clear that as the number of lap spliced bars increased the ultimate load decreased. The ultimate loads of beam specimens AGIII1, AGIII2, and AGIII4 which strengthened with glass fiber were higher than that of beam specimens ACIII1, ACIII2, and ACIII4 strengthened with carbon fiber by 102.4%, 103.7%, and 102.6% respectively. The ultimate load of the beam specimens AGIII1, AGIII2, and AGIII4 strengthened with glass were higher than that of the beam specimens A1, A2, and A4 by 110%, 106.33%, and 109.7% respectively. The ultimate load of the beam specimens ACIII1, ACIII2, and ACIII4 strengthened with carbon fiber were higher than that of beam specimens A1, A2, and A4 by 107.5%, 102.53%, and 106.94% respectively.

3.1.4 THE EFFECT OF LAP SPlice LOCATION

Fig.8 shows the ultimate load for the different strengthened beam specimens with different number of glass fiber reinforced polymer layers in lap splice zone with lap spliced bars in different places or at the same place. The ultimate load of beam specimens A4D, AGI4D, and AGIII4D were 74 KN, 80 KN, 83 KN respectively. Beam specimens AGI4D, and AGIII4D achieved an ultimate load of 111 % and 115.3% of that of beam specimen A4D respectively.

It is clear that when we changed the place of lap splice the ultimate load increased. The ultimate load of beams specimens A4D, AGI4D, and AGIII4D which we changed the place of lap splice were higher than that of beams specimens A4, AGI4, and AGIII4 which we spliced 100% of the bars by 102.78%, 103.9%, and 105.1% respectively. The ultimate load of beam specimen AGIII4D strengthened with three layers of glass fiber strips and spliced its bars in different places was higher than that of beam AGI4D strengthened with one layer of glass fiber strips by 103.75%. The ultimate load of beam AGI4D strengthened with one layer of glass fiber strips was higher than that of beam specimens A4D by 108.1%.

3.1.5 THE EFFECT OF PERCENTAGE OF TENSION REINFORCEMENT

Fig.9 shows the ultimate load of beam specimens AGIII4, BGIII3, and CGIII2 with spliced 100% of reinforcement was 79 KN, 68 KN, and 41 KN respectively. Beam specimens AGIII4 and BGIII3 achieved 187.8 %

and 165.85% of that of beam specimen CGIII2 respectively.

It is clear that as the percentage of tension reinforcement increased the ultimate load increased. For splicing 100% of the reinforcement, the decreasing of percentage of spliced reinforcement in beam specimens the increasing of ultimate load.

Table 2: Experimental results specimens

Tested beam		Ultimate Load Pu (KN)	Deflection at mid-point at max load.	Deflection at Py (mm)	Deflection at 80% Pu (mm)	Final Ductility Factor	Mode of Failure
Group1	A0	81	34.2	20	47	2.350	Flexure tension
	A1	80	30.4	17	38	2.235	Flexure comp-
	A2	79	26.1	16	35	2.188	Splitting
	A4	72	22.5	18	30	1.667	Splitting
Group2	AGI1	84	38.2	17	51	3.000	Debonding
	AGI2	82	36.8	18	49	2.722	Debonding
	AGI4	77	32.5	18	44	2.444	Debonding
	AGIII1	88	30.4	16	44	2.750	Flexure tension
	AGIII2	84	29.2	18	41	2.278	Flexure tension
	AGIII4	79	28.3	18	40	2.222	Flexure tension
Group3	ACIII1	86	36.4	17	50	2.941	Flexure tension
	ACIII2	83	34.2	18	46.5	2.583	Flexure tension
	ACIII4	77	30.8	18	41	2.278	Flexure tension
Group4	AD4	72	22.4	16	27	1.688	Splitting
	AGID4	80	40.3	16	51	3.188	Debonding
	AGIIID4	83	44.3	16	54	3.375	Flexure tension
Group5	BGIII3	68	26.7	16	37	2.063	Splitting
	CGIII2	41	24.4	14	28	1.875	Splitting

Py : the yield load; Δy: Deflection at yield load.

