Structural Behavior of Reinforced continuous Reactive Powder Concrete Beams

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Abstract

The present study can be split into four aims next its four aims. The first aim was to check the effectiveness of compressive strength of normal concrete on the structural behavior of continuous beams.The second aim was to study the effectiveness of concrete type on the structural behavior continuous beams. The third aim was to study the effectineness of steel fibre ratio from (0 to 2.5%) on the structural behavior of RPC continuous beams. The fourth aim was to study the effectiveness of longitudinal reinforcement bar on the structural behavior of RPC continuous beams by using (CFRP and GFRP). Therefore, nine continuous beams consist of two span were tested under one-point loading for each span. Seven All beams had the matching overall length of 2700 mm, the clear span distance equal to 1250 mm foe each span, and the same width of 150 mm. The test results show that the continuous beam made with RPC had a superior ultimate load compared with the NC continuous beam and that the ultimate load increased when steel fibre ratio increased. The ultimate load of the continuous beam was also Found to be increased when the using of CFRP bar as a longitudinal reinforcement ratio. In supplement, the ultimate load of the continuous beam was decrees when using GFRP bar as a longitudinal reinforcement ratio.

Key words: Reactive powder concrete (RPC), Portland cement, Continuous beams, Steel fiber, Carbon Fiber Reinforced Polymer (CFRP) Rebar, Glass Fiber Reinforced Polymer (GFRP) Rebar.

1. Introduction

Structural designers are constantly looking for new techniques and proposals that will make their structures further aesthetically and economically pleasing. Historically, the refinement of structures has depended strongly on the characteristics of engineering materials. Thus, a new type of material with excellent properties, reactive powder concrete RPC, has been developed. It offers superior strength, ductility and durability [1]. Because RPC consists of a high cement content, silica fume, fine sand (grain-size distribution of 150–600 mm as a substitution for natural coarse and fine aggregates), and a special water reducer, it makes it possible to adopt a w/c ratio of shorter than 0.20 and enables the use of special fine fibers[1]. With RPC beams being continuous, architects, designers, and structural designers seeking the best low-weight, high-strength systems are able to create and implement aesthetic architectural designs. A continuous beam is a structural integration that supply impedance when a force or load is exercised. These beams are usually used in bridges . A beam of this kind has further than two points of support over the length of the beams. These are ordinarily in the horizontal plane, and the spans in the middle of the supports are in one straight line.[2].

This research focused on the examination of beams with variable parameters to study the effectiveness of these parameters on the structural behavior, such as the ultimate load, first cracking load, load–mid span deflection and maximum deflection.

Performed empirical investigation on continuous concrete beams reinforced with GFRP bars below the impact and static loading . In their work, they performed empirical tests on twelve reinforced continuous concrete beams. The focus was to evaluate the impact of glass fiber reinforcement on the intensity of the concrete beam when they are under static and dynamic impact loading conditions, and the remaining six were reinforced externally with GFRP systems. They showed that the higher GFRP reinforcement ratio resulted in higher rate of cracking and less ductility under static loading conditions. But under dynamic loads the beams' strength was 15-20% higher than the strength obtained by the static loading conditions [3].

Tested fifteen of reinforced concrete continuous beams strengthened with (CFRP) carbon fibre reinforced polymer ,the results shown when using CFRP plate at positive moment zone with width of 50 mm and 100 mm effective to increase the ultimate load about (24-52)% and (29-48)% respectively while when using CFRP plate at position and negative moment zone with 50 mm and 100 mm the increasing ratio was(28-57)% and (20-54)% respectively [4].

[5] Studies the effect of steel fibers ratio by 2% on the mechanical properties of RPC led to increasing in the compressive strength by 22.28% and increasing splitting tensile strength by 329.7%, modulus of rupture by 234.44% and modulus of elasticity by 20.8%.

[6] Focused on the behavior of the high strength concrete continuous beam strengthened with carbon fibre-reinforced polymer (CFRP) sheet with different CFRP sheet lengths. Three full-scale continuous beams are analyzed under two points load, and the data of analysis are compared with the experimental data provided by other researchers. ANSYS program is used and the results obtained from analysis give good agreement with experimental data with respect to load–deflection curve, ultimate strength, and the crack patterns. The length of CFRP sheet is changed in the negative and positive regions and the results showed that the ultimate strength of the beam was reached when the value of Lsheet/Lspan reaches 1.0, and when the value decreases, the ultimate strength of beam also decreases a little (1.4%), but when it decreases less than 0.6, the ultimate strength also decreases a lot (15%) .

2. Experimental Program

2.1. Beam Description

In this study , all the sample have the same total length (L) of 2700mm with two span each span has distance (Ln) equal to 1250mm centre to centre of the support overall depth 250mm and width 150mm.

