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PII: S2352-0124(18)30037-7  
DOI: doi:[10.1016/j.istruc.2018.03.012](https://doi.org/10.1016/j.istruc.2018.03.012)  
Reference: ISTRUC 268  
To appear in: *Structures*  
Received date: 7 February 2018  
Revised date: 20 March 2018  
Accepted date: 21 March 2018

Please cite this article as: Abathar Majid Abd Aoun, Ali Hameed Nasser Al-Mamoori, Ali Ghanim Abbas AL-Khafaji , Improvement of Flexural Strength of Precast Concrete Spliced Girder Using Reactive Powder Concrete in Splice Region. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Istruc(2017), doi:[10.1016/j.istruc.2018.03.012](https://doi.org/10.1016/j.istruc.2018.03.012)

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### ABSTRACT

This paper presents an experimental study of improvement of flexural strength of precast concrete spliced girders using reactive powder concrete (RPC) in splice region. Experimental work has been carried out on testing of eight full scale rectangular reinforced concrete girders divided into two groups, four of them were simply supported and the other four were continuous supported. Two of these girders (one of each group) were cast as one unit without splice region as a monolithic while the other were cast of three segments for each of them and then connected in the splice region by using hooked dowels and cast-in-place splice region. All the spliced and non-spliced girders has total length of (2800 mm) and have rectangular section of (150 mm width, 230 mm height). The parameters studied in this experimental work were the concrete types of the splice region (normal concrete, RPC with 1% of steel fiber ratio, and 2% of steel fiber ratio), supports type and comparing with normal concrete non-spliced girders. Experimental tests had been carried out to investigate the behavior of each girder like first cracking load, crack width, failure load, maximum deflection and failure modes. The test results showed that the value of ultimate load capacity of the girder with normal concrete splice region is less than the value of non-spliced girder for all cases that have been tested. Furthermore, the obtained results indicated a significant increase in stiffness and ultimate load of the spliced girders due to the effect of using RPC in the spliced regions resulting in a clear improvement in the overall performance of these girders. Also, the increase of steel fiber ratio from 1% to 2% in case of RPC splice was efficient in minimizing crack width and meanwhile reducing the possibility of corrosion of steel reinforcement.

Key words: Spliced girders, Reactive powder concrete RPC, Precast concrete

## 1. INTRODUCTION:

It is widely known that the precast concrete girder bridges have taken a great interest in the recent three decades due to the high quality, high strength, and economical cost to produce a very long girders that difficult of transportation as a one unit. As a solution for this problem and to accelerate the construction of bridges taking into account the cost, spliced precast concrete girder bridges has been produced [1]. The splicing technique of concrete girder has provide significantly increasing in span ranges of precast concrete girders. It has also used for reducing the number of interior supports which be consider as an obstacle for navigation where this method is less expensive than other alternatives for this purpose. Typically spliced girders has consisted of two or more segments connected to each other at short splice region and casted in place at the site of project to obtain the total length of the girder that has been required.

There are limited studies had been carried out about the experimental tests on the spliced girders. In 1993 **Garcia** [2] described the implementation of a continuous posttensioned bulb-tee girder system in Florida. The test was conducted prior to the full production of the bulb-tee girder system for the Eau Gallie Bridge near Melbourne, Florida. The specimen consisted of two (145 ft) length girders spliced together at an intermediate support. Failure of the specimen was governed by flexure at the intermediate support. The specimen exhibited highly ductile behavior of the post-tensioned bulb tee girder system and a capacity significantly greater than the design loads.

**Holombo, Priestley, and Seile** in 2000 [3] described the overall behavior of precast prestressed spliced girders with superstructure column continuity. The primary objective of this study was focused on the behavior of splices between the girder and the bentcap under seismic load. The experimental work was applied on two 40 percent scale model bridge structure. These girders were spliced with posttensioned strand through the supporting bent. The two model of bridge superstructure displayed ductile behavior under the force, and the displacement exceeded the seismic requirements. The superstructure exhibited mainly elastic response throughout the tests with development of minored cracks. In (2008) **Al-Mamuree** [4] presented experimental and analytical investigation on pre-stressed concrete girders with field splice. The experimental and theoretical variables were types of support and load, splice location, amount of the area of pretensioned reinforcement, the effect of posttensioning reinforcement, and whether the girder has pre-stressed or not. The test implemented on sixteen rectangular section of concrete girders, eight of them were spliced girders and the other were without splices as a reference for comparison purposes. The tested girders were of different lengths, supports location, and splicing locations. Each of the spliced girders consisted of three segments. Hooked dowels were used for splicing method, and temporary supports were sitting down the spliced regions. The applied load was either concentrated or distributed, the deflection and strain were measured at mid span of the girder. Analytical study was carried out using three dimensional finite element computer program (written in fortran). Results showed that at about 50% of the ultimate load which is approximately corresponds to the serviceability limit state, the deflection of the spliced girders is greater than those of the reference non-spliced girders in the range of (10%-15%) and the ultimate loads for the non-spliced girders are greater than those of the spliced girders in the range of (12%-17%). It was also found that when the area of posttensioned reinforcement increased from (50%-100%), the deflection was decreased from (8%-14%) and the ultimate load was increased by (11%-16%).

**Al-Quraishy** in 2012 [5] presented experimental and theoretical investigations for behavior of precast concrete girders with connections. Fifteen rectangular cross section specimens spliced and non-spliced reinforced concrete beams were tested. The

experimental variables were strengthening the splice region by steel plate and using post-tensioning of the spliced girders. Nonlinear three dimensional finite element (ANSYS) computer program has been used to represent all the spliced and non-spliced girders. Hooked dowels and cast-in-place joint were used in the spliced girders. All the test girders had total length of (1500 mm). The load was applied as two points load for the all girder specimens. The results indicated generally that there was a good consensus among experimental and theoretical studies, where the highest difference in the ultimate load ranging from (3%-11%), and the difference between the results of deflection by the range (3%-20%). It was also found from experimental results that using of steel plates in the splice region has given continuity, nevertheless using of bottom plate only was enough to provide continuity and to resist the flexural strength in this region.

