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EXPERIMENTAL STUDY OF THE REINFORCED CONCRETE CONTINUOUS BEAMS EXTERNAL STRENGTHENED WITH CARBON FIBER REINFORCED PLATE

Hassanien M. Thiyab
Assistant Professor, Department of Civil Engineering, Kufa University, Najaf, Iraq

Hussein Raad Shaker
Post Graduate Student, Department of Civil Engineering, Kufa University, Najaf, Iraq

ABSTRACT

This study includes of tested fifteen reinforced concrete continuous beams (Rcc beam) two span. It's designed to fail in flexural under two point load each load subjected on the mid span. All beams are classified to three groups G1, G2 and G3, each group included five reinforced concrete beams, first beam in each groups as controlled beam (un strengthened beam) and others external strengthened by CFRP plates with 50 mm width and 100 mm width in positive moment zone and in positive and negative moment zone. The results showed when Using of CFRP plates at positive moment zone with width of 50 mm is effective to increase the ultimate load from (24- 52) % , and when using of CFRP plates at positive moment zone with width of 100 mm is effective to increase the ultimate load from (29- 48) %, and when using of CFRP plates at positive and negative moment zone with width of 50 mm is effective to increase the ultimate load from (28- 57) % , and when using of CFRP plates at positive and negative moment zone with width of 100 mm is effective to increase the ultimate load from (20- 54) %.

Keywords: CFRP plates, strengthening, continuous beam.

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1. INTRODUCTION

Reinforced concrete beams are structure elements representing more than 80% of the total structural elements in other buildings around the world. Used as horizontal elements to transfer loads from the roof slabs to vertical elements such as columns and walls. It is also used to stabilize the structure by connecting the columns together and creating a stiffing system structural. There are many types of reinforced concrete beams depending on supporting systems are simple support beam, continues beam, semi- continues beam, and cantilever beam. A continuous beam is defined as the statically indeterminate multi span beam that is fixed on hinge support. The end of these spans may be cantilever or may be free supported or fixed supported. A continuous beam used to increase structural safety. This type of beam provides alternate load path in the case of failing. This type of beam has been high seismic danger, continuous beams and frames are choice in buildings and bridges. There are many methods which used to flexural strengthening such as dimension enlargement, steel plate bonding, near-surface mounted (NSM) system, external post tensioning method and externally bonded (EB) system. While many methods of strengthening structures are valid. Strengthening structures by external bonding of fiber-reinforced polymer composite (FRP) has become very wide use [(1)]. This research is studying flexural strengthening of reinforced concrete continuous beam by using carbon fiber reinforcement polymer plate (CFRP plate) and sees the behavior of this, Figure (1) show carbon fiber reinforcement polymer plate. A large number of research, both theoretical and experimental has been studied on the behavior of FRP in strengthening reinforced concrete continuous beams structures (Grace et al.,1999; Grace et al., 2001; El-Refaie et al., 2003; Aiello et al., 2007 ; Akbarzadeh et al., 2010; Majid Mohammed Ali Kadhim et al., 2011; Abdul Ridah Saleh et al., 2013).

Figure 1 Carbon fiber reinforcement polymer plate.

2. EXPERIMENTAL TEST

The experimental study included of cast Fifteen reinforced concrete continuous beams (Rcc beam) two spa. It's designed to fail in flexural less than two point load each load subjected on the mid span. All beams are classified to three group G1, G2 and G3,each group consist the control beam (unstrengthen beam). The beams are external strengthened by capon fiber reinforced polymer plates (CFRP plates). All beams have the same dimension (3300mm*150mm*250mm).

2.1. The mixing proportion and casting of samples

To make the experiment, for G1 the mixing proportion are 1 : 2.32 : 3.04 (C:S:G), and for G2 and G3 are 1 : 1.287 : 2.098 (C:S:G) . The mixing is done by using concrete mixture. The maximum size of gravel was 12.5 mm. The reinforced concrete continuous beams are cured for 28 days. For each beam three concrete cube samples (150mm*150mm*150 mm) and two concrete cylinder samples (100mm*200mm) were made at the time of casting beams and were kept 28 days for curing. The concrete cube samples are used to the uniaxial compressive tests, and concrete cylinder samples are used to the split-cylinder test. Compressive Strength Test for cubes for G1 was 34 MPa and for G2&G3 was 49 MPa.

