Flexural Action of Continuous Reinforced Reactive Powder Concrete Beams

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Abstract. In this current study can be split into two aims next its two aims. The first aim was to study the effectiveness of steel fibre ratio from (0 to 2.5%) on the flexural action of RPC continuous beams. The other aim was to investigate the effectiveness of longitudinal reinforcement bar on the flexural behavior of RPC continuous beams by using (CFRP and GFRP). Therefore, seven continuous beams consist of two span were searched under one-concentrated load for each span. All specimens had the same dimensions 150 mm width, 250 mm depth and 2700 mm length. The experimental outcomes display that the continuous samples made with RPC had an excellent compressive strength and that the maximum load improved when steel fibre ratio increased. The maximum load of the continuous sample was also discover to be improved when the using of CFRP bar as a longitudinal reinforcement ratio. In supplement, the maximum load of the continuous beam was decrease when using GFRP bar as a longitudinal reinforcement ratio.

1. Introduction

Concrete has become one of the major elements of the structure in the new structural buildings. With the advance of time the world has noticed an intensification in the population intensity. High-rise buildings are one of the solutions for this problem, these buildings need to be high strength concrete. One of the achievements of the new revolution of concrete is “Ultra-high-performance concrete” UHPC like reactive powder concrete RPC [1]. Reactive concrete powder is very high strength and high ductility combined material with sophisticated mechanical properties, which is advanced in 1990’s by French company Bouygues. It is a special concrete where in the microscopic structure is improved through the precise gradation of all particles in the mixture to obtain maximum density [2]. 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 [3].This study concentrate on the test of beams with different parameters to exam the effectiveness of these parameters on the behaviour of continuous beams, like the ultimate load, first crack load, maximum deflection and load–mid span deflection .A summarized review of several research concerning to the currently research is presented at this part.

Goldston \textit{et al.}, (2016) [4] performed experimental investigation on continuous concrete beams reinforced with GFRP bars down static and impact loading. In their work, they performed experimental tests on twelve reinforced continuous concrete beams. The focus was to evaluate the effective for glass
fiber reinforcement in the strength for the concrete beam when they are under static and dynamic impact loading conditions. Six of the tested samples were reinforced with GFRP bars and subjected to static loading 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 [4].

Shaker, (2018) [5] tested fifteen of RCCB strengthened with (CFRP), the results shown when using CFRP plate at positive moment zone with width of 50mm and 100mm 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 50mm and 100mm the increasing ratio was (28-57)% and (20-54)% respectively [5]. Kadhim, (2018) [6] 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].

2. Experimental Program

2.1. Beam Description

In these research, 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. Seven continuous beams tested under two points louds the reinforcement detailing of five beams in figure 1. Where other two beam reinforced in the top and bottom by using glass a carbon reinforcement bars as shown in figure 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. characterization of test samples show in table 1. The firmness steel plates were applied down a loading and over the support to stop the domestic failure.

Figure 1. Details of Beams (RPC).
Figure 2. Details of B6 and B7.
Table 1. Show the description of tested beams.

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

2.2. Reactive Powder concrete Materials
Several materials were using at this study. Table 2. Show the movables of this materials.

Table 2. Movables for materials used of testing Beams.

| Reactive Powder concert | Cement | Sand | Gravel | S.F | Superplasticizer | Vf | Water |
|-------------------------|--------|------|--------|-----|-----------------|----|-------|
|                         | Portland cement type V | Normal sand | --- | micro-Defect free | ViscoCrete 5930 | Small steel straightforward fibers with L/D of 65 | Clean water |

2.3. Mixing Properties
Table 3 show the percent of material that selected from many trial mix. Silica fume was using as a percentage of cement weigh, water and superplastizer as a percentage of cementinuous material (silica fume and cement) and steel fiber as a percentage of flume mixing.

Table 3. Mix rates for Current study.

| Cement kg/m³ | Sand kg/m³ | S.F kg/m³ | Sup. % | w/c % | V.F % |
|--------------|------------|-----------|--------|-------|-------|
| RPC          | 935        | 1100      | 233.75 | 5     | 0.17  | 0-2.5 |

2.4. Reinforcement Bars (Steel and FRP)
Properties of reinforcement (steel and FRP) are shown in Table 4.

Table 4. Properties of FRP and Steel Bars.

| 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                     |

* used in sample 6 in the top and bottom as longitudinal reinforcement bar.
** used in sample 7 in the top and bottom as longitudinal reinforcement bar.

The methods and instrumentation used during the tests were as follows:
1. Deflection Measurement
The central deflections were measured by using A LVTD linear variable displacement transformers at the each mid spans of the beams sensitivity at each load stage.

2. Crack Width Measurement
CRAK meter is a device used to measure the width of the incision, where all of its teaching is about 0.005mm.

3. Strain measurement
Strains measured by using strain gauges, these strains are connected to an electronic device (Data Lockle) where the glues are pasted using a special adhesive (Epoxy) with a concrete.