**Williams** in 2015 [6] studied the behavior of the cast-in-place region of spliced I-section girder bridges. The experimental program was applied to show the behavior of spliced I-section girders, more specifically. The primary objective of that research work was to evaluate the structural behavior of the Cast-In-Place splice region. Two large scale of simply supported concrete girder specimens were tested, each girder consist of two precast segments connected together and cast-in-place splice region. Three posttensioning tendons were used to provide continuity along the girder length of (50 ft.). The amounts of longitudinal reinforcement within the bottom flanges of the test girders were varied between the two specimens to show the effect of the bars on the behavior of the splice region. Each of the tested girders were loaded monotonically until the specimen exhibited a shear-compression failure of the web concrete. The results showed that spliced girders failed at shear strengths exceeding calculated values, furthermore splice region details were recommended based on the results of the research program.

## 2. EXPERIMENTAL TESTS

### 2.1 Specimens

Eight reinforced concrete girders have been tested for representing the experimental variables of the research plan. Two of these girders have been casted without splice as a monolithic to be reference girders and the other girders consisted of three precast concrete segments connected at splice region using hooked dowels and cast-in-place in the splice region. All the spliced and non-spliced girders have total length of (2800 mm) and rectangular section of (150 mm width, 230 mm height). The girders were divided into two groups, simply supported and continuous according to the supports. Each group has consisted of four reinforced concrete girders. The simply supported girders have the reference girder for the comparison purpose which cast as one segment while the other have consisting of three segments spliced at the quarter of the girder length from each edge. The spliced girders have differ from each other in term of spliced region characteristics. The splice region in the girder (SSG-1) was made from normal concrete, while in other two spliced girder was made from reactive powder concrete. In the reactive powder concrete splice, the steel fibers were used with two volumetric ratios, the first was ( $V_f = 1\%$ ) for girder (SSG-2) and the second was ( $V_f = 2\%$ ) for girder (SSG-3). The continuous girders group also have the reference girder as one segment for the comparison purpose while the other three were spliced girders consisting of three segments. The region of splice in this group was at the inflection points, i.e. approximately at zero moment points. The variables that used in this group were the same that for the first group. The details of all girders for

the two groups are illustrated in Table (1). Dimensions of the tested girders, details of the reinforcement, type of support and characteristics of splice region were explained in Figures (1).

Table (1): Variables of the Tested Girders

Group	Type of support	Name of specimen	Length of splice region (mm)	Type of concrete in splice region
1	Simply supported	SSG-R	Without splice (reference)	--
		SSG-1	300	NC
		SSG-2	300	RPC:1% steel fiber
		SSG-3	300	RPC :2% steel fiber
2	Continuous	CG-R	Without splice (reference)	--
		CG-1	300	NC
		CG-2	300	RPC:1% steel fiber
		CG-3	300	RPC :2% steel fiber