Nine continuous beams tested under two points loads the reinforcement detailing of seven beams in Fig.1, where other two beam reinforced in the top and bottom by using glass an carbon reinforcement bars as shown in Fig. 2. All beams reinforced by using strips Ø10 mm at 10cm c/c to avoid shear failure. The ends of all beams extend 100mm beyond the supports. The concrete cover was 25mm. Table 1 show the characterization of tested beams. The bearing steel plates were used under the point loading and above the support to prevent a local failure.

Table1. Show the Description of Tested Beams

Group No.	Symbol	Percent of Superplasticizer %	Percentage of V.F %	Percentage of S.F %	No.and diameter of Longitudinal Reinf.
1	B1(NC)	-	-	-	4Ø12
	B2(NC)	2	-	-	4Ø12
2	B1(NC)	-	-	-	4Ø12
	B3(RPC)	5	0.0	25	4Ø12
3	B3(RPC)	5	0.0	25	4Ø12
	B4(RPC)	5	0.6	25	4Ø12
	B5(RPC)	5	1.3	25	4Ø12
	B6(RPC)	5	1.8	25	4Ø12
	B7(RPC)	5	2.5	25	4Ø12
4	B6(RPC)	5	1.8	25	4Ø12
	B8(RPC)	5	1.8	25	4Ø13(CFRP)
	B9(RPC)	5	1.8	25	4Ø13(GFRP)

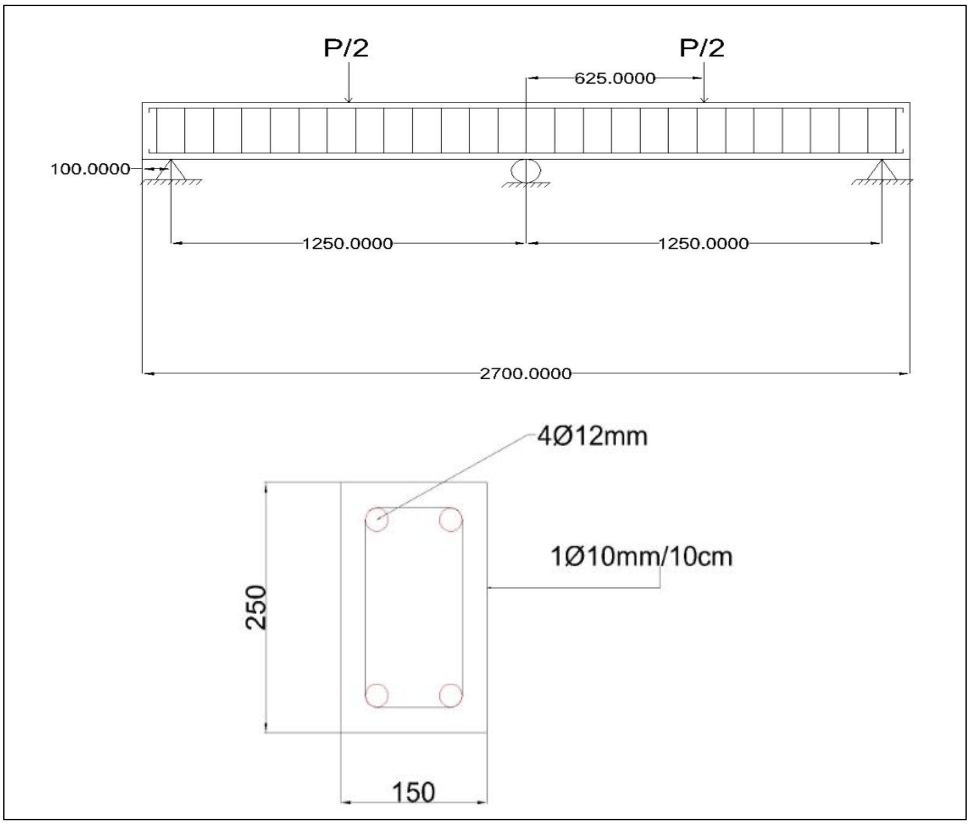

Fig.1 Details of Beams (NC and RPC)

