Structural Behavior of Continuous Steel-Reactive Powder Concrete Composite Member under Repeated Loads

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Submission date:- 25/1/2018	Acceptance date:- 22/2/2018	Publication date:- 31/12/2019

Abstract:

This paper presents an experimental investigation on the structural behavior of continuous steel-reactive powder concrete composite member under repeated loads. Composite-beam, including one steel I-beam and concrete slab, which are jointed together by shear connector. The study was conducted in experimental and theoretical parts. The concrete deck slab was connected to steel I-beams by headed steel studs welded to the top flanges of the steel I-beams. The dimensions of the deck slab are (2200×250×80mm: length×width×thickness), while the type of I-beam is (IPE 140) with length of (2200mm). To study the continuous steel-reactive powder concrete composite member such as the ultimate load carrying capacity, deflection and crack pattern at the ultimate load, six different types of beams were tested. The parameters of the study were type of concrete (RPC and Normal Concrete (NC)), type of loading, type of boundary condition and different number of shear connector. In the theoretical part, the tested beams were numerically modeled then analyzed using the finite element method. The numerical models were carried out in three dimensions of the software package (ANSYS 16.1). The results of the study indicate that the general trend in ultimate load is to decrease with (use normal concrete, test under repeated load, use simply supports and reduce the number of shear connectors), by (23.4, 9.2, 42.4, 18.7 and 23.15) % respectively.

Keywords: Continuous composite member, Reactive Powder Concrete and Repeated loads.

1)Introduction

Continuous composite construction as one of the common methods of construction in bridges and buildings. Composite member is connecting different materials together in order to build a composite structural member with desirable properties of the materials. The reason behind that is to make full advantage of the construction materials since there is no material that can provide all the structural requirements. Continuous composite steel-concrete beams have been widely used because of the satisfactory utilization of the two materials, steel and concrete. Reducing or preventing the relative displacement of concrete and steel section guarantees the composite action. Shear connectors are used to provide this composite action.

Occurs in practical structures, such as a continuous beams in multistory buildings and long span bridges, when a concrete slab is in tension and a lower flange of a steel girder is in compression under hogging moments, there are shortcomings from the point of view of durability and strength. Concrete cracking in the slab affects the durability and service life of structures [1].

2) Composite Actions

Structure can be considered composite only when the various components are connected together by shear connectors or any shear transfer materials such as adhesive materials (epoxy). The strength and stiffness of a composite section depend on the degree of composite action between the concrete and the steel components. The degree of composite action mainly affected by mechanical and geometrical properties of shear connectors. Using adequate connection leads to make the two components work as one unit, and the situation is known as full or complete interaction. Complete connection is not preferable connection in the composite section while the non-deformable connectors may cause crushing in concrete[2]. However, all shear connectors, particularly the studs which are commonly used as connectors at the present time are flexible to some extent and a certain slip is inevitable. This problem is more severe when few connectors less than the number required for interaction are used. The situation is called a partial interaction.

3)Reactive Powder Concrete

One of the achievements of the recent revolution of concrete is Ultra-high performance concrete (UHPC) like reactive powder concrete RPC [3]. Reactive powder concrete is an ultra -high strength and high ductility composite material with advanced mechanical properties which is developed in 1990's by French company Bouygues. The disadvantages of RPC are that its ingredients are expensive and require special attention in preparing, mixing, handling, casting and curing. Therefore using RPC in a structural application requires special analysis to use smaller section size to reduce the overall cost. The producers expect that as RPC becomes more common in practice, the cost of use will decrease and they suggest that savings will be achieved over the life cycle when compared to conventional solutions.

- Its superior strength combined with high shear capacity results in significant dead load reduction and less limited shape of structural members [4].
- RPC has ability to restrict the direct tensile stresses so rebar shear indispensable.
- RPC provides improved seismic performance by reducing inertia loads with lighter members, allowing larger deflections with reduced cross sections, and providing higher energy absorption [5].
- The finess of the product allows high – quality surface finish [6].
- Superior strength can lead to more slender structures resulting in a significant dead load reduction [7].

4. Experimental Program

4.1 Materials

-Cement

Ordinary Portland Cement OPC (type I) manufactured by the Al - Kufa factory was used throughout the investigation. Its physical and chemical composition and properties are conformed to the Iraqi Specifications limits (I.Q.S. 5/1984) for ordinary portland cement.

-Fine Aggregate

Natural sand from (Al-Akaidur) regions were used as fine aggregate both RPC and normal concrete. For NC the sand is sieved to achieve maximum particle size of (4.75mm) and for RPC it was sieved to achieve finer particles with a maximum size of (600 μm). The results were compatible with the limitations of the Iraqi specification (I.Q.S.45/1984).

- Superplasticizer

Polycarboxylate ether polymer manufactured by a PAC technology company under the commercial name PC200 was used in reactive powder concrete mixes. PC200 was used for producing the concrete mix in order to make advantages of the following properties of the Superplasticizer:-

- Improving workability of concrete.
- Improving concrete early and tensile strengths and final compressive.
- Enabling concrete production with low water/cement ratio.

-Silica Fume

A gray densified silica fume (which was a byproduct from manufacture of silicon or ferro-silicon metal) was used.