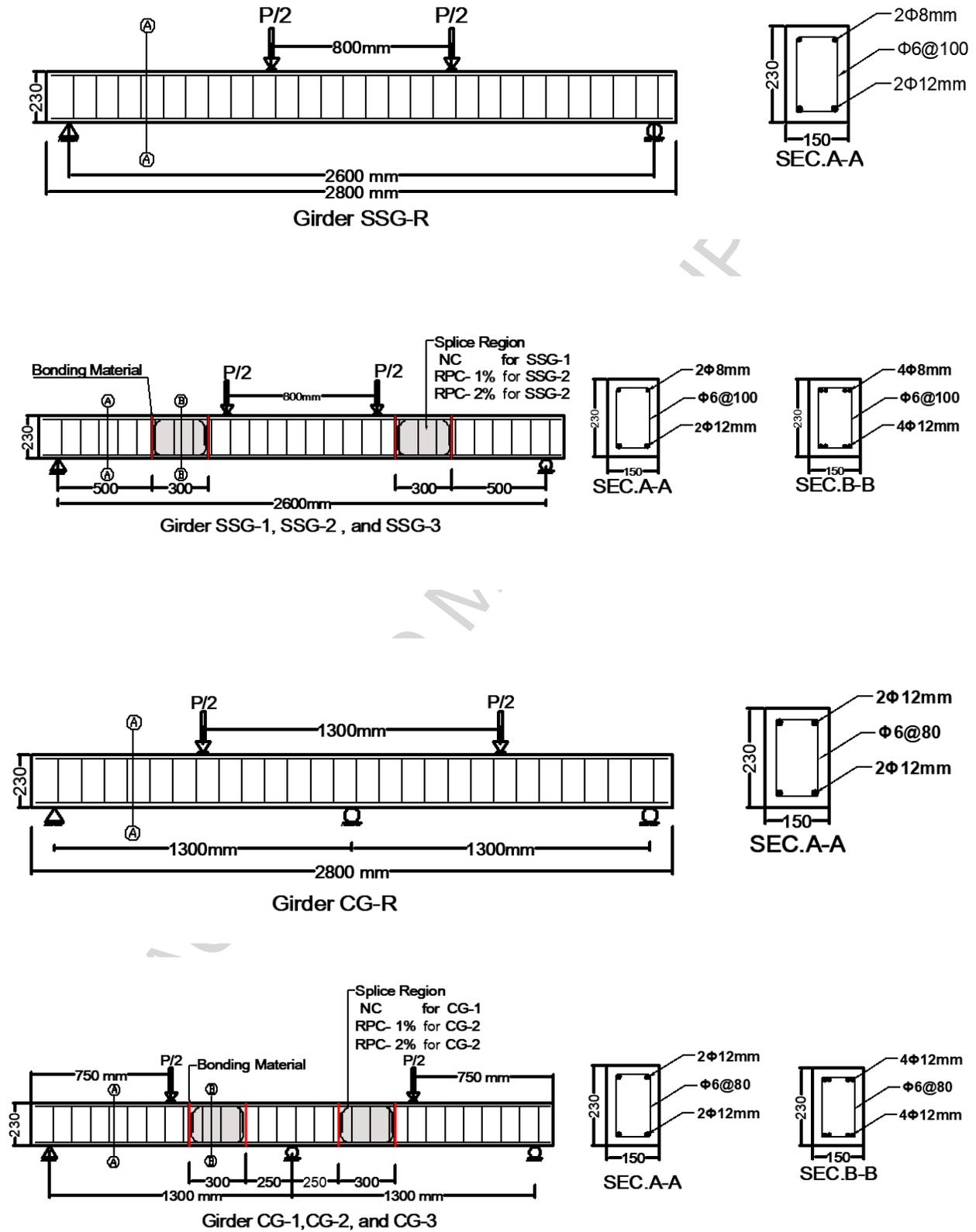


Figure (1): Details of the Tested Girders

## 2.2 Materials

### 2.2.1 Concrete:

Two types of concrete have been used in experimental work, normal concrete (NC) and reactive powder concrete (RPC). The normal concrete mixture consisted of Portland cement (type V), sand with maximum particle size of 4.75 mm, coarse aggregate with maximum particle size of 19 mm, and tap water. Some trial mixes have been carried out to get the required strength. The mix proportions for normal concrete are shown in Table (2).

Table (2): Mix Proportions of Normal Concrete (NC)

Mix	Cement (kg/m <sup>3</sup> )	Gravel (kg/m <sup>3</sup> )	Natural sand (kg/m <sup>3</sup> )	W/C
NC	563	787	680	0.4

The reactive powder concrete was also manufactured by Portland cement (type V), very fine sand with maximum particle size of 600  $\mu\text{m}$ , silica fume, steel fiber, super plasticizer and low water/cement ratio. The type of silica fume which used in the RPC mixtures of the experimental program was commercially known as (Megaadd MS (D)) and produced in UAE. This type was a very fine pozzolanic material consisted typically of amorphous silica that produced by electric furnaces as a secondary production. The silica content was 20% from weight of cement as additive. Table (3) shows the main properties of silica fume used in the present study which conforms the requirements of ASTM C-1240, 2005[7].

Table (3): Characteristics of Silica Fume Used in the Present Study

Property		Test result	Limit of specification requirements ASTM C-1240
Color		Grey powder	---
Density (kg/m <sup>3</sup> )		600	(500-700)
Specific gravity		2.25	(2.1-2.4)
<b>Chemical properties</b>	SiO <sub>2</sub> %	87.6	85.0 (minimum)
	Moisture content %	0.8	3.0 (maximum)
	Loss of ignition %	3.8	6.0 (maximum)
<b>Physical properties</b>	Specific surface m <sup>2</sup> /gm	21	15 (minimum)
	Percent retained on 45 $\mu\text{m}$ NO (325)	7	10 (maximum)

Hooked ends steel fibers have been used in RPC mixture with two volumes fraction ( $V_f = 1\%$ , and  $V_f = 2\%$  by volume of cement only). The steel fibers used in the present study were manufactured in Istanbul, Turkey. Table (4) presented the properties of this type of steel fiber, and figure (2) shows a sample of it.

Table (4): Characteristics of Steel Fiber \*

Property	Data
Diameter (D)	1.05 mm
Average length (L)	50 mm
Aspect ratio (L/D)	47.6
Tensile strength	1100 N/mm <sup>2</sup>
Relative density	7860 kg/m <sup>3</sup>
Modulus of	200 GPa
Melting point	1482 °C



Figure (2): Sample of Steel Fiber

\* Supplied by the manufacturer

A high range water reducing admixture (super plasticizer) was used in the producing of RPC. It was supplied by Sika Company under the name of (Sika ViscoCrete®-5930).

Many mix proportions were carried out to obtain required compressive strength according to some previous studies (Al-Amery 2013[8], and Kindeel 2015[9]). The selected proportions of materials were listed in Table (5).

Table (5): Mix Proportions for RPC

Mix	Cement (kg/m <sup>3</sup> )	Silica fume (kg/m <sup>3</sup> )	Fine sand (kg/m <sup>3</sup> )	W/(cementitious materials)	SP (kg/m <sup>3</sup> )	Steel fiber* V <sub>f</sub> (kg/m <sup>3</sup> )
RPC-1	960	192	1000	0.2	19.2	54
RPC-2	960	192	1000	0.2	19.2	108

\* The amount of steel fibers was calculated as a percentage of cement volume only.

### 2.2.2 Steel Reinforcement:

Three sizes of steel deformed reinforcement bars were used in the present study. Bar size of (φ8 mm) and (φ12 mm) have been used for longitudinal reinforcement while the size of bar (φ6 mm) was used for stirrups. Tensile tests on three specimens for each bar size according to ASTM A615/A615M-05a [10] have been carried out. The yield and ultimate stresses for these bars are listed in table (6).

Table (6): Properties of Steel Reinforcement

Bar size (mm)	Actual diameter (mm)	Elongation (mm)	Yield stress (MPa)	Ultimate stress (MPa)
Φ 6	5.62	7.3	510.4	540.5
Φ 8	7.74	14.2	592.9	659.9
Φ 12	11.89	14.3	636.2	706.8

## 2.3 Concrete Casting and Curing

### 2.3.1 Precast concrete segments

Normal strength concrete was used to cast all precast segments. The mold were prepared and oiled of the internal surfaces for easiness of mold output after hardening of concrete. After well mixing of the materials and getting homogeneity of the mixture, the concrete was decant into the mold by three layers and compaction was provided by using electrical rod vibrator for some minutes to remove the voids and to prevent occurrence of segregation problem. The surface was leveled and covered by nylon sheet to reduce loss of mixture water due to evaporation. After 24 hours of casting the molds were opened and the concrete samples were cured by water of temperature 25°C. The stages of casting and curing of precast segments are illustrated in Figure (3).



Figure (3): The Stages of Casting and Curing of Precast Concrete Segments

### 2.3.2 Splicing of the Precast Segments

The precast segments are placed in the molds in longitudinal direction. All spliced girders consist of three precast segments connected together by two splice regions. Two types of concrete had been adopted for the splice region; the first type is normal strength concrete (NC) and the second type is reactive powder concrete (RPC). Special epoxy material called commercially (Sikadur®-32 LP) has been used in order to provide enough bonding

between old and new concretes. Figure (4) shows the splice regions of the simply supported and continuous girders.