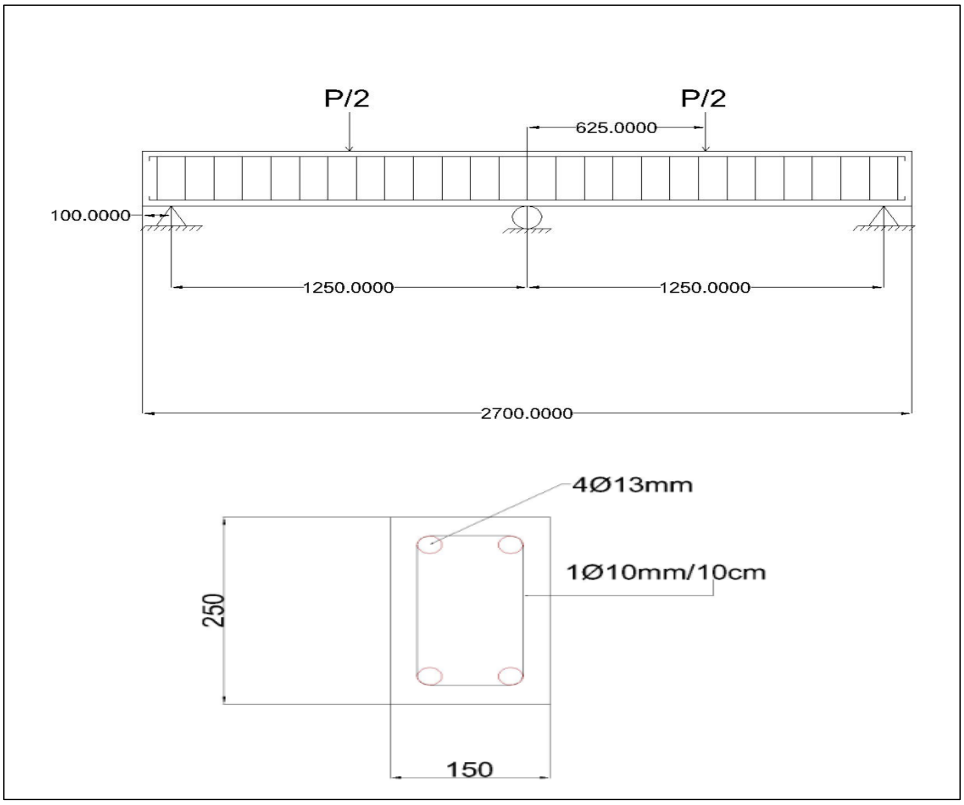

Fig.2 Details of Beams (RPC 1.8%S.F Use CFRP and GFRP Bars)

2.2. Materials

Many materials were used in the testing of the beams in the current study. The movables of these materials are presented in Table 2.

Table 2. Movables of Materials Used for Tested Specimens

Material	RPC	NC
Cement	Sulfate-resisting cement type V	Sulfate-resisting cement type V
Sand	Normal sand (from Al-Najaf region) with ultimate size of 600 *m*m	Normal sand (from Al-Najaf region) with ultimate size of 4.75 mm
Gravel	-	Crushed gruff aggregate with ultimate size of 19 mm
Silica fume	Grizzly densified micro-silica fume	Gray densified micro-silica fume
Superplasticizer	Sika (Lyndhurst, New Jersey) ViscoCrete 5930	Sika (Lyndhurst, New Jersey) ViscoCrete 5930
Steel fiber	Micro straightforward steel fibers with aspect ratio of 65	-
Water	Clean tap water	Clean tap water

2.3. Mix Proportions

All the mix rates were selected according to trial mix and are presented in Table 3.

Table 3. Mixing Rates of Present Study

Concrete type	Cement kg/m3	Sand kg/m3	Silica fume kg/m3	Sup. %	w/c %	Gravel (Kg/m3)	V.f %
RPC	935	1100	233.75	5	0.17	-	0-2.5
NC1	488	644	-	-	0.42	1008	-
NC2	488	644	-	2	0.2	1008	-

*Silica fume was used as a replacement material.
*steel fibre Percent of mix volume.
*The water–cement ratio is the proportion of cementitious materials (silica fume & cement).
*Superplasticizer is the proportion of cementitious materials (cement & silica fume).

2.4. Reinforcement Details

The properties and details of the reinforcement for the tested speci-mens are provided in Table 4.

Table 4. Steel bar Properties

Nominal diameter mm	Yield stress Mpa	Ultimate strength MPa	Modulus of elasticity MPa
10	620	719	200000
12	560	671	200000
13 CFRP	-	2172	124000
13 GFRP	-	758	46000

3. Experimental Results and Discussion

3.1. Control Specimen Results

The supervision samples were casted and tested to define the mechanical movables of the RPC and NC mixtures used to construct the tested beams. The cube of compressive strength was tested in correspondence with BS 1881-116[7], and cylinder compressive strength was tested in correspondence with ASTM C39-96[8]. The splitting tensile strength was tested in accordance with ASTM C496-11 [9]. The flexural strength was tested in correspondence with ASTM C78-75 [10]. Table 5 provides the test results of the mechanical movables for RPC and NC mixes.