- Steel Fibers

Steel fibers straight were used throughout the experimental test. Each steel-fiber has diameter about 175 μm and length of approximately 13 mm and tensile strength 2300MPa.

- Coarse Aggregat

Crushed, natural gravel that brought from AL- Nibaey region was used as coarse aggregate of a normal concrete mix in this research. The maximum aggregate size was 12.5mm.

- Steel Reinforcing Bars

For all slabs, deformed steel bars were used as the steel reinforcement at top and bottom of slab. All steel bars, in long and short direction have the same size of (ϕ 6 mm) in diameter. The mechanical properties of testing steel bar were given in Table (1).

Table (1): Tested steel bars mechanical properties.

Nominal Bar size mm	area (mm^2)	weight (kg/m)	density (kg/m^3)	E (GPa)	Yield strength Fy (MPa)	Ultimate strength Fu(MPa)
ϕ 6	28.3	0.222	7844	200	560	620

- Structural steel (I-Section)

A hot rolled IPE_140 structural steel I-section was used in all tested specimens. This section has 140 mm height, 72mm flange width and 13kg/m weight. The flange and web thicknesses are (6 and 5) mm, respectively. Properties of steel beam are given table (2).

Table (2): Properties of steel beam and results of tests steel

Sectional Area mm^2	I_X mm^4	Yield stress (MPa)	Ultimate strength (MPa)
1504	4.75*106	340	498

- Steel Shear Connector

The prepared stud shear connector (shape and size and properties of stud connector) should be match the requirements and limitations the composite section design. The headed shear connector of size 10mm diameter and 50mm length welded to the upper flange of steel.

4.2 Specimens Description

The continuous steel-reactive powder concrete composite beams, six were tested. The test parameters included type of concrete (RPC and Normal Concrete (NC)), type of load, type of boundary condition and different number of shear connectors Table (3) and Figure (1) show the details of all test beam.

Table (3) Details of all the test beams in the present study

Name of sample	Type of concrete	Type of support	Shear connectors		Type of loading
			Number	Spacing mmc/c	
BC1	NC	Continuous	64	60 in negative 65in positive	monotonic
BC2 (control beam)	RPC	Continuous	36	110 in negative 125in positive	monotonic
BC3	RPC	Continuous	36	110 in negative 125in positive	Repeated 70%Pu
BC4	RPC	Simply	36	110 mid span 125 nearsupport	monotonic
BC5	RPC	Continuous	18	250 in negative 250in positive	Repeated 70%Pu
BC6	RPC	Continuous	9	250 in negative 250in positive	Repeated 70%Pu

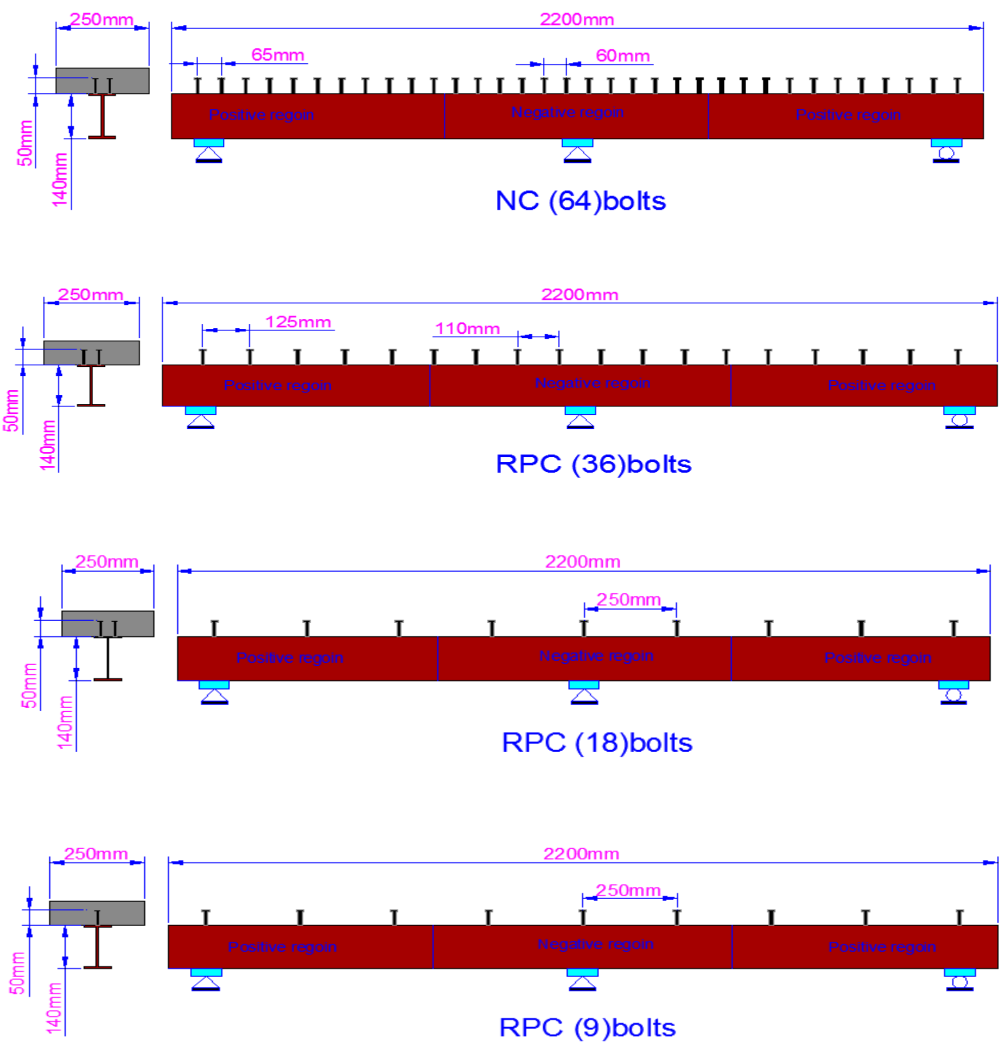


Figure (1): Distribution of shear connectors used in the present work.