Spliced region for simply supported girders



Spliced region for continuous supported girders

Figure (4): Joint region of Spliced Girders

After well mixing of the materials, it was poured carefully into the joint regions and nylon sheets have been used to cover this area to minimize the loss of water of mixture by evaporation. The molds around the joints have been opened in 24 hours after casting, then curing of specimens in 60°C temperature water was adopted until 3 days and completed to 28 days in 25°C temperature water. Figure (5) shows the curing of spliced reinforced concrete girders in basins which were filled with water.



Figure (5): Curing of Spliced Reinforced Concrete Girders

## 2.4 Testing Procedure

After 28 days of curing the samples (after casting the splice regions), girder specimens have been moved from the water basins and the surface of the attached area has been leveled, cleaned and painted by white color so as to clarify cracks and distinguishing the failure modes during testing. In simply supported girders the loads have been applied by two points of steel plates under a rigid rode with 400 mm distance from each side of girder center in longitudinal direction. In continuous girders two supports have been placed at 100 mm distance from each end of the girder while the third support has been placed under the center of girder. However, the effective length of each one of the two spans was 1300 mm.

Concentrated loads have been applied at the centers of each span where the distance between the two points of loading was 1300 mm. The test was carried out on the girder up to failure by using hydraulic testing machine with 2000 kN ultimate capacity shown in figure (6). The load was applied progressively at increments of (6 kN) up to failure.



Fig. (6): Hydraulic Testing Machine of Concrete Girder Specimens

The deflections have been measured by using LVDT of 20 mm settlement capacity. LVDT was placed on a magnetic holder beneath center of the span. The width of cracks has been determined by using a microscope type AEM40X with accuracy of 0.05 mm as shown in Figure (7).



Figure (7): The Microscope used in the Present Study

### 3 Experimental Results

For both types of concrete (NC and RPC) and for each batch, control specimens have been taken to determine the mechanical properties of concrete. Control specimens were included three standard cubes of dimensions (100\*100\*100) mm for compression strength test, six cylinders of dimensions (100\*200) for splitting tensile strength test and modules of elasticity test and two prisms of dimensions (100\*100\*500) mm for modules of rupture test (flexural strength).

### 3.1 Mechanical Properties of NC and RPC

Test results of mechanical properties of NC and RPC are listed in Table (7). The mechanical properties reached of NC are compressive strength of 32.16MPa, modulus of elasticity of 27350MPa, splitting tensile strength of 3.5MPa, and flexural strength of 4.21MPa. While, the reactive powder concrete (RPC) with 1% steel fibers, the mechanical properties reached are compressive strength of 95.3MPa, modulus of elasticity of 42750MPa, splitting tensile strength of 11.66MPa, and flexural strength of 9.57MPa. It has noticed that from these results that when steel fibers ratio increases from 1% to 2%, the compressive strength, modulus of elasticity, splitting tensile strength and flexural strength of RPC increase by 15.6%, 9%, 19.2% and 50.88%, respectively. It is clearly shown that the effect of steel fibers on splitting tensile strength and flexural strength is higher than that on the compressive strength and modulus of elasticity. This confirms that steel fibers are used essentially to enhance the tensile properties of RPC. The above results were found similar to those obtained by other researchers [11, 12].

Table (7): Mechanical Properties of NC and RPC

Type of concrete	Description of segment	Steel fibers ratio $V_f$ %	Compressive strength (cube) MPa	Compressive strength (cylinder) MPa	Modulus of elasticity MPa	Splitting tensile strength MPa	Flexural strength MPa
NC	precast	0	40.4	32.16	27350	3.35	4.21
	Splice region	0	38.5	30.96	25400	3.23	3.39
RPC	Splice region	1	110.8	95.3	42750	11.66	9.57
		2	124.5	110.2	46600	13.9	14.44

### 3.2 Results of Tested Girders:

The tested girders were divided according to the support conditions into two groups: the first was simply supported and the second group was continuous supported.

#### 3.2.1 Simply Supported Girders:

##### 3.2.1.1 Load- Deflection Behavior

The load –deflection curves of the tested simply supported girders are shown in Figure (8). Deflections have been measured at the mid-span of girders for each load increment. In general, at early stages of loading; girders behave elastically with no visible cracks which explains the behavior of girders before the first cracking load. At further stage, girders tend to shift from elastic behavior and become rather to possess a nonlinear behavior with visible minor tension cracks. After that (at the third stage), the flexural cracks continue to propagate toward the compression zone, then yielding in tension steel reinforcement occurs and the girders behave plastically. The first crack load, ultimate load, and maximum deflections were illustrated in Table (8).

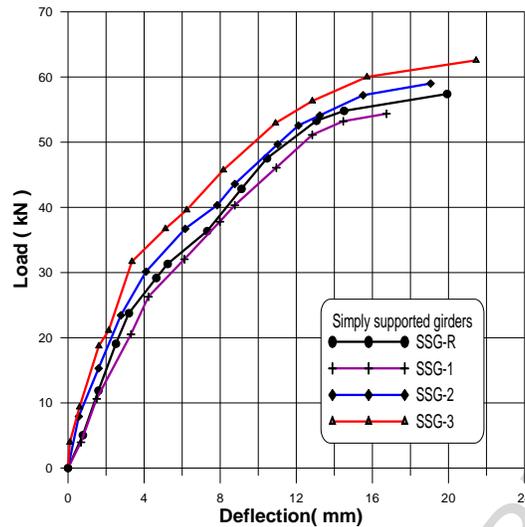


Figure (8): Load-Deflections Curves for Simply Supported Girders

Table (8) Results of Tested Simply Supported Girders

Girder Name	Type of concrete in splice region	First cracking load	Ultimate load kN	$P_u/P_{u(Ref)}$	Max. deflection
SSG-R	Without splice	21	57.4	1	19.93
SSG-1	NC	19	54.3	0.94	16.74
SSG-2	RPC:1% steel fiber	20	59	1.03	19.06
SSG-3	RPC :2% steel fiber	21	62.56	1.09	21.45

### 3.2.1.2 Crack Patterns and Failure Modes

Under the influence of applying load, there are several kinds of cracks that appeared at various load stages and different regions. Flexural, diagonal cracks, and special kind of cracks that appeared only in the interfaces between precast segments and the joint region known interface cracks. The cracks start from the bottom surface of the girder specimens and prorogate upward with increasing the loads. The first crack was appeared in the simply supported one unit reference girder named SSG-R at load of (21 KN) and it was occurred in the region of constant moments between the two points of load in the tension surface. When the applied load has increased, the width of cracks increases also and the cracks propagates along the girder length and extended to the top.