Pu : the ultimate load; Δu: Deflection at ultimate load.

0.8 Pu : 0.8 ultimate load; Δ0.8u: Deflection At 0.8 ultimate loads.

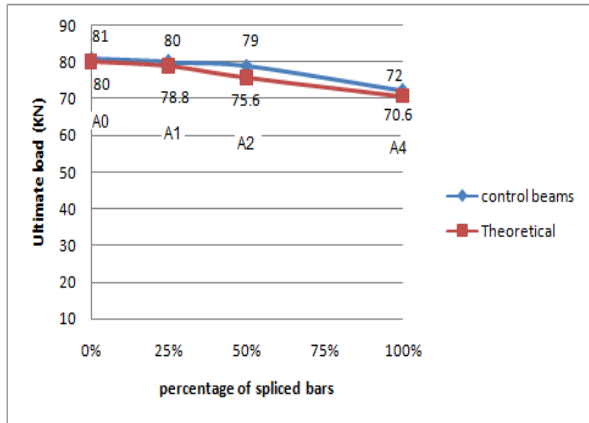


Fig. 5: Ultimate load vs. the percentage of spliced bars.

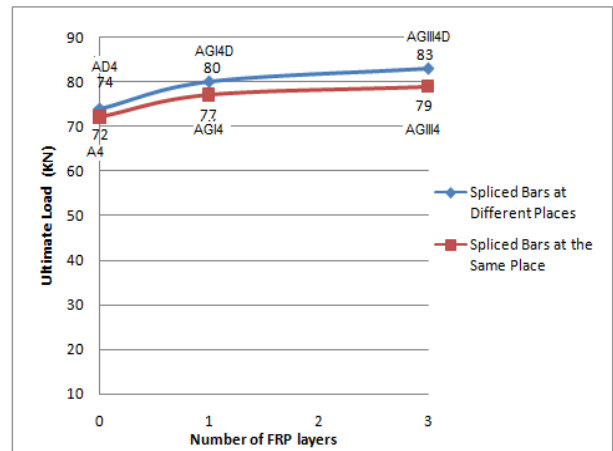


Fig.8: Ultimate load vs. different number of GFRP layers for different lap splice location.

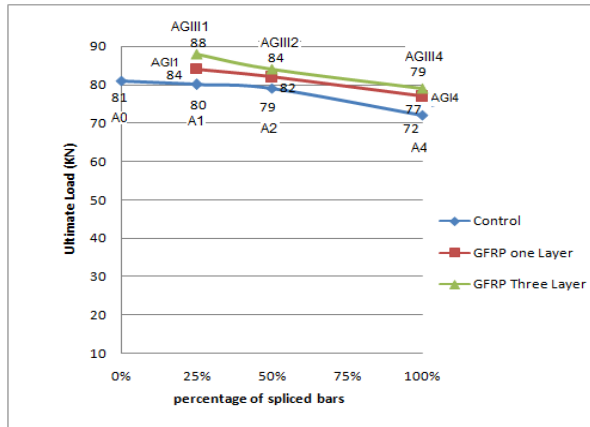


Fig.6: Ultimate load vs. the percentage of spliced bars for different number of GFRP layers.

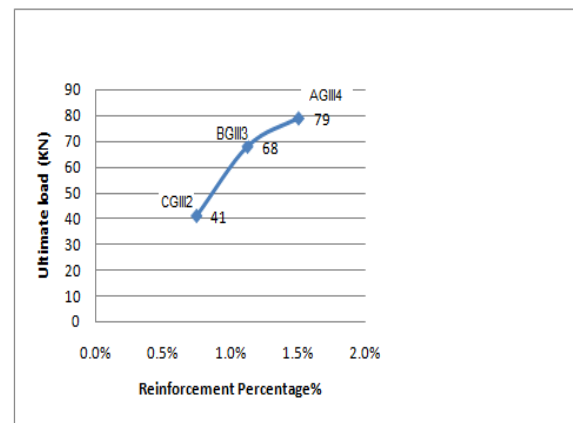


Fig.9: Ultimate load vs. percentage of tension reinforcement for spliced 100% of reinforcement bars.