All "beams are test under two symmetric concentrated" loads applied at midpoints of each span". Bearing "plates with dimensions" (100 × 250 × 10) mm "under each load have been designed to carry" the maximum load to "avoid any local crushing in concrete". All "beams were continuing supported" at the ends except "one beam was simply support shown in Figure" (2).

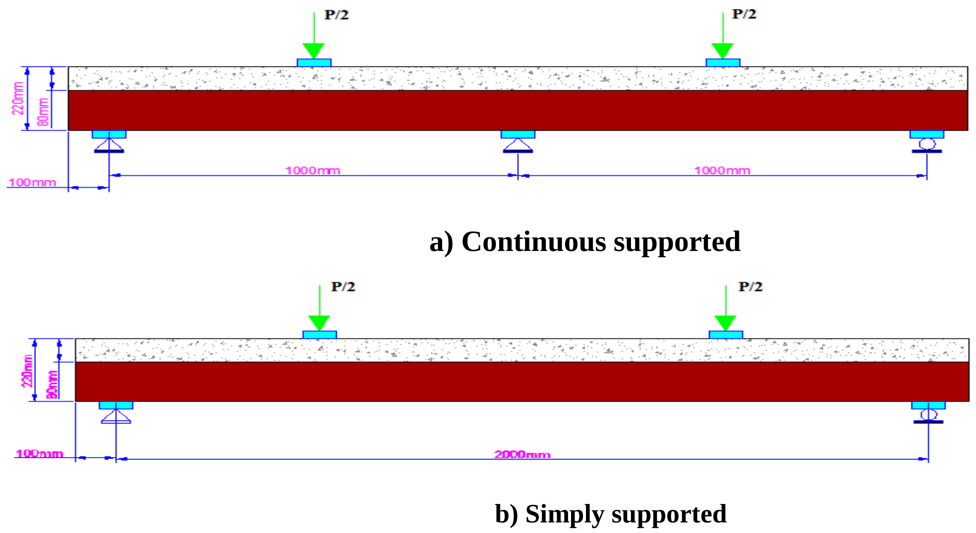


Figure (2): Loading and supporting conditions of test samples

4.3 Concrete Mixes

This study contains two types of concrete (RPC and NC). The steps of producing the concrete will be explained in the following. One reactive powder concrete and one normal concrete mixes were used in the present research Table(4). Many trail mixes should be done to accomplish the required characteristics for the RPC and NC.

Table (4) Details of all trail mixes of the present investigation

Mix Type	Cement (Kg/m3)	Gravel (Kg/m3)	Sand (Kg/m3)	Micro silica fume (Kg/m3) *	Steel fiber % by volume **	w/cm ratio ***	HRWRA %
RPC	825		1100	275(25%)	2	0.18	8
NC	450	1050	630			0.3	0.5

*****Percent by weight of cement
** Percent of mixer volume
*** Percent of cementitious materials (cement +silica fume) weight

4.4 Mixing of Concrete

RPC mix is performed in a rotary "mixer of 0.024m3 capacity". In RPC concrete, "the fine sand and cement" were mixed "in a dry state for about 2 minutes" to disperse "the fine sand particles throughout" the cement particles. Then "the silica fume is added and the mixture" was mixed for 2 minutes. "The super plasticizer dissolved in water" and the solution of water "and super plasticizer was gradually added during" the mixing process, then "the whole mixture was mixed for 4 minutes". Fibers "were uniformly distributed in the mix in 2 minutes". In total, "the mixing of one batch required approximately" 10 minutes from adding water to the mix.

4.5 Casting Sample, Curing and Surface Preparation

The first step in the formation of a composite structure was preparing steel beam of length (2.2m) according to the section mentioned previously, after that, headed stud shear connectors were welded to the top flange of the steel beam in one or two lines according to the case of the beam, plywood molds (16mm) thickness was used for manufacturing the slab. The molds are cleaned well and the internal faces are lubricated before the assembled reinforcement was put in the mold directly before casting. The molds were correctly placed on the ground, then put the Steel Reinforcement inside it with the lack of movement, then the structure I-section placed on the molds. The concrete mix was cast in the form and manually vibrated by steel rods and by hammering the outer faces of the form by rubber hammer Figure(3).

After 24 hours of casting opened all the molds and the samples were extracted from them, all the beams were cured by sprinkler with a canvas for all faces of the beams. This curing was continued for 28 days. Also, cubic, cylinders, prism and push out were cured by the same method.

Figure (3): Casting samples

5) Test Procedure

After 28 days, lifted the wet canvas from the samples and processed for examination, left to dry. Then, the steel beam was cleaned by steel brush with a grinder machine.