Table 5. Mechanical Properties of Hardened NC and RPC

Concrete Type	Cylinder Compressive Strength (f'c) (MPa)	Cube Compressive Strength (fcu) (MPa)	Splitting Strength (ft) (MPa)	Modulus of Rupture (fr) (MPa)	Modulus of Elasticity (E) (GPa)
NC1	21.3	27.28	1.85	5.66	23.168
NC2	33.796	44.88	2.56	9.468	29.269
RPC 0.0%V.F	37.85	71.03	3.1669	7.348	32.4849
RPC 0.6%V.F	49.1933	78.63	3.467	8.212	38.909
RPC 1.3%V.F	54.815	90.48	9.3774	13.584	39.662
RPC 1.8%V.F	72.509	105	12.344	18.808	41.0935
RPC 2.5%V.F	81.08	112	12.9663	18.96	42.0015

*Each amount is an average of three samples.

3.2. Effect of Compressive Strength

The specimens for the tests of the effectiveness of compressive strength consisted of two beams, B1, B2. The objective for this group was to study the structural behavior with different compressive strength of NC concrete. The experimental results offer that using two beam with different compressive strength a significant effect on the ultimate load capacity and first cracking load .the experimental results show that Beam B2 exhibited enhanced increased strength, with increases in the initial cracking load and the ultimate load capacity of approximately 100 and 14.285 percent, respectively, compared with Beam B1. A compendium of the results for this group is provided in Table 6, and the load–midspan deflection is summarized in Figs. 3 .

Table 6. Experimental Results for The First Group of Tested Beams

Group No.	Beam Designation	(f'c)(MPa)	Pcr(kN)	Pu(kN)	Ds(mm)	Du(mm)
1	NC(B1)	21.3	30	210	2.8	7.11
	NC(B2)	33.796	60	240	3.2	6.5

Note: Pcr = cracking load; Pu = ultimate load; Ds = service deflection (deflection at load of 70% of Pu); and Du = maximum deflection.

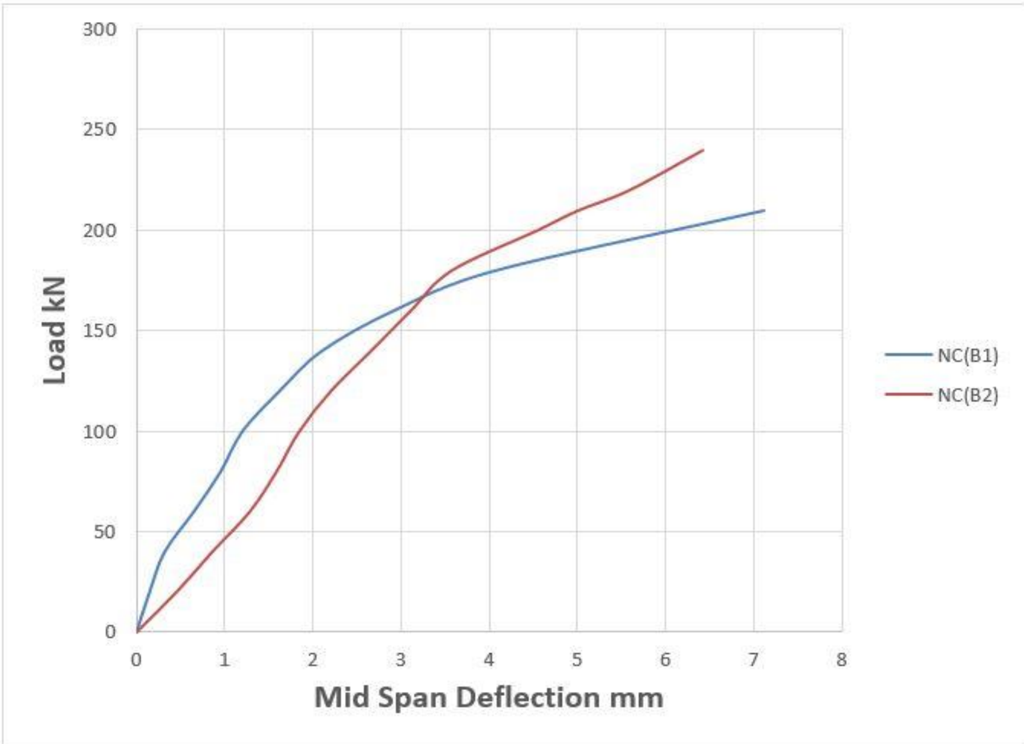

Fig. 3. Load- Deflection for Beams B1 and B2

3.3. Effect of Concrete Type

The aim of this group was to study the flexural behavior with different type of concrete. NC1 and RPC with zero steel fiber beams have the same details of tensile steel ratio but they are different in concrete type to explain the flexural behavior under static load.

The experimental results show that the exercies of RPC instead of NC had a considerable effect on the first cracking load because of a high modulus of rupture (fr). In addition, the use of RPC also had an effect on the capacity of the ultimate load. The experimental results show that Beam B3 exhibited enhanced increased strength, with increases in the initial cracking load and the ultimate load capacity of approximately 66.67 and 23.809%, respectively, parallel with Beam B1. A summary of the results of the tested beams is provided in Table 7, and the load–midspan deflection curves are presented in Fig.4.