2.2. CFRP plates Strengthening System

In the experimental study of this project include tested fifteen reinforcing concrete continuous beams, divided into three groups. Each group consist of five Rcc beams, first beam in each groups as controlled beam (un strengthened beam), second beam in each groups strengthened by CFRP plates with width 50 mm in positive zone in each span, third beam in each groups strengthened by CFRP plates with width 100 mm in positive zone in each span, fourth beam in each groups strengthened by CFRP plates with width 50 mm in positive and negative zone, fifth beam in each groups strengthened by CFRP plates with width 100 mm in positive and negative zone. Figure (2) show the strengthening system for beams.

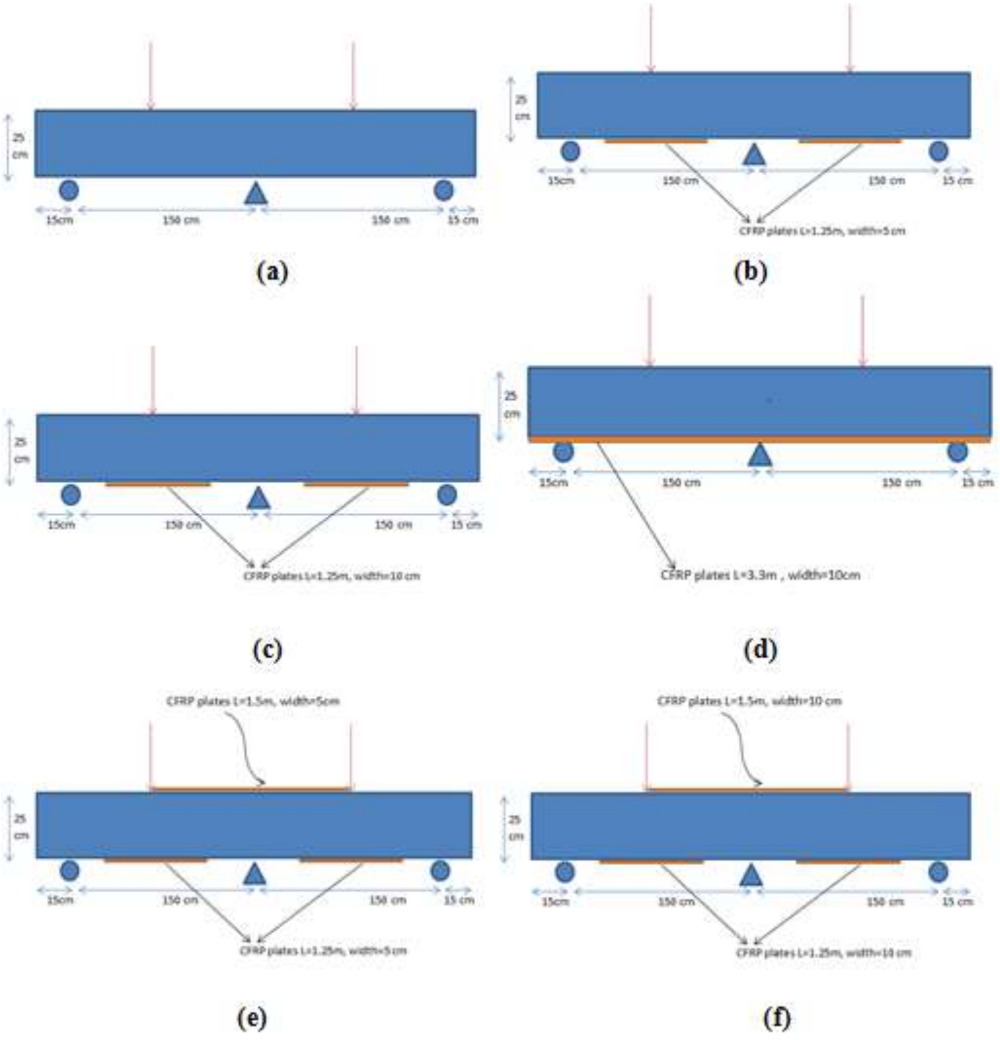

Figure 2 strengthening system for beams (a) G11, G21, G31. (b) G12, G22, G32. (c)G13, G33. (d) G23. (e) G14, G24, G34. (f) G15, G25, G35.

2.3. Steel reinforcement

Two types of steel bars were used in this work (ϕ12mm & ϕ 10 mm). G1 and G2 used ϕ12mm as longitudinal bars in top and bottom, G3 used ϕ 12mm as longitudinal bars in top and ϕ10mm in bottom, all groups were used ϕ10mm as Stirrups. All steel bars of diameter ϕ12mm and ϕ10mm had yield stress of 644.43MPa and 436.01MPa respectively. All sample hade the same dimension as show in Figure (3).