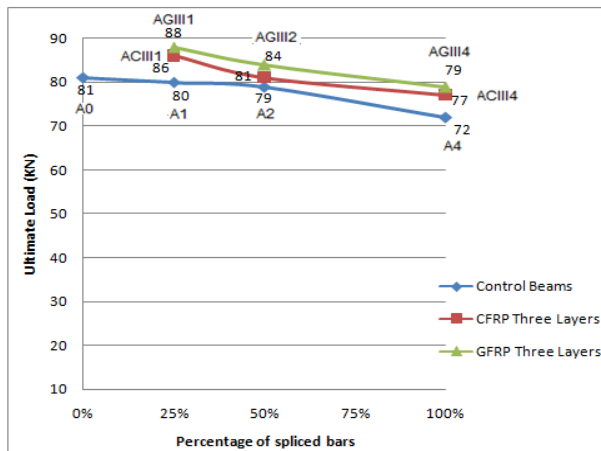


Fig.7: Ultimate load vs. the percentage of spliced bars for different strengthening materials.

3.2 DEFLECTION

Deflection is an important parameter was noticed during the testing of beams. The load-deflection behavior for the beams specimens with different percentage of lap spliced bars, one layer of GFRP, three layers of GFRP strips, three layers of CFRP strips, different lap splice location and different percentage of tension reinforcement are shown in Fig.10 to Fig.16.

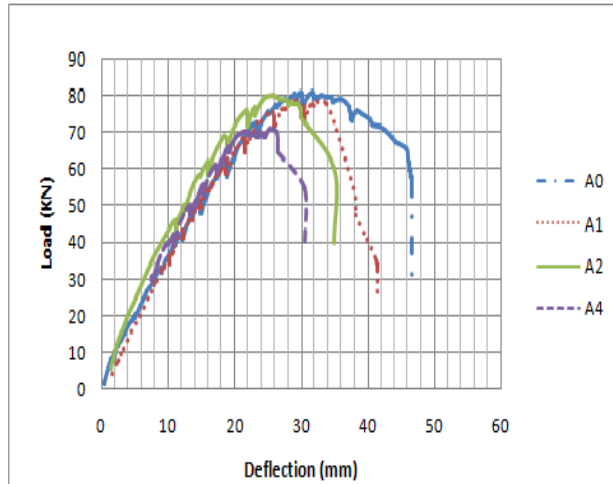


Fig. 10: Load-Deflection curves for control specimens.

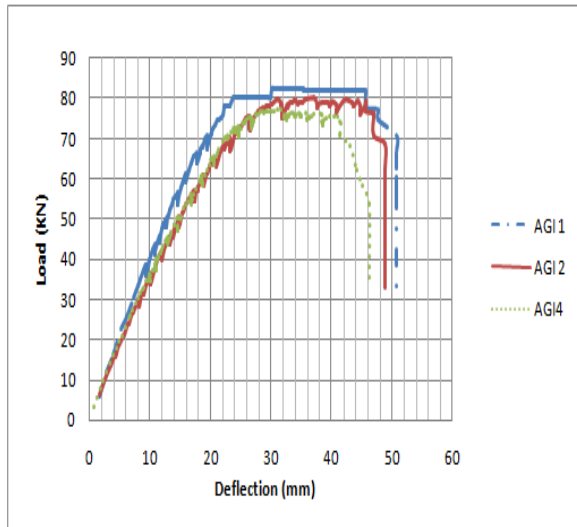


Fig. 11: Load-Deflection curves for specimens with GFRP (one layer).