Table 7. Experimental Results for the Second Group of Tested Beams

Group No.	Beam Designation	Pcr (kN)	Pu (kN)	Ds(mm)	Du(mm)
2	NC(B1)	30	210	2.8	7.11
	RPC(0.0%V.F)	50	260	4.1	10.47

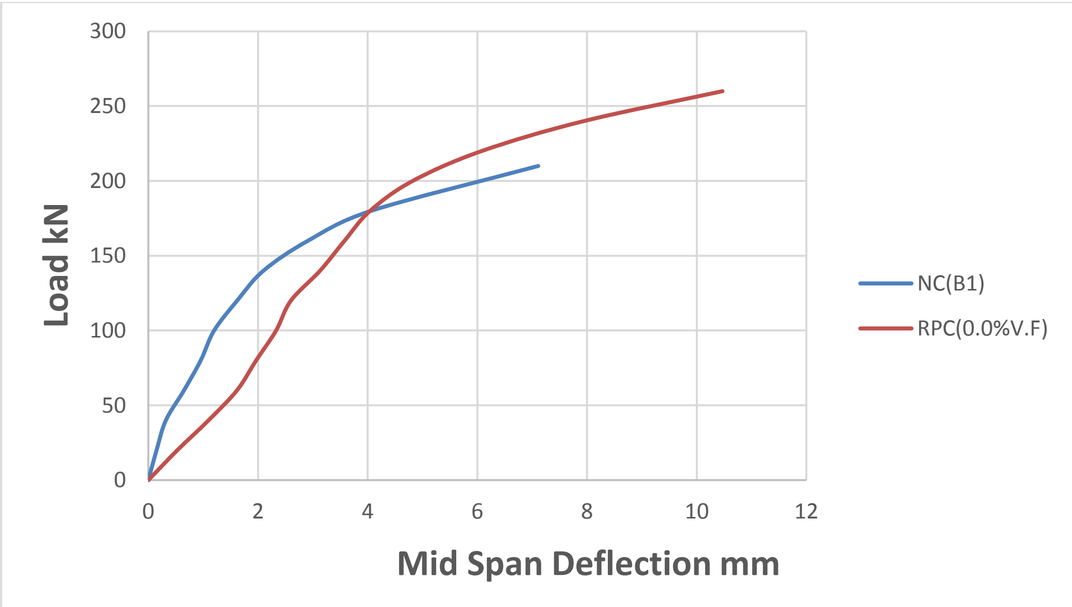

Fig. 4. Load –deflection Curves for NC1 and RPC (0.0%V.F)

3.4. Effect of Steel Fiber Percentage

The objective of this group was to indicate that the increasing of steel fiber capable of swelling the ultimate load and ductility of beams with same amount of prismatic member concrete. The experimental results showed that RPC(0.0%V.F), RPC(0.6%V.F) , RPC (1.3%V.F),(1.8%V.F) and RPC(2.5%V.F) beam enhance and give an increase in the flexural ultimate capacity and first cracking load at about 30.76 ,42.3,48.07,53.84, 20,30 and 30 %respectively with an increase in number of cracks (more warning before failure) as compared with RPC (0.0%V.F). A summary of the results of the tested beams is provided in Table 8, and the load–midspan deflection curves are presented in Fig.5.