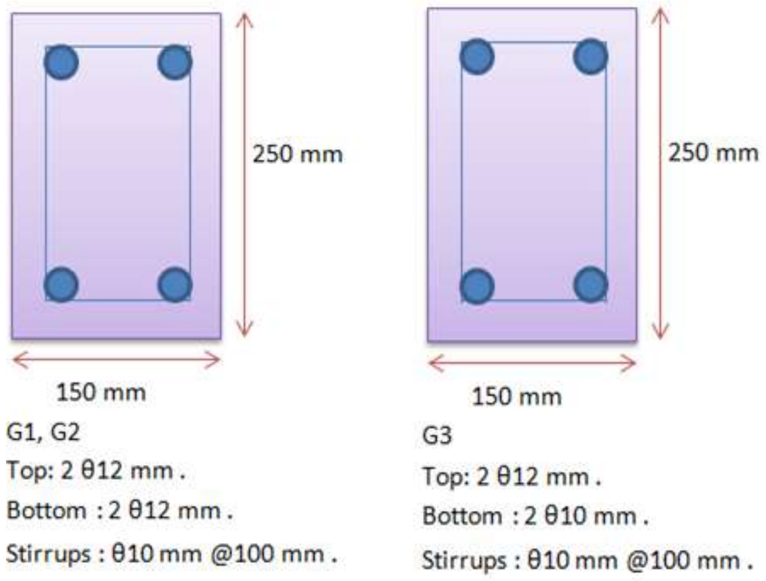

Figure 3 the dimension and steel bars for all beams.

2.4. Fixation of carbon fiber reinforced polymer to reinforced concrete beams

After 28 days from casting and curing the beams, cleaning and smoothing of the surface of reinforced concrete beam by using a scraper machine and then washing the surface by water and then adding epoxy to plates to paste on concrete surface as shown in Figure(4), Figure(5), Figure(6), and Figure (7). The properties of carbon fiber reinforced polymer and epoxy shown in Table (1) and Table (2).

Table 1 The properties of carbon fiber reinforced polymer.

Density	Glass Transition Temperature	Fibre Volume Content	E-Modulus	Tensile Strength	Strain at break	Thickness	Width
1.60 g/cm3	> 100°C	> 68%	165’000 N/mm2	3'100 N/mm2	> 1.70%	1.2 mm	100 mm 50 mm

Table 2 explain the information of epoxy

Chemical base	Packagin g	Color	Shelf life	Coefficient of Thermal Expansion	Mixing ratio	Substrate Temperature
Epoxy resin	6 kg (A + B)	A:white B: black A + B: light grey	24 months from date of production	2.5 x 10−5 per °C(Temperature range: -20 °C min. / +40 °C max).	A:B =3:1 (by weight or volume)	+25 °C min. / +55 °C max.

Figure 4 Tools

Figure 5 Surface leveling, and cleaning

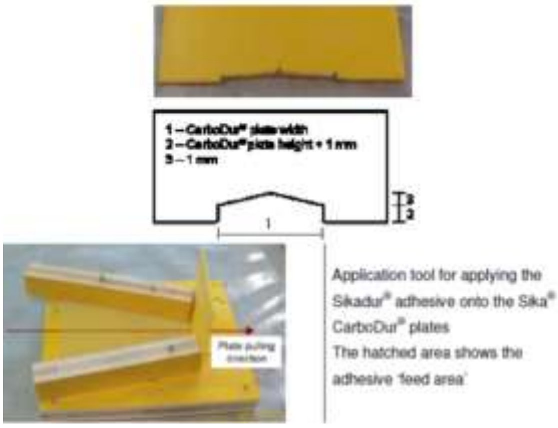

Figure 6 Tools of adding epoxy to plates

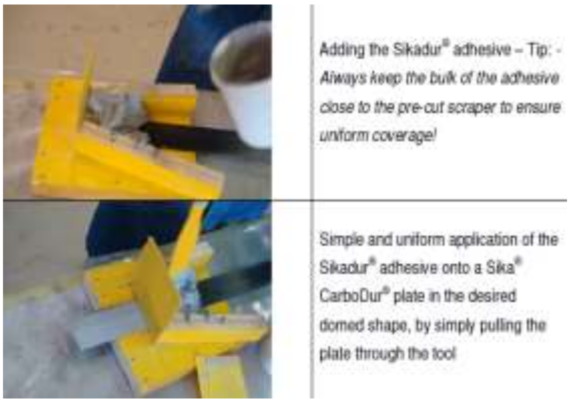

Figure 7 Adding epoxy to plates.