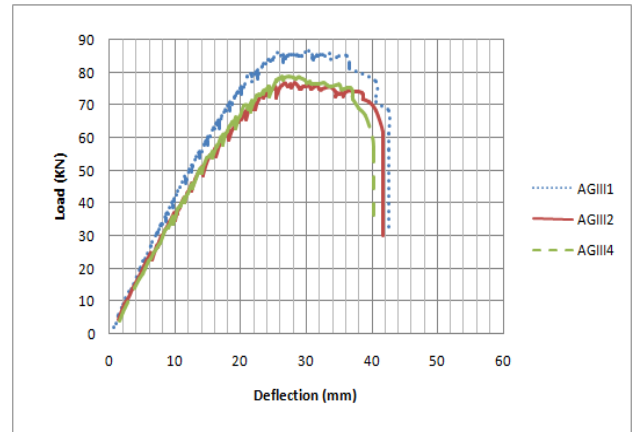


Fig. 12: Load-Deflection curves for specimens with GFRP (three layers).

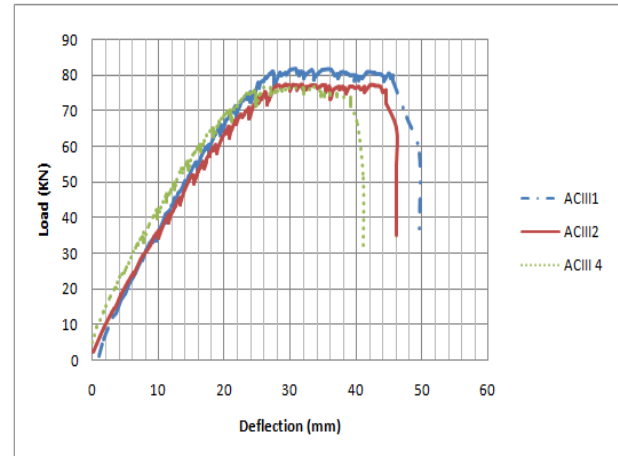


Fig. 13: Load-Deflection curves for specimens with CFRP (three layers).

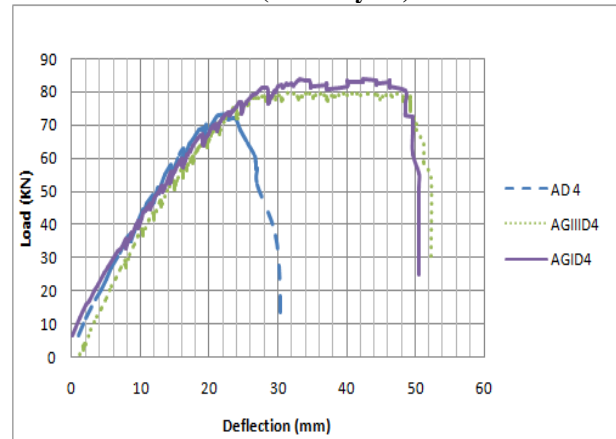


Fig. 14: Load-Deflection curves for specimens with different number of GFRP layers for different lap splice location.

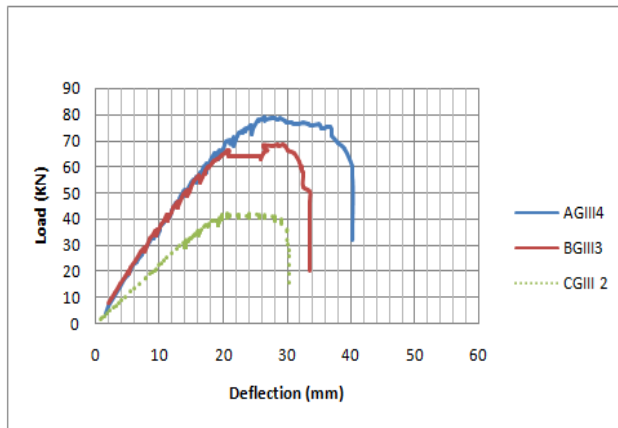


Fig. 15: Load-Deflection curves for specimens with different percentage of tension reinforcement for spliced 100% of reinforcement bars.