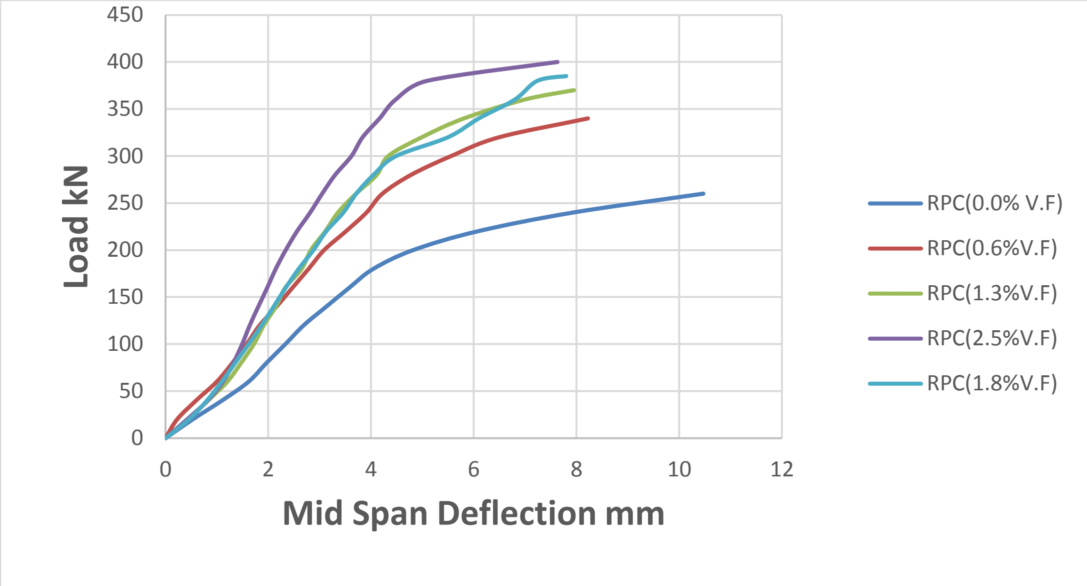

Fig. 5. Load - Deflection for RPC (0.0%V.F, 0.6%V.F, 1.3%V.F, 1.8%V.Fand 2.5%V.F)

Table 8. Experimental Results for The Third Group of Tested Beams

Group No.	Beam Designation	Pcr (kN)	Pu (kN)	Ds(mm)	Du(mm)
3	RPC(0.0%V.F)	50	260	4.1	10.47
	RPC(0.6%V.F)	60	340	3.5	8.223
	RPC(1.3%V.F)	65	370	3.8	7.95
	RPC(1.8%V.F)	65	385	3.82	7.8
	RPC(2.5%V.F)	70	400	3.5	7.63

3.5. Effect of Longitudinal Reinforcement Bars Type

The justification of this group was to study the effectiveness of longitudinal reinforcement bars type were use (CFRP, GFRP and Iraqi bars) on overall structural behavior of tested beams.

The experimental results showed that using GFRP and CFRP as a longitudinal reinforcement bar for RPC (1.8%V.F) decreased the ultimate load capacity at about (10) % and increase the ultimate load capacity at about (48.051) % as compared with RPC (1.8%V.F) respectively.But did not affect the first cracking load . A summary of the results of the tested beams is provided in Table 9, and the load–midspan deflection curves are presented in Fig. 6.

Table 9. Experimental Results for The Fourth Group of Tested Beams

Group No.	Beam Designation	Pcr (kN)	Pu (kN)	Ds(mm)	Du(mm)
4	RPC(1.8%V.F)	65	385	3.82	7.8
	RPC(1.8%V.F) GFRP bar	60	350	2.8	9.564
	RPC(1.8%V.F) CFRP bar	60	570	4.5	6.89

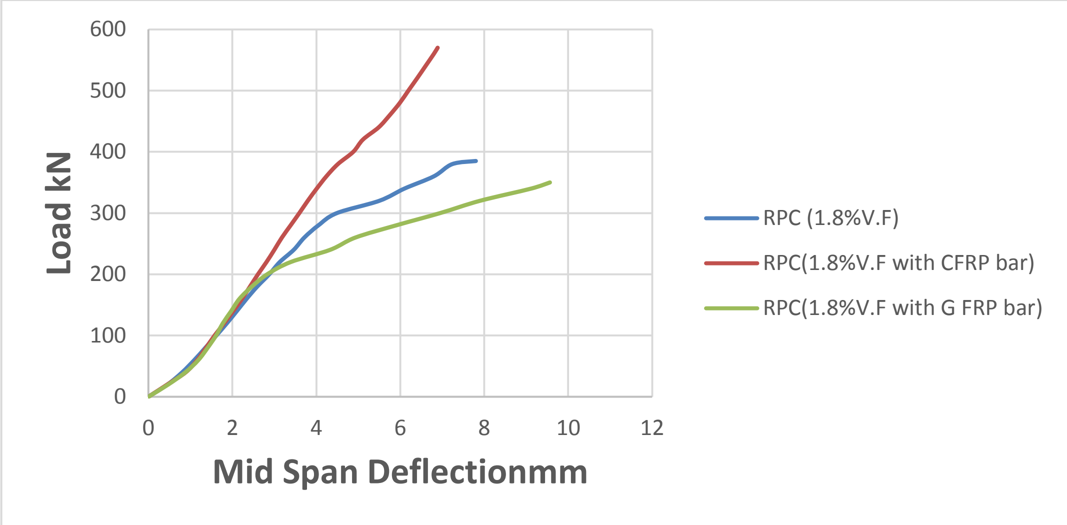

Fig. 6. Load - deflection for RPC (1.8%V.F, 1.8%V.F With CFRP Bar, and 1.8% V.F With GFRP Bar)

4. Crack Patterns

In general, at the low loading level, the beams were free from any cracks; therefore, all tested specimens behaved in an elastic manner. As the load was increased and tensile stress resulted from the applied load exceeding the tensile strength of the concrete, cracks were formed. For continuous beams that failed in the flexural mode, the initial crack was generated at the bottom face of the beam near the midspan region for each span. This is due to the variation of depth (variation of moment of inertia). New cracks were propagated when the loading level was further increased. For the beam made from normal concrete with different compressive strength crack append at the bottom and top face with incense in number of crack by 25% as compare with NC1. For the beams made with RPC, the cracks appeared only at the bottom face, whereas the top face did not suf-fer from cracks or crushing. This is attributable to the high strength of the concrete in these beams. Also, it was found that when the steel fibre ratio ingreased by (0-2.5) % , the number of cracks increased by 42.85% compared with the RPC (0.0%V.F), and when using (CFRP, GFRP) as a longitudinal reinforcement bar.