3. EXPERIMENTAL RESULTS

All beams were tested by using a graduate electrohydraulic testing machine (PHILIPP HOLZMANN) with a maximum wander occupation of 2000 kN in structure work place of Kufa university. The beams are put on three supports where the clear distance was 1500 mm for each span, and the free edge from each span was 150 mm. Two dial gauges are put under the beams to measure the deflection, each one are put under the center of distance from each span. Two points of load were subjected on the beams; each point of load was subjected on the center of distance from each span. A rubber plate was used to avoid the consternation of stress under two point load and then put the steel plate above a rubber plate in order to distribution the load from the bridge load to beams.

Bridge load was used to transfer point load from machine to two points load on beams ,When the machine is turned on and the load is gradually increased, the deflection is measured every 10 KN, crack width every 20 KN and change in strain every 50 KN. Figure (8) shows the details for machine test. The experimental result for each beam was shown in Table (3).

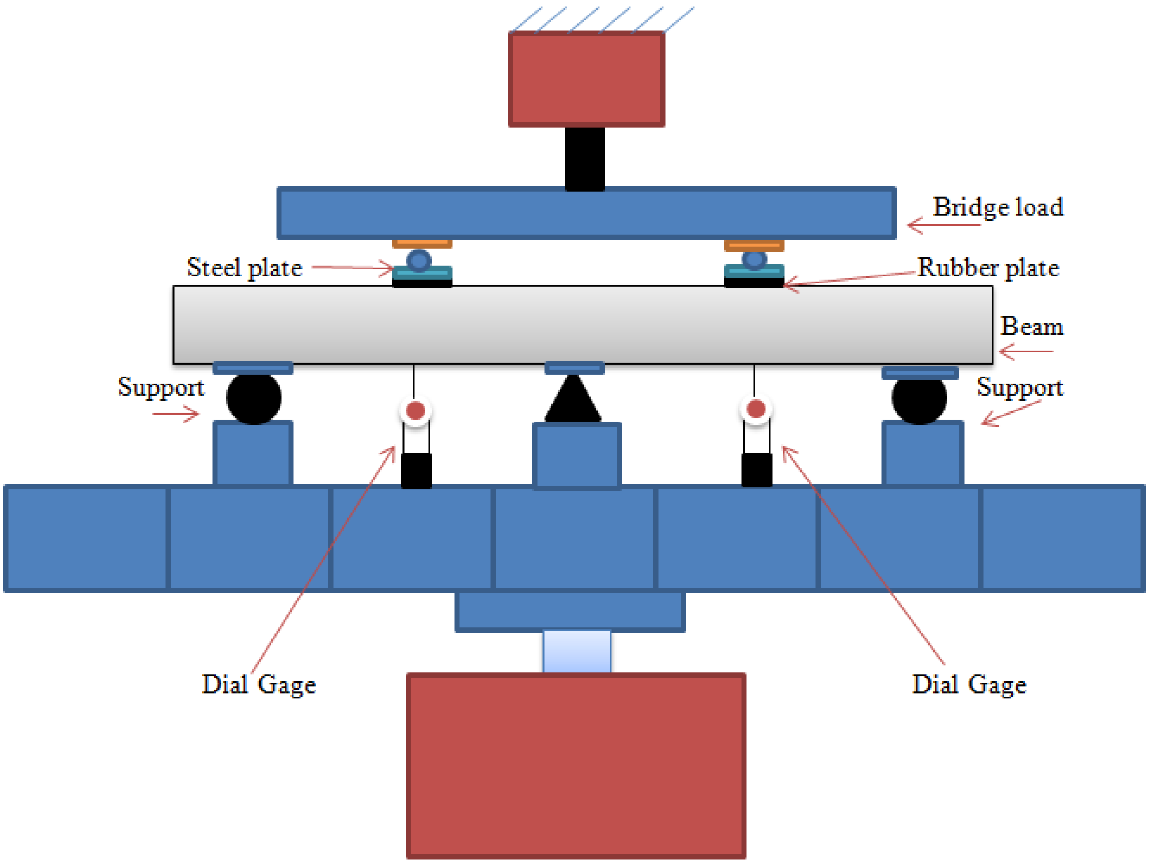

Figure 8 the details for machine test.