Each beam was transmitted to the testing machine. The samples have been supported by means of three (two hinges and one roller) and loaded transversely by two line loads applied approximately at points of mid- each span. Three crane rail steel beams have been used to support the samples. Another two crane rail steel beams have been used to apply two line loads. Two strips (10cm width) plate of steel was placed between concrete face and line loads to avoid early crushing of concrete beneath line loads Figure(4).

Repeated load was applied to the three samples was loaded gradually until (70%), and then unloading is followed, Thus, a cycle of loading was applied. Each applied cycle is loaded and unloaded step by step and at each step readings of deflection, slip and strain were recorded Figure(5). The number of the applied cycles was 20. Finally, the sample was loaded gradually up to failure. The total time during the examination of the beam under static loads was 40 minutes, and in the case of repeated loads was 5 hours.

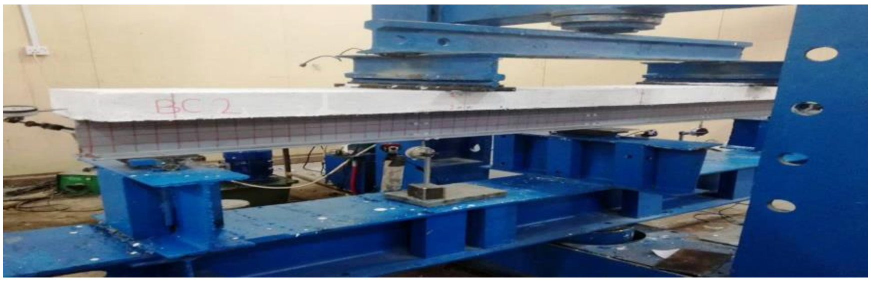


Figure (4): Test samples

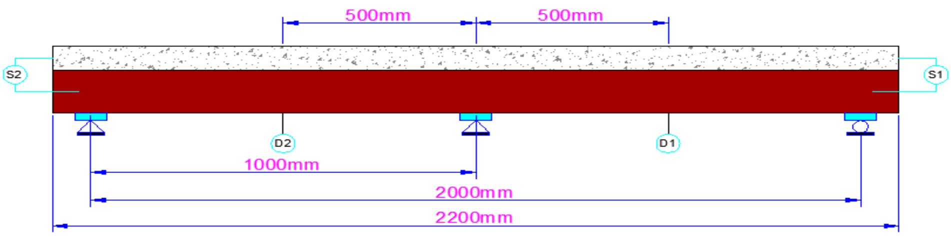


Figure (5) Positions of dial gauges

6) Experimental Results and Discussion

The obtained results from the experimental testing of the present study are:

1. Deflections at the center of each span for all beams. The symbols of these deflections are (D1) and (D2).
2. Slip on the ends between concrete slab and steel beams. The symbols of these slips are (S1) and (S2).

All of the for-mentioned results were recorded at each stage of loading. The value of the load was obtained from analog reader of the test machine. The experimental data were obtained by using a dial gauge for deflection and slip.

Table (5) shows ultimate load recorded for each beam and load of first crack formed in concrete slab and the ratio between them.

Beam (BC2) is the control beam. It was failed under ultimate load of (Pu=445kN). The first crack appeared under load (218kN). In addition to the appearance of cracks on the surface of the concrete above the internal support tensile result.

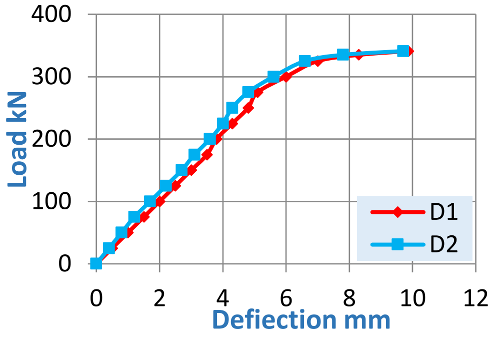
There is a reduction in the value of the ultimate load by a ratio of (23.4 %) for sample (BC1), (Pu=341kN). This reduction occurred due to the difference in the type of concrete where NC was used for sampling (BC1). Also, the number of cracks is more than the control sample (BC2). Also, the first crack appeared of less load (93kN).

The beam (BC3) was tested under repeated load, a reduction in the value of the ultimate load by a ratio (9.2%), (Pu= 404kN). Also, the number of cracks increased due to repeated of the load by (70%Pu) for twenty times. It can be noted from Table 5 that the load of first crack is (179kN) for the beam (BC4), appeared at the bottom face of slab and under point load. Also, we can see in the same table the decrease in the “ultimate load” (256.4kN). The percentage of decrease in (BC4) (42.4%). The reason for this decrease ther (BC4) was tested under simply support condition. This provided a longer length for the sample and thus less resistance to the forces imposed on them. beams (BC5 and BC6) reduction in the value of the ultimate load of a ratio (18.7% and 23.15%) respectively. The appearance of longitudinal and transverse cracks on the concrete surface additional to the lower face cracks upwards of the thickness of the beam. This reduction occurred due to decrease of the number of shear connectors from (36) in (BC2) to (18)in (BC5) and (9) in (BC6).