In the simply supported NC splice girder named SSG-1, the first flexural crack was noticed between the two points of loading in the tension zone of girder at load 19 KN after the interface cracks were occurred at the interfaces between precast segments and joint region at load 15 KN. The interface cracks firstly appeared at the interfaces near the point load. When the loading was increased, flexural and interface cracks extended to the compression zone of girder and they were increased in width. Other flexural cracks had been appeared especially at the area between the two point loads. While, in the simply supported 1% and 2% steel fiber RPC girders SSG-2 and SSG-3 flexural cracks were appeared firstly at load 20 kN and 21 kN respectively, and they are observed approximately at mid-span, also the

interface cracks between the precast segments and joint regions were also appeared at load 24 kN and 26 kN respectively. Mode of the failure in the most girders of this group was by tension control known flexural failure. Crack patterns and failure modes of the tested simply supported girders are explained in Figure (9). The crack width was determined using a microscope type AEM40X with an accuracy of 0.05 mm. The measurement process begins during the appearance of crack where the loading process stops for a short time and the microscope places on the crack region to measure and record crack width against the corresponding load. The loading process continues until the next desired crack reading in order to create the crack width - load relationship as plotted in Figure (10).

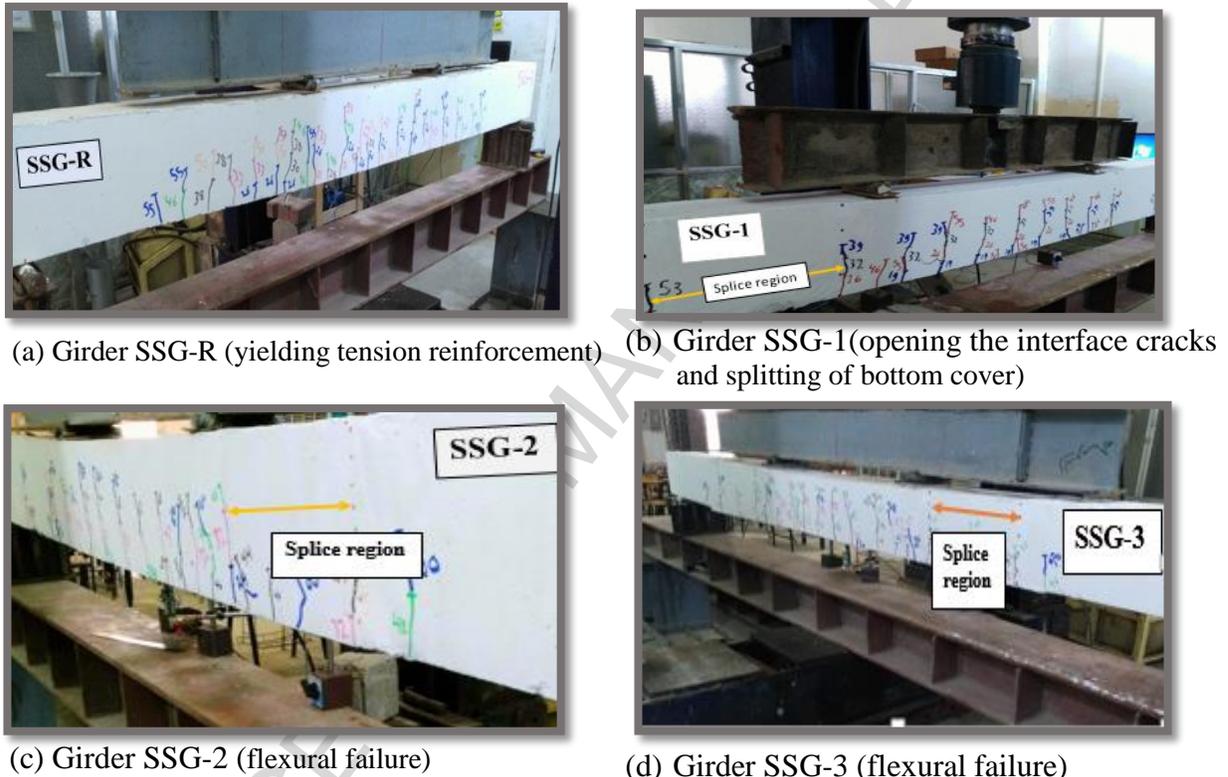


Figure (9) Crack Patterns and Failure Modes of Simply Supported Girders

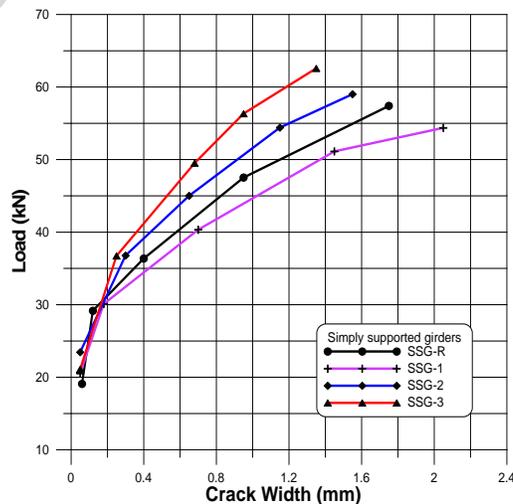


Figure (10): Load-Crack Width Curve of Simply Supported Girders

### 3.2.2 Continuous Supported Girders:

#### 3.2.2.1 Load- Deflection Behavior

This group consist also of four continuous reinforced concrete girders. One of these girders was casted as a one unit without splicing for comparison purposes whereas other three girders were spliced girders of three precast segments linked together at the inflection points of zero moments. The studied parameters that used in this group was similar to those used in simply supported girders as described previously in Table (1).