Table 3 The experimental results for each beam.

beams	First crack loading	Ultimate load (KN)	Increasing of ultimate load %
G11	30 KN	185 KN	------------------
G12	30 KN	280 KN	51.351 %
G13	40 KN	270 KN	45.945 %
G14	30 KN	290 KN	56.756 %
G15	40 KN	285 KN	54.054 %
G21	40 KN	250 KN	------------------
G22	50 KN	310 KN	24 %
G23	80 KN	370 KN	48 %
G24	100 KN	320 KN	28%
G25	60 KN	300 KN	20 %
G31	40 KN	210 KN	------------------
G32	80 KN	260 KN	23.809 %
G33	60 KN	270 KN	28.571%
G34	60 KN	270 KN	28.571%
G35	60 KN	280 KN	33.333%

3.1. Group 1 (G1)

Included five reinforced concrete continuous beams as the following:

3.1.1. Beam G11

Beam G11 represent a controlled beam for group 1 and design to fail in flexural. When testing the specimen and applying the load the beam failed by flexure, the first crack is appear at negative zone when the load was about of 30 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam to fail in flexural in this zone at ultimate load was about of 185 KN. The patterns crack of this beam was shown in Figure (9).

Figure 9 The patterns crack of beam G11.

3.1.2. Beam G12

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span with width 50 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 280 KN. The first crack is appearing at negative zone when the load was about of 30 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam. The patterns crack of this beam was shown in Figure (10).

Figure 10 The patterns crack of beam G12.

3.1.3. Beam G13

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span with width 100 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 270 KN. the first crack is appear at negative zone when the load was about of 40 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (11).

Figure 11 The patterns crack of beam G13.

3.1.4. Beam G14

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 50 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 290 KN. the first crack is appear at negative zone when the load was about of 30 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (12).

Figure 12 The patterns crack of beam G14.

3.1.5. Beam G15

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 100 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 285 KN. the first crack is appear at negative zone when the load was about of 40 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (13).

Figure 13 The patterns crack of beam G15.

3.2. Group 2 (G2)

Included five reinforced concrete continuous beams as the following:

3.2.1. Beam G21

Beam G21 represent a controlled beam for group 2 and design to fail in flexural. When testing the specimen and applying the load the beam failed by flexure, the first crack is appear at negative zone when the load was about of 40 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam to fail in flexural at ultimate load was about of 250 KN. The patterns crack of this beam was shown in Figure (14).

Figure 14 The patterns crack of beam G21.

3.2.2. Beam G22

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span with width 50 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 310 KN. the first crack is appear at negative zone when the load was about of 50 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (15).

Figure 15 The patterns crack of beam G22.

3.2.3. Beam G23

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at along the bottom of beam with width 100 mm of plate. When testing the specimen and applying the load the beam failed by rupture of CFRP plates at ultimate load was about of 370 KN. the first crack is appear at negative zone when the load was about of 80 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails by rupture of CFRP plates. The patterns crack of this beam was shown in Figure (16).

Figure 16 The patterns crack of beam G23.

3.2.4. Beam G24

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 50 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 320 KN. the first crack is appear at negative zone when the load was about of 100 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (17).

Figure 17 The patterns crack of beam G24.

3.2.5. Beam G25

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 100 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 300 KN. the first crack is appear at negative zone when the load was about of 60 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (18).

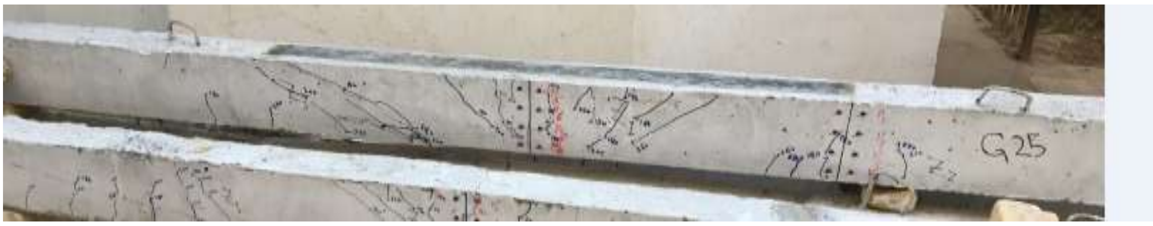

Figure 18 The patterns crack of beam G25.

3.3. Group 3 (G3)

Included five reinforced concrete continuous beams as the following:

3.3.1. Beam G31

Beam G31 represent a controlled beam for group 3 and design to fail in flexural. When testing the specimen and applying the load the beam failed by flexure, the first crack is appear at negative zone when the load was about of 40 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam to fail in flexural at ultimate load was about of 210 KN. The patterns crack of this beam was shown in Figure (19).

Figure 19 The patterns crack of beam G31.

3.3.2. Beam G32

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span with width 50 mm of plate. When testing the specimen and applying the load the beam failed by de bonding of CFRP plates from concrete surface at ultimate load was about of 260 KN. the first crack is appear at negative zone when the load was about of 80 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (20).