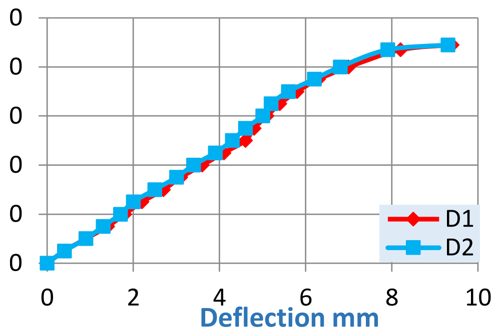
The response of each test beam is presented through load-deflection curves shown in figure (6) to (13).

Table (5) Ultimate Load and First Crack Load

Beams	First Crack Load Pcr (kN)	Ultimate Load Pu (kN)	Pcr / Pu (%)	Mid span deflection at (mm) ultimate load		Type of Failure
				D1	D2	
BC1	93	341	27.27	9.87	9.7	Buckling in the internal support and unsymmetrical web buckling
BC2	218	445	49	9.4	9.3	Yielding of the steel beam and buckling in the internal support
BC3	215	404	53.2	9.72	9.8	Yielding of the steel beam and buckling in the internal support
BC4	179	256.4	69.8	22.4	23	Yielding of the steel beam and
BC5	200	361.75	55.3	9.6	9.2	Buckling in the internal support and unsymmetrical web buckling
BC6	170	342	49.7	10.1	9.9	Buckling in the internal support and unsymmetrical web buckling



Load-deflection curve of the beam Figure (6): (BC1)



Load-deflection curve of the beam Figure (7): (BC2)

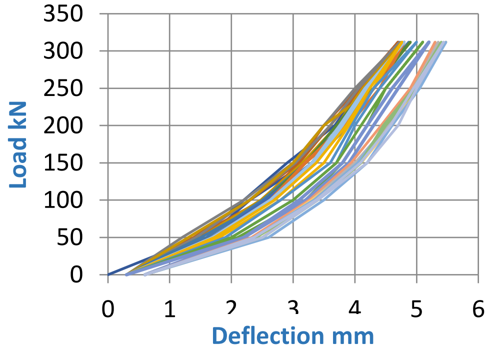


Figure (8): Load-deflection curve average (BC3)of repeated load(D1and D2)

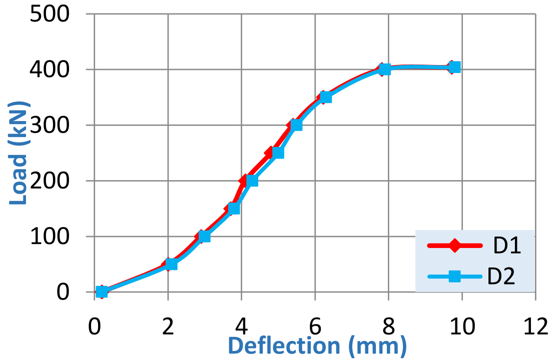
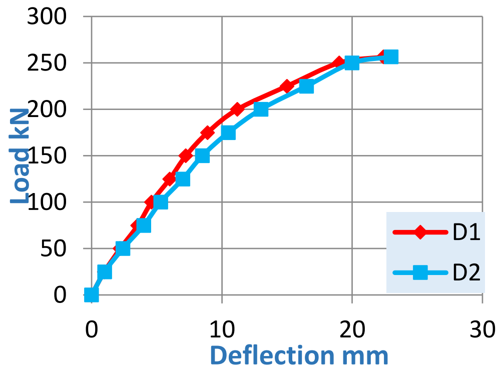


Figure (9): Load-deflection curve of repeated load beam (BC3), final loading



Load-deflection curve of the Figure (10): beam (BC4)

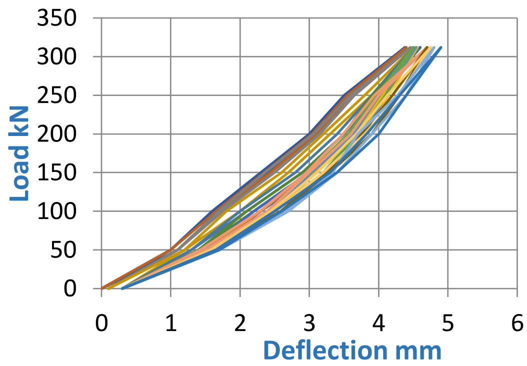


Figure (11): Load-deflection curve average (D1and (BC5)of repeated loadD2)

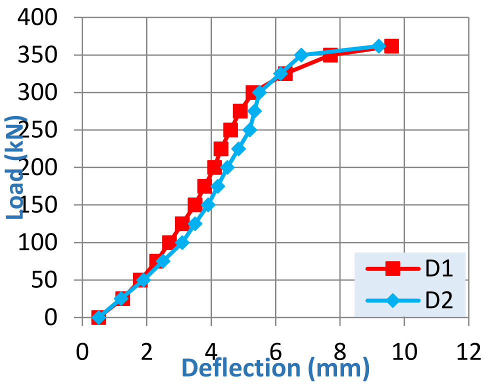


Figure (12) Load-deflection curve of repeated load beam (BC5), final loading

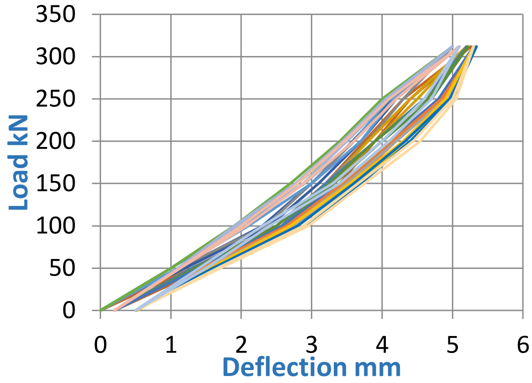


Figure (13): Load-deflection curve average (BC6)of repeated load(D1and D2)