The number of cracks increased by 34.69 and decrees 8.88% respectively compared with the RPC (1.8%V.F) Thus, the mode of failure flexural load for all tested beams are shown in figures (7to15).

Fig. 7. Crack Patterns of Beam B1 (NC)

Fig. 8. Crack Patterns of Beam B1 (NC)

Fig. 9. Crack Patterns of RPC (0.0%V.F)

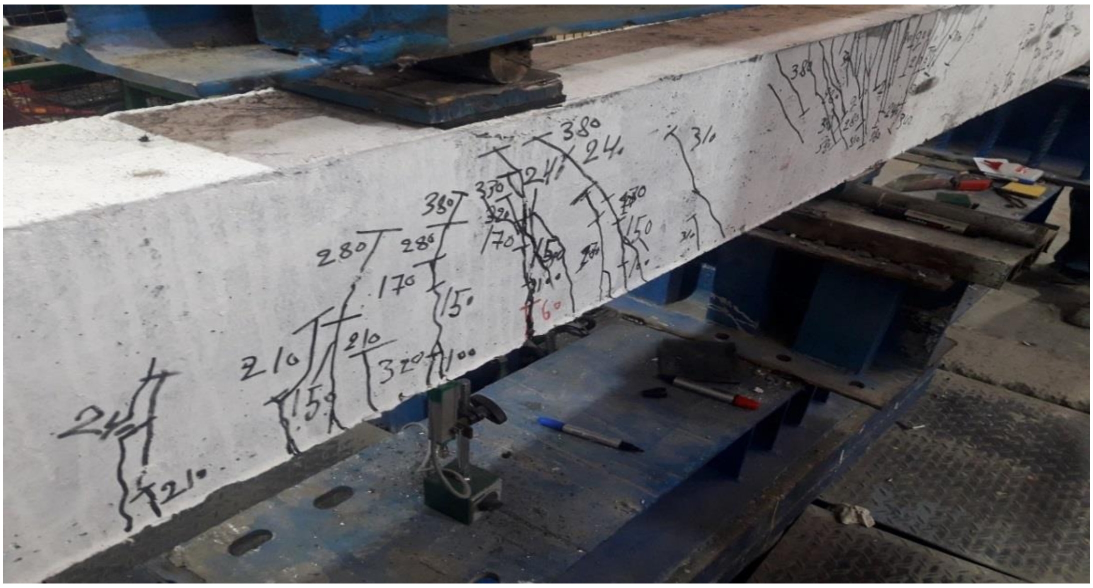

Fig. 10. Crack Patterns of RPC (0.6%V.F)

Fig. 11. Crack Patterns of RPC (1.3%V.F)

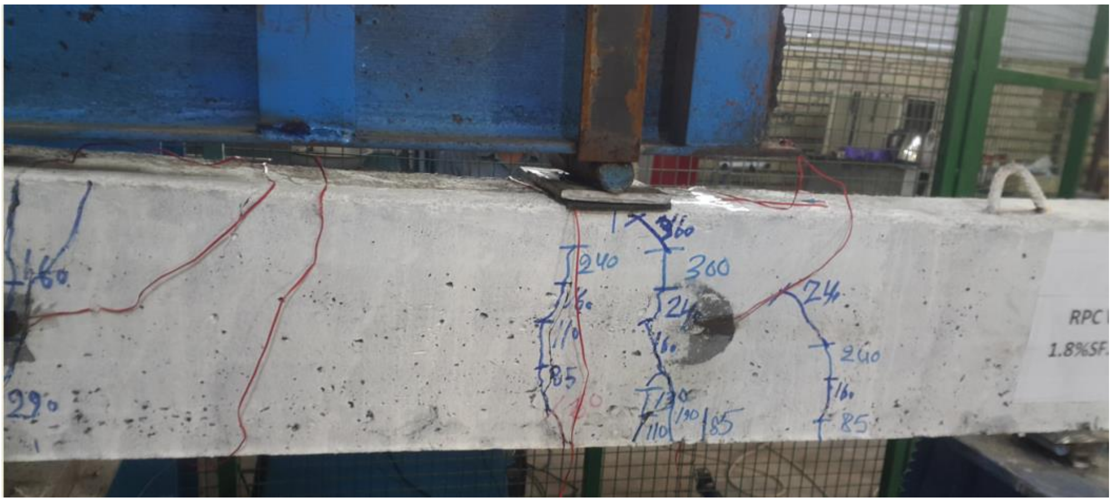

Fig. 12. Crack Patterns of RPC (1.8%V.F)