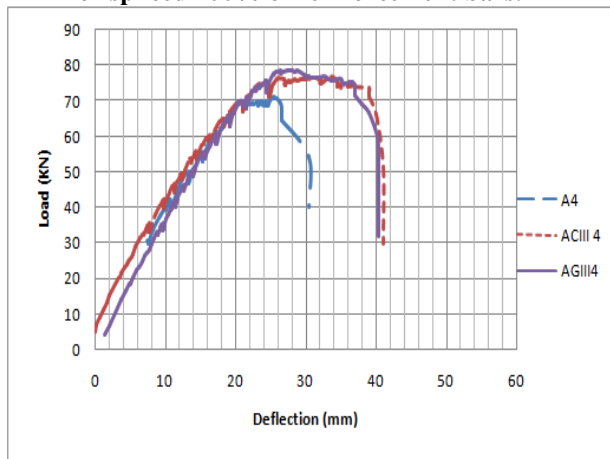


Fig. 16: Load-Deflection curves for specimens for different strengthening materials.

3.3 DUCTILITY RATIO

Ductility is one of the most important parameters to reflect the plastic deformability of members and structures. Ductility factor defined as the ratio between the maximum deflection (the mid span deflection when the load decreased to 80% of the ultimate value along the descending branch of the load deflection curve) and the yielding deflection (the mid span deflection at tension steel yielding), as shown in Table 2.

The final ductility factor for the beams specimens with different percentage of lap spliced bars, one layer of GFRP, three layers of GFRP strips, three layers of CFRP strips, different lap splice location and different percentage of tension reinforcement are shown in Fig.17 to Fig.21.

As shown in the curves of loads versus mid span deflection, FRP wrapping strengthened beams significantly improved both ultimate load, deflections prior to failure of beam which were greater than of the control beam, the use of FRP sheets produced higher deflection for the same load up till failure than control, for all stages of loading up to failure.

As indicated by comparison of the beam specimens, spliced the bars at different place and different number of glass fiber layers at lap spliced zone , the deformation before failure increased as the place of lap splice changed, and with increasing the number glass fiber layers.

As indicated by comparison of beam specimens with different percentage of tension reinforcement, the deformation before failure increased as the ultimate load increased, and this increase was more rapid with increasing the percentage of tension reinforcement, and also accompanied by increasing in load.

It is clear that as the number of GFRP layers increased the final ductility factor increased. The final ductility factor of beam specimens AGI1, AGI2, and AGI4 strengthened with one layer of glass fiber strips were lower than that of beams AGIII1, AGIII2, and AGIII4 strengthened with three layers of glass fiber strips by 9.1%, 13.9%, and 10%, respectively.

As indicated by comparison of test results of beam specimens with different number of glass fiber reinforced polymer layers in lap splice zone. The final ductility factor increased as the number of glass fiber reinforced polymer layers in lap splice zone increased and this increase was more rapid with the decreasing of the number of lap spliced bars.

It is clear that as GFRP layers used in strengthening the beams, the final ductility factor increased. The final ductility factor of beam specimens AGIII1, AGIII2,

and AGIII4 strengthened with glass fiber were higher than that of beam specimens ACIII1, ACIII2, and ACIII4 strengthened with carbon fiber by 2.01%, 5.4%, and 7.29%, respectively.

It is clear that as we changed the place of lap splice the final ductility factor increased.