The difference of the concrete type has a slight effect on the deflection, from a comparison of BC1 with a control beam BC2, The deflection increased by (5%) with decrease load by (23.4%). Deflection of repeated beams indicates that there is an increase in deflection at the same point and the same increment of load with the increase of the number of cycles. This causes not to return the beam to the original shape when the load decreased to zero level at the end of each cycle of loading. The increase in deflection occurred when tested beam (BC4) under simply supported condition. The increase has reached to (144.7%) compared to the control beam (BC2) with decrease load by (42.4%). The maximum deflection of the beam (BC4) at ultimate load is (23mm). The decrease in the number of shear connectors to (50% and 25%) from (BC2) for beams (BC5 and BC6) led to decrease in the ultimate load and the increase in the deflection with a reduction in the girder stiffness compared with control beam (BC2).

End slip readings are denoted as (S1) and (S2) Table (6). The few increased of the measured end slip value when used normal concrete in the beam (BC1). It is obvious, the increase of the measured end slip value in the sample (BC4) from the control beam (BC2) when tested under simply support. The beams of repeated load record slip values greater than control beams at the zone of repeated loading 70%Pu. This is may be caused by initial slip stored in the beam due to repeated loading. Results showed that the partial connecter increased the value of the end slip, so the comparison of the end slip results for the (BC5, BC6 and BC2) that the end slip results of beams (BC5, BC6) increased with a ratio (11.4% and 30.7%) respectively. All shape failure in Figure (14)

Table (6) Ultimate load and end slip at ultimate load

Specimens	Ultimate load (kN)	End slip (mm)		
		S1	S2	Average Slip
BC1	341	0.76	0.74	0.75
BC2	445	0.72	0.7	0.71
BC3	404	0.78	0.65	0.715
BC4	256	3.2	3.1	3.15
BC5	361	0.8	0.76	0.78
BC6	342	0.9	0.93	0.915

Figure (14) Cracks pattern of specimens

7) Finite Element Modeling

Finite "element analysis "by ANSYS (16.1) as "used in structural engineering"," determines overall the behavior of" structure "by dividing it into a number of single elements", each of "which has well defined mechanical" and physical properties. "Modeling of the constitutive material properties"is an important aspect of "any finite element analysis". The choice "of proper element type"is very important in FE analysis". The chosen "element type depend up on geometry of the "structure and number of independent"space coordinates necessary "to describe problem". Composite members "are made of different materials" i.e. steel, concrete, "shear connectors and reinforcing bars"," which are brought together to constitute a composite system". Table (7) Element types for working model.

Table (7) Element types for working model

Representation	Element Type
Concrete Slab	SOLID65
Steel I-Beam	SOLID45
Steel Reinforcement Axial action of stud connect	LINK180
Lateral action (slip) of stud connector	COMBIN39
Bearing contact between concrete slab and steel beam	CONTAC52
Supporting Base Plate	SOLID45

Studying the effect of the shear connectors number and distribution faces a difficulty in simulation the connectivity between stud's elements with concrete and steel beams elements. If the bond between concrete slab and steel beams is fully bonded (which can be achieved by using an excessive number of studs) this difficulty will be solved by connecting directly the neighboring concrete elements and steel beams elements through concerted nodes. Thus, a need for using more types of elements is appear to represent the bond action between concrete slab and steel beams. Figure 15 shows the overall finite element meshing of the test beams.

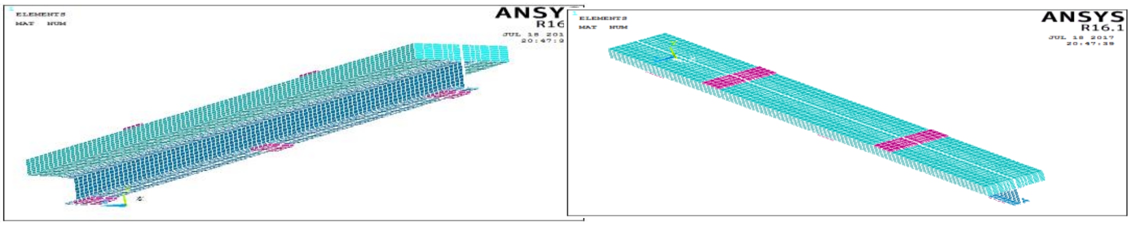


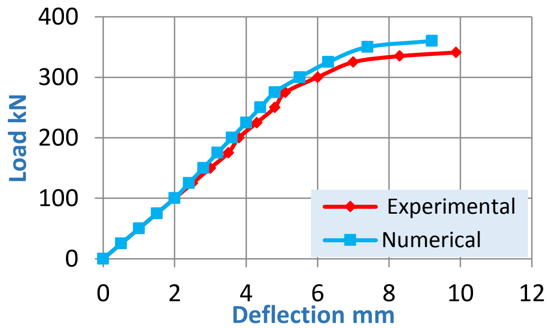
Figure (15) Geometry of numerical model

The “numerical result of ultimate load“, vertical deflection, “and horizontal slip are concerned“to compare them “with those of the experimental work“. This comparison was conducted to verify numerical model. “Table 8 shows a comparison between experimental and“numerical ultimate loads for study beams. In general, the ultimate loads which predicted“by the numerical analyses “were rather greater than those of experimental testing“.