Figure 20 The patterns crack of beam G32.

3.3.3. Beam G33

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span with width 100 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 270 KN. the first crack is appear at negative zone when the load was about of 60 KN. In the next stages of applying load , the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (21).

Figure 21 The patterns crack of beam G33.

3.3.4. Beam G34

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 50 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 273 KN. the first crack is appear at negative zone when the load was about of 40 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (22).

Figure 22 The patterns crack of beam G34.

3.3.5. Beam G35

This beam was strengthened by carbon fiber reinforced polymer plates (CFRP plates) at positive moment zone from each span and negative moment zone with width 100 mm of plate. When testing the specimen and applying the load the beam failed by flexure and peeling of CFRP plates with cover of concrete at ultimate load was about of 280 KN. the first crack is appear at negative zone when the load was about of 60 KN. In the next stages of applying load, the crack was appeared in the positive zone of continuous beam and then fails. The patterns crack of this beam was shown in Figure (23).

Figure 23 The patterns crack of beam G35.

Load-deflection curve for group one shown in figure(24), load-deflection curve for group two shown in figure(25), and load-deflection curve for group three shown in figure(26). And load- crack width curve for group one shown in figure(27), load- crack width curve for group two shown in figure(28), and load- crack width curve for group three shown in figure(29).

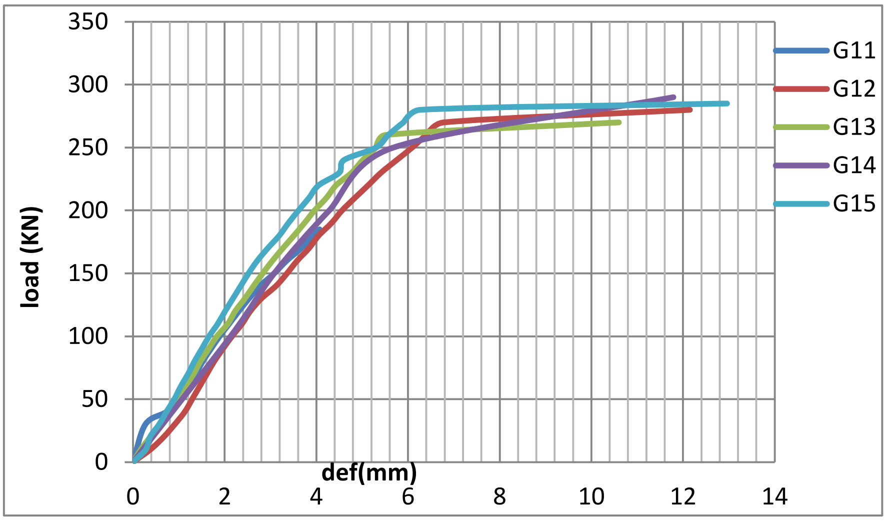

Figure 24 load-deflection curve for Group 1 (G1).

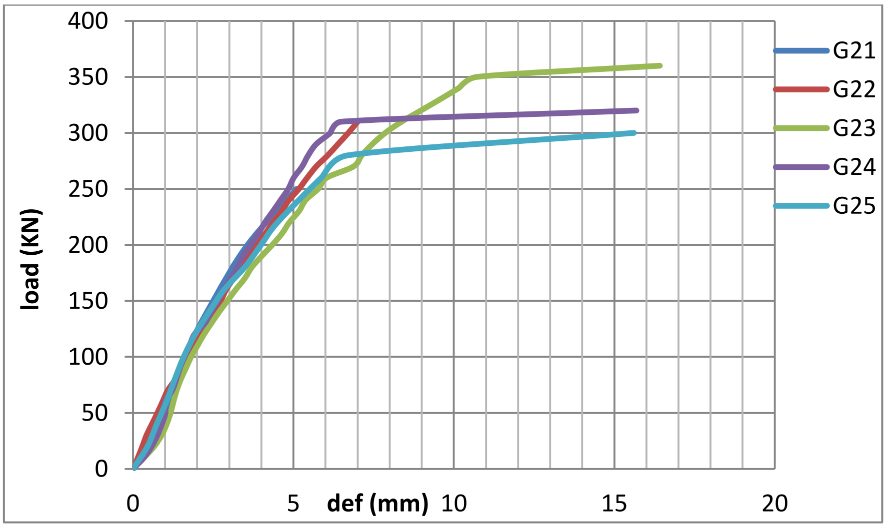

Figure 25 load-deflection curve for Group 2 (G2).