Figures (11) show the load –deflection behavior of the four tested continuous girders. Deflections were measured at center of each span of the girder for each load increment. The first crack load, ultimate load, and maximum deflections are explained in Table (9).

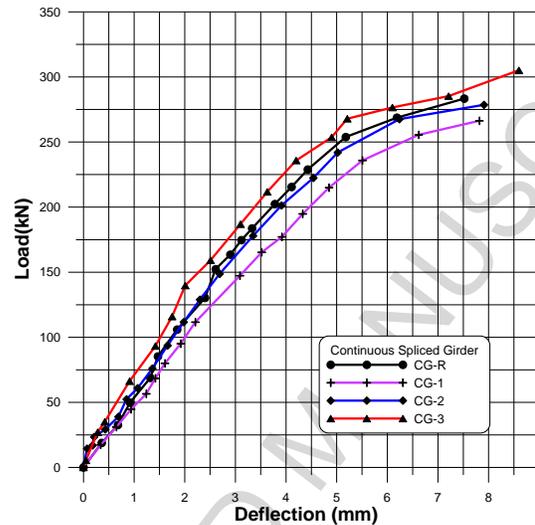


Figure (11): Load-Deflections Curves for Continuous Spliced Girders

Table (9) Results of Tested Continuous Spliced Girders

Girder name	Type of concrete in splice region	First cracking load	Ultimate load kN	$P_u/P_{u(Ref)}$	Max. deflection mm
CG-R	Without splice	73	283.3	1	7.52
CG-1	NC	46	266	0.938	7.82
CG-2	RPC:1% steel fiber	51	278.5	0.983	7.91
CG-3	RPC :2% steel fiber	62	305.1	1.077	8.6

#### 3.2.2.2 Crack Patterns and Failure Modes:

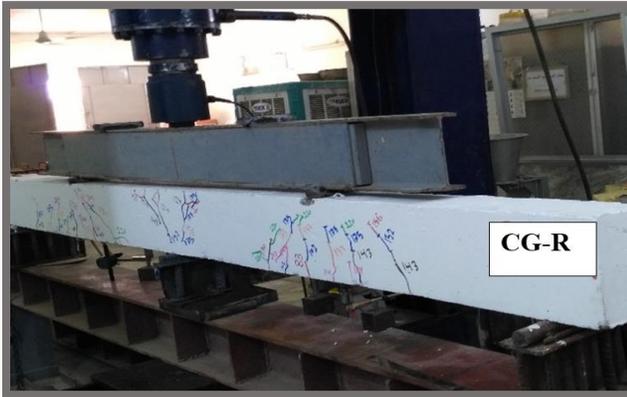
Several types of cracks were appeared when applying the loads, flexural and diagonal cracks were observed in the non-spliced girder in addition to the interface cracks that noticed in the spliced girders at the interfaces of the precast segments and joint region. At the first stages of loading the cracks started from the bottom face of girder at the middle of

each span and extended to the top of girder with increasing the applied load. Then when the load was reached to about 50% or more of ultimate load, another cracks had started from the upper surface of girders at the top of intermediate support and trying to intersect, they had often propagated diagonally. In the continuous reference girder CG-R, the first crack was observed at load of (73 KN) under the point load at middle of span. Another flexural cracks wear appeared at the bottom of each span. When the load reached to about (124 KN) another cracks started from the top of girder and trying to intersect near the intermediate support. Diagonal cracks appeared at the bottom of girder of each span under applied load of (143 KN). These cracks went to the points of loading with increasing of load. The girder has failed by yielding the tension steel reinforcements (i.e. flexural failure) under load of (283.3 KN).

First crack was appeared in the continuous girder with NC splice CG-1 at load (30 KN) at the joint between precast segments and the splice area. These cracks are called as interface cracks then flexural cracks were observed at the middle of girder under load of (46 KN). When the applied load has increased, several flexural cracks have been occurred at the bottom of girder and then another flexural cracks started from the top of girder at the negative moment zone. This girder has failed suddenly by direct shear and splitting of concrete cover under load of about (266 KN).

The continuous 1% steel fiber RPC splice girder CG-2, early appearing of flexural cracks, interface cracks have been noticed under load of (37 kN) at the joint between precast segments and the splice area. Then flexural cracks were appeared at load of (51 kN) and they are found approximately at the middle of each span i.e. under the point load. When the load reaches to about (105 kN), another flexural cracks have been started from the top of girder at the intermediate support. The failure mode of this girder was the incidence of direct shear under load of about (278.5 kN).

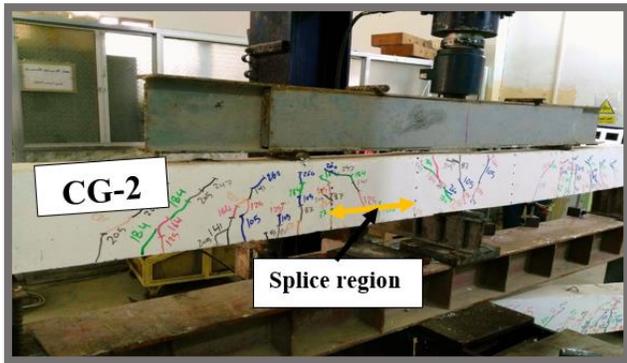
While, in the continuous girder of 2% steel fiber RPC CG-3, interface cracks were appeared at the joint between precast segments and the splice region under load of (50 KN). The first flexural crack was observed at the middle of each span under the load of (62 KN). Sudden failure has been occurred by direct shear when the load was increased to about (305.1 KN). Figure (12) shows the crack patterns and failure modes of the tested continuous girders. The microscope was used to determine the crack width as previously mentioned in the simply supported girders. The crack width with respect to incremental load relations for all continuous girders are explained in Figure (13).