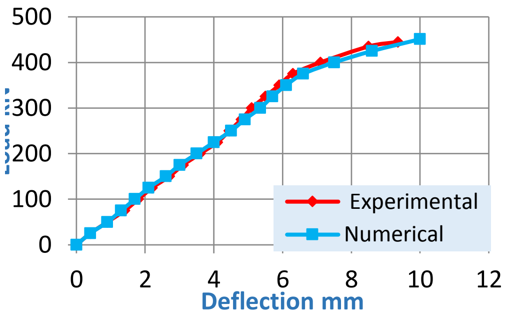
Table (8) Comparison of Load and Deflection at Ultimate Stages for the Tested Beams

Beam	Ultimate Load Pu (kN)		Max. Deflection (mm)	
	Experimental	Numerical	Experimental	Numerical
BC1	341	360	9.87	9.2
BC2	445	451	9.4	9.834
BC3	404	412	9.72	8.955
BC4	256.4	275	23	22.41
BC5	361	376	9.6	8.42
BC6	342	353	10.1	9.23

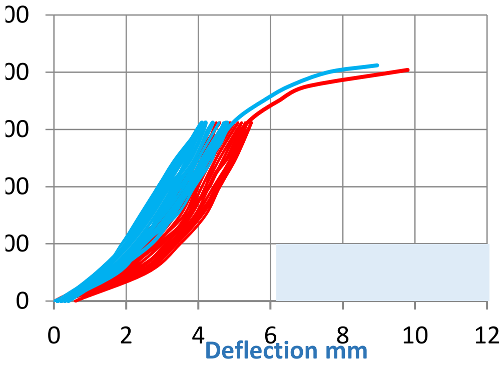
A comparison between mid-span deflection at ultimate load of the experimental tested beams with numerical at mid-span deflection from finite element models as shown in Figure (16) to (21).

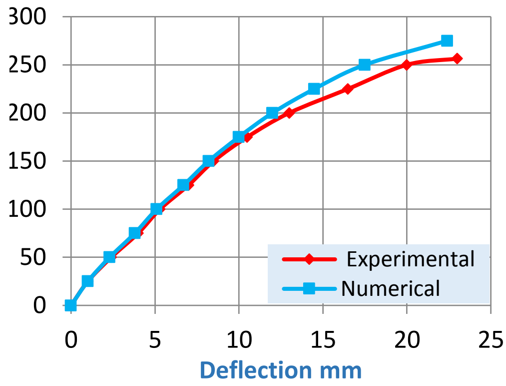


Figure(16): Load-deflection relationship of the beam (BC1)



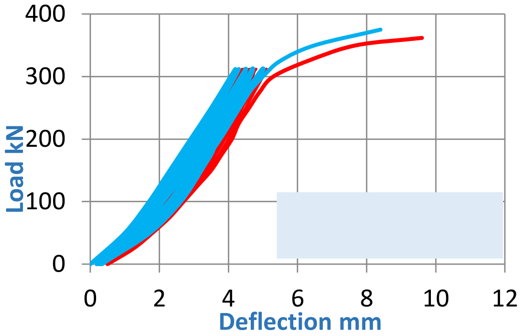
Figure(17): Load-deflection relationship of the beam (BC2)

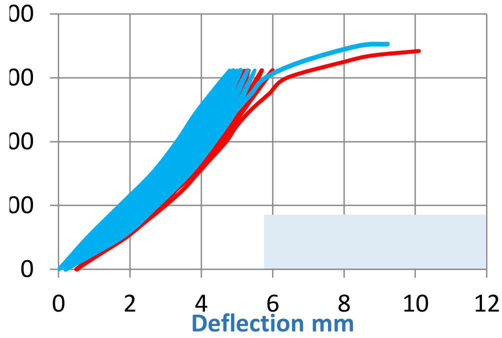




Figure(18): Load-deflection relationship of the beam (BC3)

Figure(19): Load-deflection relationship of the beam (BC4)





Figure(20): Load-deflection relationship of the beam (BC5)

Figure(21): Load-deflection relationship of the beam (BC6)

The previous tables and figures presented comparison between experiment, numerical result related to load, “deflection“, and slip for all the beams of the present study. “This“ comparison shows in general that the numerical models are stiffer, and the“ “numerical“ analyses give a “smaller“ “result for the deflection“ and greater for ultimate load. These differences may be due to the following reasons:

1. The concrete of experimental beams are not perfectly homogeneous as assumed in numerical models.

2. The compressive strength of the tested concrete cubes may not represent exactly the actual compressive strength.

3. Finite element modeling based on assumed displacement field gives stiffer structure.

4. Numerical integration on element volume based Gauss-Techinqe means surveying the plastic behavior at (Gauss) points which is not so efficient to cover all important points in each element.