2.5. Testing procedure
Beams were casted and handled like aforesaid before. At age of 28 days the curing was stopped, disused to dry, and then coated with white colour so that cracks can be noticed quickly.
Concrete strains were measured using strain gage at interior support and at top, mid and bottom of right span. Each beam was examined up to failure under one concentrated load at the centre of each left and right span applied by a universal testing machine of capacity 2000 kN.
A LVTD was attached firmly to the bottom face at mid of left and right span to record deflection. The load was increased progressively and in every 30 kN step, deflection was listed. Also crack propagation was marked on the sample during the loading and maximum crack width was counted approximately using crack meter device. The support was made by using shaft and steel plate of (125*50*10) mm.

3. Discussion for Experimental Results

3.1. Samples Results
The supervision samples were moulded and examined to define the mechanical movables of the RPC mixtures used to build the examined samples. The $f_{cu}$, $f_{c}$, $f_{t}$ and $f_{r}$ were examined in correspondence with BS 1881-116 (BSI 1983) [7], ASTM C39-96 (ASTM 1996) [8], ASTM C496-11 (ASTM 2011) [9], and ASTM C78-75 (ASTM 1975) [10] respectively. Table 5 shows the result of tested beams.

| Concrete Type | Cylinder Compressive Strength ($f'c$) (MPa) | Cube Compressive Strength ($f_{cu}$) (MPa) | Splitting Strength ($f_t$) (MPa) | Modulus of Rupture ($f_r$) (MPa) | Modulus of Elasticity (E) (GPa) |
|---------------|------------------------------------------|-------------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 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                       |

3.2. 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 rising on the ultimate load and first cracking load at about 30.76, 42.3, 48.07, 53.84, 20, 30 and 30 % respectively with increasing the number for cracks (more warning before failure) as compared with RPC (0.0%V.F). Table 6 show the result of this beams, and the deflection curves are show at the figure 5. The deformation for specimen (RPC (0.0% VF)) is higher than the others the reason is due to the lack of a steel fibre ratio the weakest samples of this group, because the presence of a steel fibre increases the durability of the samples. After the crack appears to us when the strength of the beam increases the crack width increase and increase until the failure occurs and at the same time the deflection increase as well.

Table 6. Results for tested beams of group one.

| Designation of beam | Pcr (kN) | Pu (KN) | service deflection (mm) | Ultimate deflection (mm) |
|---------------------|----------|---------|-------------------------|--------------------------|
| B1(0.0%V.F)         | 50       | 260     | 4.1                     | 10.47                    |
| B2(0.6%V.F)         | 60       | 340     | 3.5                     | 8.223                    |
| B3(1.3%V.F)         | 65       | 370     | 3.8                     | 7.95                     |
| B4(1.8%V.F)         | 65       | 385     | 3.82                    | 7.8                      |
| B5(2.5%V.F)         | 70       | 400     | 3.5                     | 7.63                     |

Figure 3. Load versus mid span deflection for B1, B2, B3, B4 and B5.

3.3. 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 steel 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. The test beams result in Table 7, and load versus mid span deflection for the beams are showing in the Figure 6.
Table 7. Results of Samples for the two group.

| Beam Designation       | Pcr(kN) | Pu (kN) | Ds(mm) | Du (mm) |
|------------------------|---------|---------|--------|---------|
| B4 (1.8%V.F)           | 65      | 385     | 3.82   | 7.8     |
| 4                      |         |         |        |         |
| B6 (1.8%V.F) GFRP bar  | 60      | 350     | 2.8    | 9.564   |
| B7 (1.8%V.F) CFRP bar  | 60      | 570     | 4.5    | 6.89    |

Figure 4. Load deflection for B6 and B7.

4. Crack Patterns
Crack width was measured for the first crack by crack meter tool for all tested beams, for the RPC beams, the cracks show only in the bottom face, whereas the top of the beam free from any cracks. Because the high strength of the RPC beams. When using (CFRP, GFRP) as a longitudinal reinforcement bar, The number of cracks increased by 34.69 and decrease 8.88% respectively parallel with the RPC (1.8%V.F) Thus, the flexural failure is the dominate fail in exam end beams.

Figure 5. Crack patterns of B1.

Figure 6. Crack patterns of B2.
Figure 7. Crack patterns of B3

Figure 8. Crack patterns of B4

Figure 9. Crack patterns of B5.

Figure 10. Crack patterns of B6.

Figure 11. Crack patterns of B7.
5. Conclusions
1. The experimental test results show that the increasing of steel fiber extra 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 increase in compressive strength by 29.96%, 44.829%, 91.569% and 114.214% respectively.
3. The effect of micro steel fibers on the splitting strength extra significant. The present in volume of 0.6%, 1.3%, 1.8% and 2.5% to increase in the splitting strength by 9.476%, 196.1%, 289.78% and 309.43% respectively.
4. The effect of steel fibers on the modulus of rupture important. 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 effect of micro 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 the same value of increment in the volume of fibers in continuous beams show rising in the initial cracking load of 20, 30, 30 and 40%, and the ultimate load failure by 30.76, 42.3, 48.07 and 53.84% respectively.
7. The results show that using CFRP and GFRP bars in continuous beams generated increasing in the failure load by 48.05% and decreasing in failure load by 10% respectively.

6. References
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