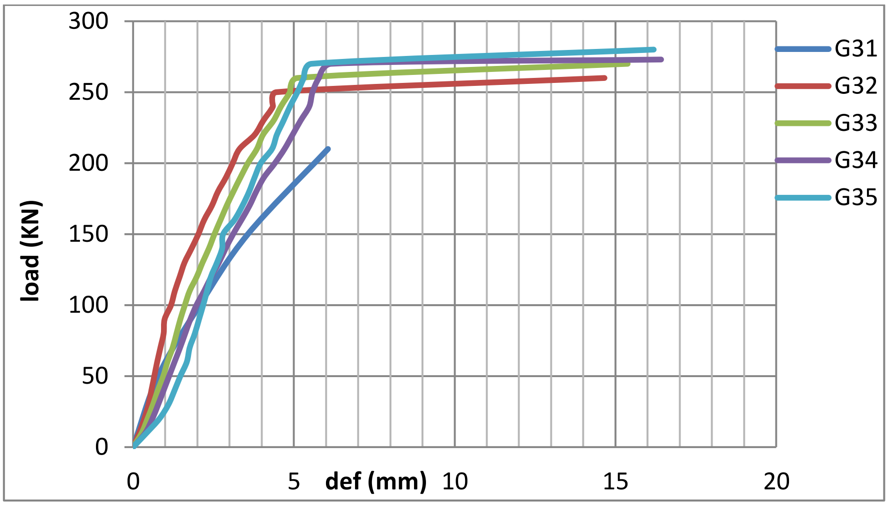

Figure 26 load-deflection curve for Group 3 (G3).

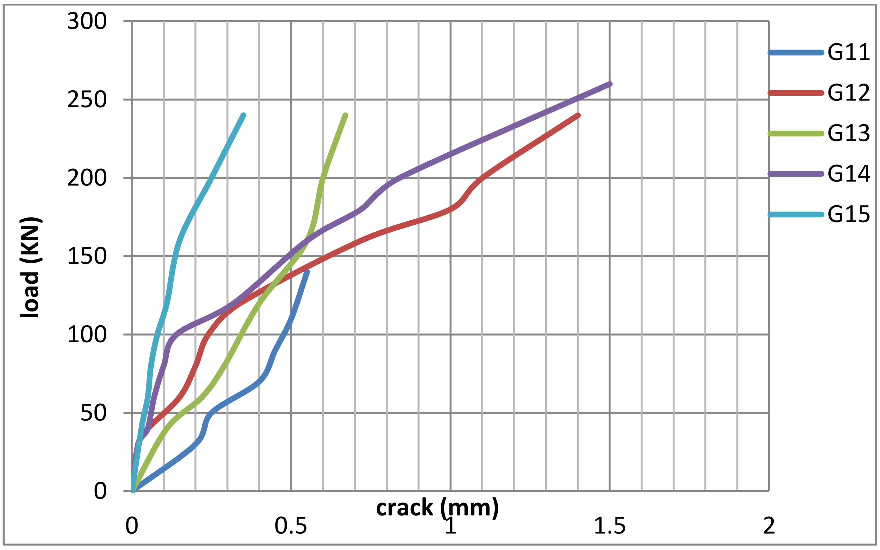

Figure 27 load- crack width curve for Group 1 (G1).

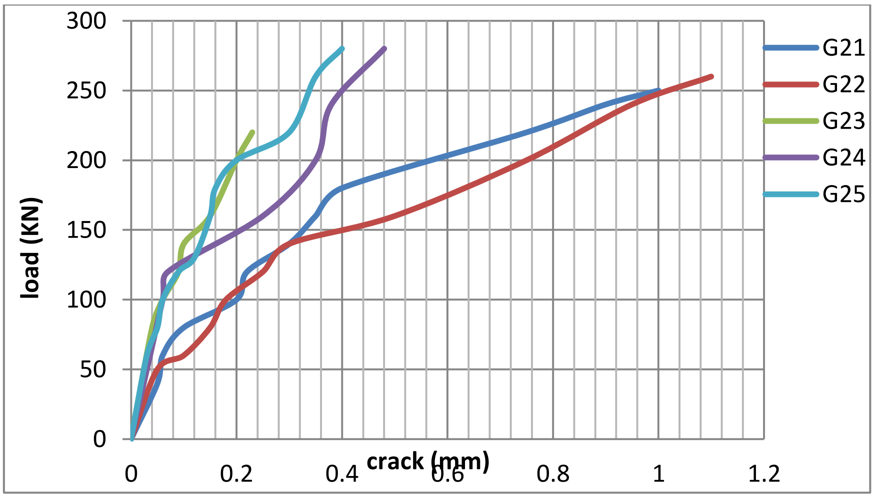

Figure 28 load- crack width curve for Group 2 (G2).