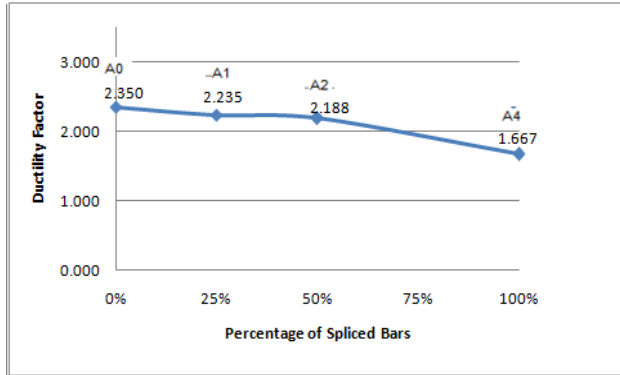


Fig.17: the ductility factor for control specimens.

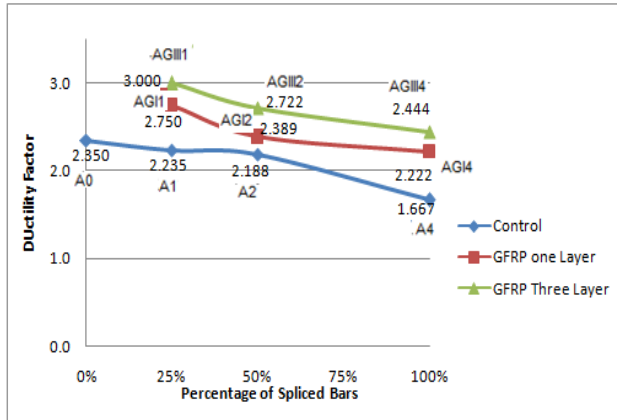


Fig.18: Ductility factor vs. the percentage of spliced bars for different number of GFRP layers

It is clear that as the percentage of tension reinforcement increased the final ductility factor increased. For 100% of the reinforcement spliced, the increasing of the percentage of spliced reinforcement in the beam specimens decreased the final ductility factor.

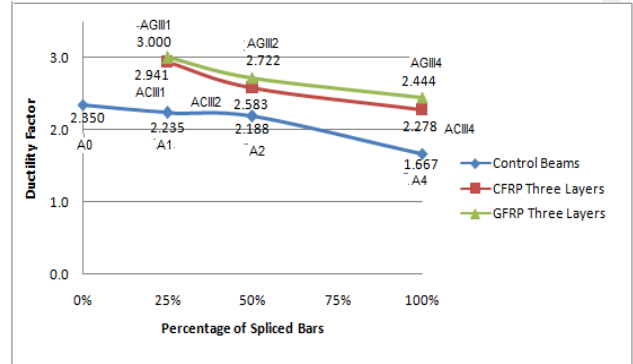


Fig.19: Ductility factor vs. the percentage of spliced bars for different strengthening materials.

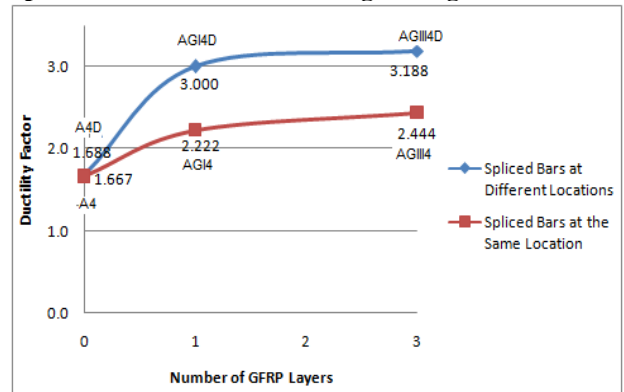


Fig.20: Ductility factor vs. different number of GFRP layers for different lap splice location.