(a) Girder CG-R(flexural failure)



(b) GirderCG-1(direct shear & splitting of concrete covers)



(c) Girder CG-2(direct shear failure)



(d) Girder CG-3(direct shear failure)

Figure (12) Crack Patterns and Failure Modes of Continuous Supported Girders

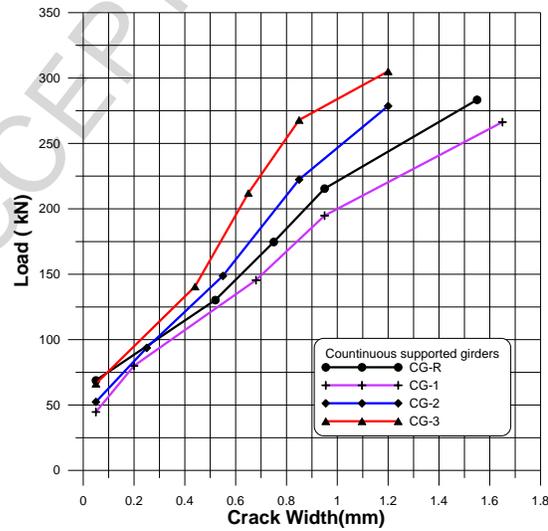


Figure (13): Load-Crack Width Relations of Continuous Girders

### 3.3 Effect of the Present Study Parameters

The main parameters which have been taken into account in the present study for both of the two tested girders groups are:

- 1- Effect of splicing technique.
- 2- Effect of type of concrete used in the splice region.
- 3- Effect of steel fiber ratio.

Detailed discussions for the effects of the above factors upon the results obtained from the experimental tests of girders are followed in the next sections.

#### 3.3.1 Effect of Splicing Technique

The first goal of this research work is to know the effect of splicing technique on the overall behavior of reinforced concrete girders. Splice region is often to be the weakest point in the spliced girders because of the effect of different stresses such as flexural, shear, and torsion on this region. It was found from the experimental results that the deflection of spliced simply supported girder (SSG-1) at load of 54 kN was higher than those of non-spliced simply supported girder (SSG-R) by 16 % whereas the ultimate load was smaller by 6.7%. Also, the experimental results showed that ultimate load of the continuous spliced girder of NC splice (CG-1) was less than that of non-spliced continuous girder (CG-R) by about 6.4% while the deflection was greater than by 28% at load of 266 kN. This decrease in the load carrying capacity of the spliced girders can be attributed to the presence of the splice region, which is considered a weak area in the flexural and shear stresses. The effect of the splicing technique on the performance of the reinforced concrete girders was similar to that mentioned by previous work [5].

Figures (14 and 15) are explaining the load- deflection curves of the reference girders (without splicing) and the spliced girders of normal concrete splice for simply support and continuous supports, respectively.

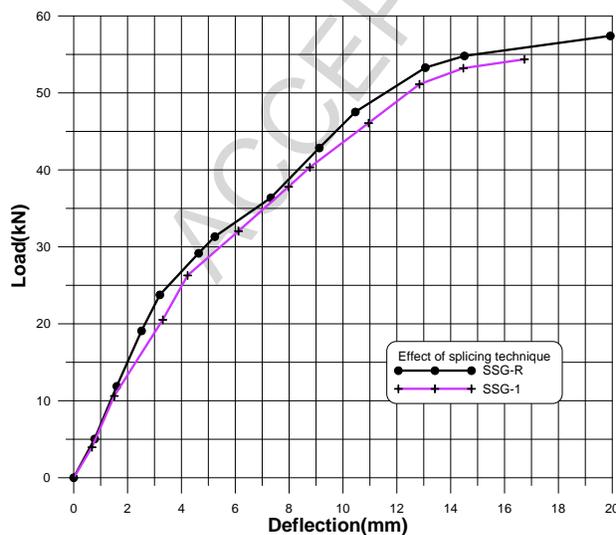


Figure (14): Effect of Splicing Technique of Simply Supported Girders

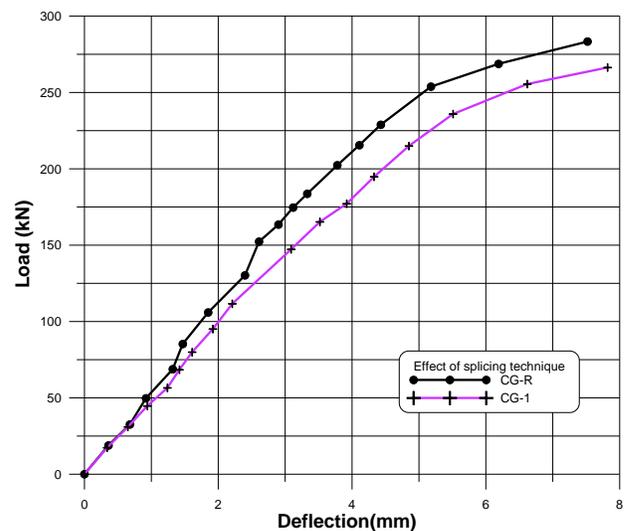


Figure (15): Effect of Splicing Technique of Continuous Supported girders

### 3.3.2 Effect of Type of Concrete Used in the Spliced Region:

Reactive powder concrete (RPC) was used instead of normal concrete (NC) in the splice region to determine the effect of this type of concrete on improving the general behavior of the spliced girder. The experimental results showed that replacement NC by RPC leads to increase the load carrying capacity of spliced girders. When used RPC in splice region, it would increasing the ultimate load by(8.6-15.2 %) as compared to the normal concrete(NC) in the case of simply supported girder, while in the case of continuous supported girder the ultimate load increase by ( 4.7-14.7 % ) , as explained in Figures (16 and 17).This improvement in the load carrying capacity of spliced girder can be attributed to the characteristics of reactive powder concrete used in the spliced region where owns this concrete compressive strength, tensile strength and modulus of elasticity higher than those in normal concrete , therefore this is reflected positively on the ultimate load ,as well as enhancement overall performance of the spliced girders.