8)Conclusions

1.The general behavior during test process is similar for all tested samples.

2.The mode of failure of RPC with steel fibers exhibited ductile behavior. Steel fibers resulted in more closely spaced cracks, reduction in the crack width and improvement in the resistance to deformation.

3.The first cracks are formed at about (27%-70%) of the ultimate load level of testing beams. This percentage is changed from a case to case of the present study.

4.The ultimate load increased when uses reactive powder concrete instead normal concrete.

5.Repeated loading produces a residual deflection which increases with the increase of the level of the repeated load. The ultimate load value decreases with the increasing the repeated loading level.

6.The increase in the deflection and the end slip occurred when a test under simply supported condition. The increase has reached to (144.7%) for a deflection and (346%) for slip, while the decrease of the ultimate load was (42.4%).

7.The decrease in “number of shear connectors“ had a small effect on maximum deflections, while there was a “clear effect on ultimate“ load, so that “decrease number of shear“ connectors resulted a decrease in ultimate load.

8.The contain of steel fiber in mix resulted in a significantly enhanced ductility and capable of undergoing large deflections before reaching the ultimate load carrying capacity. This property is very important for structural members as it allows concrete to give warning before failure and preventing sudden collapse.

9.The general behavior of models of finite element represented in the load deflection and the load-slip plots showed good convention with the data of test from the experimentally tested composite beams.

CONFLICT OF INTERESTS.

- There are no conflicts of interest.

9) References

[1] M. G. Navarro and J. P. Lebet, ‘‘Concrete cracking in composite bridges’’, *Structural Engineering International Journal*, pp.184-190, 2001.

[2] H. W. Al-Thebhawi, ‘‘Nonlinear Finite Element Analysis of Composite Steel-Concrete Beams’’, Ph.D. Thesis, University of Technology, Iraq, 2005.

[3] S. R. Chandra and J. k. Elumalai, ‘‘Study of Macro Mechanical Proprieties of Ultra High Strength Concrete Using Quartz Sand and Silica Fum’’, *International Journal of Research in Engineering and Technology*, Issue: 09, Sep-2014.

[4] E. F. O’Neil and W. H. Dowd, ‘‘Reactive Powder Concrete: A New Material for the Construction Industry’’, Third National Concrete and Masonry Engineering Conference, San Francisco, CA, pp. 43-50, June 15-17, 1995.

[5] S. Collerpardi, L. Coppola, R. Troli, and P. Zaffaroni, ‘‘Influence of TheSuperplasticizer Type on the Compressive Strength of Reactive PowderConcrete for Precast Structure’’, Congress International BIBM'99 Venezia, PP. 25-30, 1999.

[6] C. Dauriac, ‘‘Special Concrete May Give Steel StiffCompetition’’, *The Seattle Daily Journal of Commerce*, pp.15, May 9, 1997.

[7] R. Warnock, ‘‘Short-Term and Time-Dependent Flexural Behavior of Steel- Fiber Reinforced Reactive Powder Concrete Beams’’. PhD. Thesis, University of New South Wales, 201 PP, 2005.

السلوك الانشائي للأعضاء المركبة المستمرة حديد – خرسانة المساحيق التفاعلية تحت الاحمال التكرارية

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الخلاصة:

يهتم هذا البحث بدراسة السلوك الانشائي للاعضاء المركبة المستمرة حديد–خرسانة المساحيق التفاعلية تحت تأثير الاحمال التكرارية. العتبة المركبة هي العتبة التي تتكون من بلاطة خرسانية مرتبطة بعتبة من الفولاذ بمقطع على شكل حرف (I) بواسطة روابط قص على شكل براغي ذات رؤوس. أجرينا الدراسة بجزئين عملي ونظري. حيث يتألف النموذج من بلاطة خرسانية مرتبطة بعتبة من الفولاذ بواسطة روابط قص تم تثبيتها بواسطة اللحام على السطح العلوي للشفة العليا لكل عتبة فولاذية . ابعاد البلاطة الخرسانية (x2200 x250 80 مم، الطولx العرضx العمق)، وابعاد كل عتبة فولاذيه (2200 x 142مم، الطولx العمق). ستة أنواع مختلفة من الاعتاب المركبة لدراسة عدة متغيرات وقياس عدة نتائج، مثل التحميل الاقصى، والانحراف، ونمط التشقق عند الحمل الاقصى .وكانت متغيرات الدراسة نوع الخرسانة (خرسانه عاديه وخرسانة المسحوق التفاعلي)، ونوع التحميل، ونوع شرط الحدود وعدد مختلف من روابط القص .في الجزء النظري، تم تصميم الاعتاب المختبرية عدديا وتحليلها باستخدام طريقة العنصر المحدود .وقد تم تنفيذ النماذج العددية في ثلاثة أبعاد من قبل حزمة البرمجيات ANSYS 16.1 .أشارت نتائج الدراسة إلى أن الاتجاه العام في الحمل النهائي هو الانخفاض باستخدام (استخدام خرسانة عادية وفحص تحت الحمل التكراري واسناد بسيط وتقليل عدد روابط القص)، بنسبة (23.4، 9.2، 42.4، 18.7، 23.15) ٪ على التوالي.

الكلمات الدالة: العضو المركب المستمر، خرسانة المساحيق الفعالة، الاحمال التكراية.