Fig. 13. Crack Patterns of RPC (2.5%V.F)

Fig. 14. Crack Patterns of RPC (1.8%V.F with GFEP Bar)

Fig. 15. Crack Patterns of RPC (1.8%V.F with GFEP Bar)

Also, the strain mastermind by using strain gage These strains are connected to a gate connected to an electronic device (Data Lockle) where the glues are pasted using a special adhesive with a concrete as shown in Fig.(16) .

Fig.16.Connect the Strain to the Form

5. Conclusions

1. The experimental test results show that the increasing of steel fiber more than 2% few effects on compressive strength but there is more effect on ultimate load.

2. The result show significant improvement of compressive strength of RPC due to extension of steel fibers. The present in volume of 0.6%, 1.3%, 1.8%and 2.5% to inches in compressive strength by 29.96%, 44.829%, 91.569% and 114.214% respectively.

3. The influence of steel fibers on the splitting tensile strength extra significant. For the identical value of increment in the volume of fibers, the splitting tensile strength increased by 9.476%,196.1%,289.78% and 309.43% respectively.

4. The influence of steel fibers on the modulus of rupture more significant. For identical value of increment in the volume of fibers, the modulus of rupture increased by 11.758%,84.866%,155.96% and 158.029% respectively.

5. The influence of steel fibers on the modulus of elasticity more significant. For the identical value of increment in the volume of fibers, the modulus of elasticity increased by 19.775%,22.093%,26.5% and 29.29% respectively.

6. The results show that using NC2 instead of NC1 in continuous beams resulted in an excess in the initial cracking load and the ultimate load failure of 100 and 14.285%, respectively.

7. The results show that using RPC instead of NC in continuous beams resulted in an excess in the initial cracking load and the ultimate load failure of 66.67 and 23.809%, respectively.

8. The results show that using the same value of increment in the volume of fibers in continuous beams resulted in an increase in the first cracking load of 20, 30, 30 and 40%, and the ultimate load failure by 30.76, 42.3, 48.07 and 53.84% respectively.

9. The results show that using CFRP and GFRP bars in continuous beams resulted in an increase in the ultimate load failure by 48.05% and decrees in ultimate load by 10% respectively.

10. The failure of CFRP and GFRP were sudden failure.

Conflicts of Interest

The author declares that they have no conflicts of interest.

6. References

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التصرف الانشائي لاعتاب خرسانه المساحيق الفعالة المسلحة المستمرة

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الخلاصة

هذه الدراسة تتلخص في أربع اهداف الهدف الأول هو لغرض دراسة تأثير مقاومة الانضغاط للخرسانة العادية التصرف للإنشائي للعتب المستمر. الهدف الثاني هو لدراسة تأثير نوع الخرسانة على التصرف الانشائي للأعتاب المستمرة حيث تمت دراسة تأثير نوعين من الخرسانة هي الخرسانة العادية وخرسانه المساحيق الفعالة. الهدف الثالث هو لدراسة تأثير تغير نسبه الياف الحديد لخرسانه المساحيق الفعالة من (% 2.5 −0%) على التصرف الانشائي للأعتاب المستمره. والهدف الرابع لدراسة تأثير تغير نوع قضبان حديد التسليح الطولي على التصرف الانشائي للأعتاب المستمرة. ولتحقيق هذا الغرض تم صب تسعة عتبا ذات الاسناد المستمر مصممة للفشل بواسطة الانحناء حيث تم تسليط نقطتين من القوة في منتصف المسافة لكل فضاء. جميع الاعتاب لديها نفس الطول (2700)، نفس العرض (150) وعمق (250). تظهر نتائج الاختبار أن الاعتاب المستمر المصنوع من خرسانة المسحوق الفعال كان له حمولة نهائية متفوقة مقارنة مع نماذج الخرسانة العادية بعبارة وأن الحمل النهائي زاد عندما زادت نسبة ألياف الصلب. أظهرت النتائج عند استخدام الياف الكاربون كحديد تسليح طولي ان الحمل الأقصى يزداد مقارنه مع النماذج الأخرى. اما في حاله استخدام الياف الكلاس كحديد تسليح طولي فان التحمل النهائي للنموذج يقل.

الكلمات الدالة: خرسانة المساحيق الفعالة، الاسمنت البورتلاندي، العتب المستمر، المضافات.