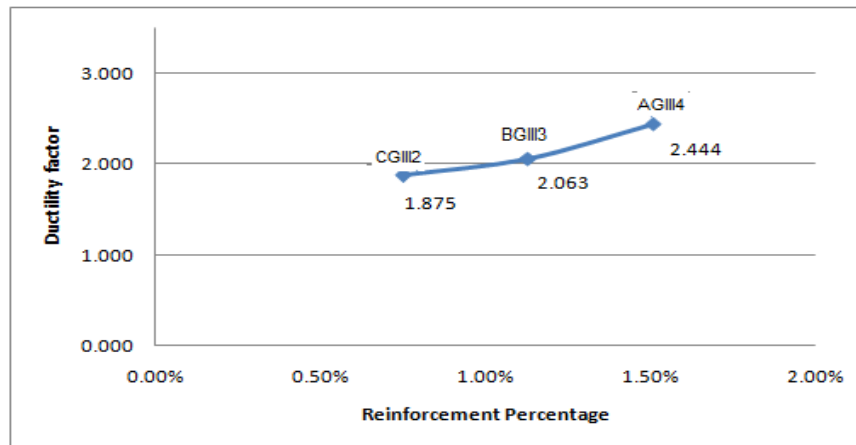


Fig.21: Ductility factor vs. percentage of tension reinforcement for spliced 100% of reinforcement bars.

3.6 THE FAILURE MODE

In all specimens, the first crack, cracks propagation, and plane of failure were observed to investigate the cracking behavior and mode. The modes of failure of all beam specimens are given in Table (2).

UN wrapped, A_0 , A_1 beams specimens failed in flexure with diagonal tension cracks increasing in ultimate load to fracture in the middle span between two points of loading as shown in Fig.21. Specimens A_2 , A_4 , A_{D4} failed by Splitting failure a horizontal splitting crack along the splice length appeared, with a small load increase, a sudden bond failure occurred and the bottom cover at the splice zone separated from the beam as shown in Fig.22.

All beams with one layer of fiber wrapped, failed by debonding of fiber and concrete failure in middle span between two points of loading. A ductile failure took place accompanied by the debonding of some fiber strips, as shown in Fig.23.

Three layer of fiber wrapped, all beams failed by flexure failure in middle span between two points of loading. As the applied load increased, the developed cracks propagated rapidly from the tension side towards the compression side, as shown in Fig.24.



Fig.21: shows failure mode of un-wrapped (A1).



Fig.22 shows failure mode of splitting failure (A4).



Fig.23 shows debonding in fiber (AGI4).



Fig.24 shows the failure mode flexure (ACIII1).

4. CONCLUSIONS

Based on the investigation and experimental results described, a number of conclusions may be considered for FRP wrapping to confining the splice region on the tension lap splice length. The factors to be taken into account are ultimate load, deflections, ductility factor. Conclusions obtained in this study were as follows.

1. In general, FRP strips wrapping provided greater ease of application, make beams more ductility, additional flexural reinforcement that refers to FRP act as confinement material as well.
2. The deflection of the strengthened beam was less for each load case compared to the unstrengthened beam, the strengthened beams suffered higher deflection compared to the reference beam.
3. The strengthening with FRP showed more deflection during concrete failure so more warning and saving of lives before failure.
4. The curves indicate that the deflection of the GFRP strengthened beam was more for each load case compared to the CFRP strengthened beam, CFRP was better than GFRP in deflection.
5. The mode of failure for beams with FRP wraps was ductile and the failure was gradual after the load reached the peak. The final failure of the beams strengthening with one layer of GFRP was debonding of GFRP layers from the sides and bottom of the beam with longitudinal splitting in the concrete cover, and flexure failure for the beams strengthening with three layer of GFRP or CFRP.
6. The yielding and ultimate loads of the tested beams seem to have a light effect by using lap splices of reinforcing bars in the constant moment zone, with a length equal to that recommended by the Egyptian code.
7. As the percentage of spliced bars increased over 25% of the total bars, the ductility of the beams decreased.
8. For beams with spliced bars the major crack concentrated at the start and end of the spliced zone.

9. Future work can investigated different techniques of fiber reinforced polymers.

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