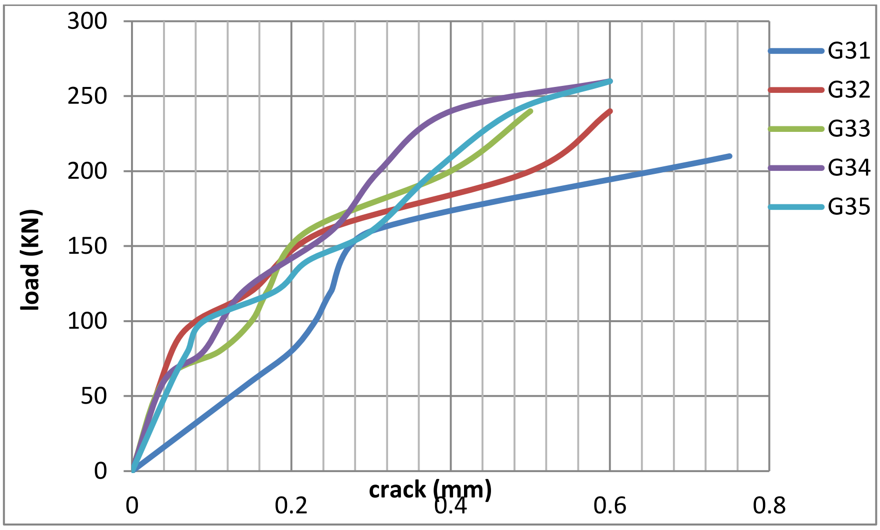

Figure 29 load- crack width curve for Group 3 (G3).

4. CONCLUSIONS

1. Using of CFRP plates at positive moment zone with width of 50 mm is effective to increase the ultimate load from (24- 52) %.
2. Using of CFRP plates at positive moment zone with width of 100 mm is effective to increase the ultimate load from (29- 48) %.
3. Using of CFRP plates at positive and negative moment zone with width of 50 mm is effective to increase the ultimate load from (28- 57) %.
4. Using of CFRP plates at positive and negative moment zone with width of 100 mm is effective to increase the ultimate load from (20- 54) %.
5. External strengthening by carbon fiber reinforced polymer plates increases ultimate load for continous beams, but decrease ductility of beams.

REFERENCES

[1] Product Data Sheet Sika® CarboDur® S (September 2016, Version 04.01) 020206010010000040.

[2] Grace NF, Sayed GA, and Saleh KR, “Strengthening of continuous beams using fibre reinforced polymer laminates”, American Concrete Institute, Farmington Hills Mich, pp. 647-657, 1999.

[3] Grace NF, “ Strengthening of negative moment region of reinforced concrete beams using carbon fiber- reinforced polymer strips ", ACI Structural Journal vol. 98, No. 3, pp. 347-358, 2001.

[4] El-Refaie SA, Ashour AF, and Garrity SW, “Sagging and hogging strengthening of continuous reinforced concrete beams using carbon fibre-reinforced polymer sheets”, ACI Structural Journal, vol. 100, pp. 446-453, 2003.

[5] El-Refaie SA, Ashour AF, and Garrity SW, “CFRP strengthened continuous concrete beams”, Proceedings of the ICE - Structures and Buildings, pp. 395 - 404, 2003.

[6] Aiello MA, Valente L, and Rizzo A, “Moment redistribution in continuous reinforced concrete beams strengthened with carbon fiber-reinforced polymer laminates”, Mechanis of Composite Materials, vol. 43, pp. 453-466, 2007.

[7] Akbarzadeh H, and Maghsoudi AA, “Experimental and analytical investigation of reinforced high strength concrete continuous beams strengthened with fiber reinforced polymer”, Materials and Design, vol. 31, pp. 1130-1147, 2010.

[8] Kadhim, (Majid Mohammed Ali Kadhim), “Effect of CFRP Sheet Length on the Behavior of HSC Continuous Beam”, Journal of Thermoplastic composite materials, Vol. 00, 2011.

[9] Abdul Ridah Saleh ,Ammar Abd Alameer, Hussein Barem (Babylon University, Engineering College, Civil Department), ‘’Experimental and Theoretical Analysis for Behavior of R.C. Continuous Beams Strengthened by CFRP Laminates’’, Journal of Babylon University/Engineer ing Sciences/ Vol.(21)/ No.(5): 2013.