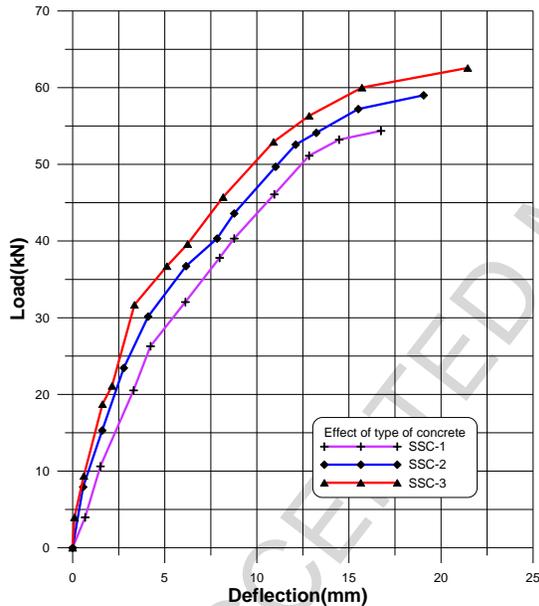


Figure (16): Effect of Type of Concrete in the Splice Region of Simply Supported Girders

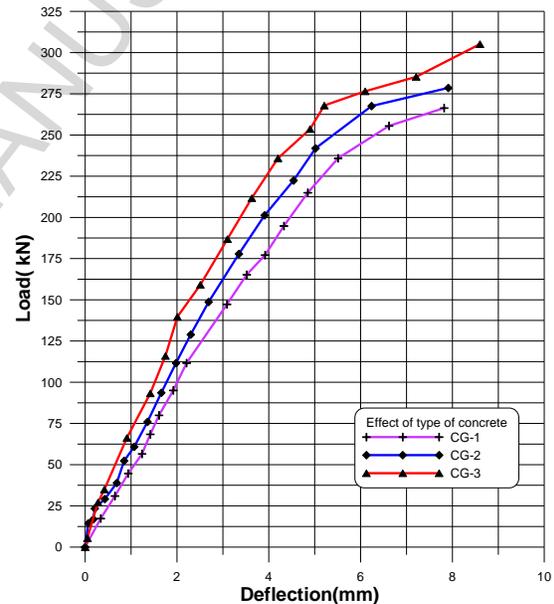


Figure (17): Effect of Type of Concrete in the Splice Region of Continuous Supported Girders

### 3.3.3 Effect of Steel Fibers Ratio:

To describe the effect of steel fibers ratio involved in the reactive powder concrete in the spliced region, two volumetric ratios of steel fibers (1% and 2%) have been used. The experimental results showed that when the volume ratio of steel fibers increased from 1 % to 2 % , the ultimate load increased from (59 to 62.56 kN) in simply supported girders with 6 % increasing, while in continuous spliced girders the ultimate load increased by 9.6 %.Also, for simply supported girders, at 50% of ultimate load, the deflections decreased

by 15 % when the steel fibers ratio increased to 2 %, while in continuous spliced girders , the deflections decreased by 20%. Finally, it is noticed that, increasing steel fibers volumetric ratio leads to enhancement of the overall behavior of spliced girders, because these fibers restricted cracks and increased the stiffness and consequently reduced the deflection of the spliced girders. Figures (18 and 19) show the effect of steel fibers ratio used in reactive powder concrete for the splice region on the behavior of spliced girders.

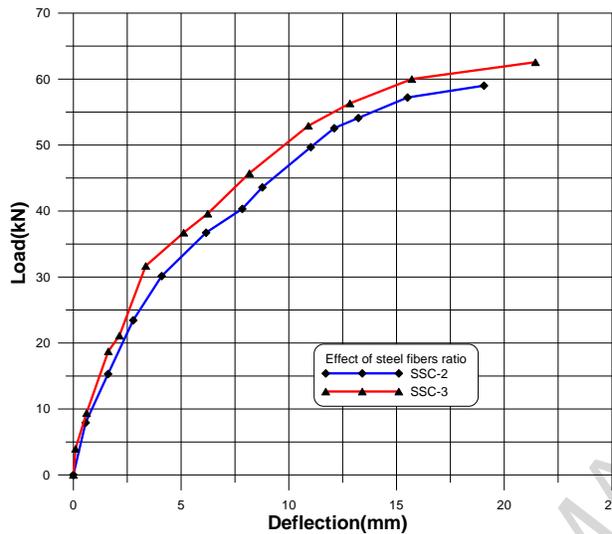


Figure (18): Effect of Steel Fibers Ratio Used in RPC in the Splice Region of S.S.Girders

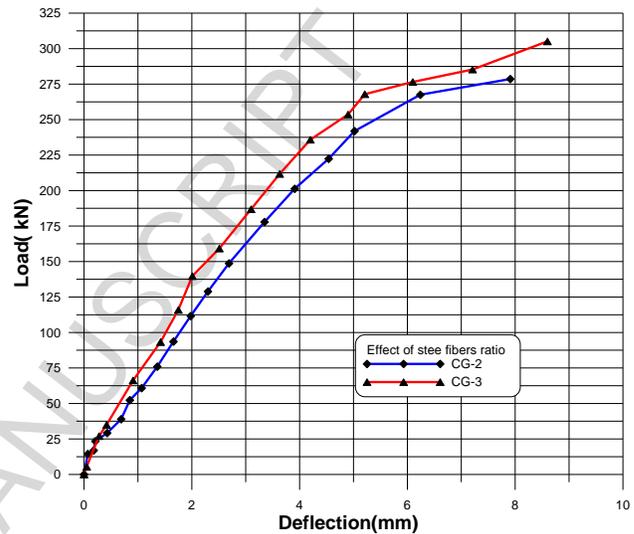


Figure (19): Effect of Steel Fibers Ratio Used in RPC in the Splice Region of C.S. Girders

## 4 Conclusions

Many conclusions can be extracted depending on the experimental results that have been obtained in the present study.

1. The results of testing showed that the ultimate load capacity of the spliced girders with normal concrete splice region is less than that of non-spliced girders as a result of the fact that the splice region is weak in carrying flexural and shear stresses. The decrease in the ultimate load capacity of the spliced girders may reaches up to 6.7% as compared to the non-spliced girders.
2. The obtained results indicated that improving the characteristics of the spliced regions using reactive powder concrete (RPC) instead of normal concrete (NC) improved significantly the overall performance of the spliced girders. This improvement led to increase the ultimate load of spliced girders to reach the level for that of non-spliced girders and sometimes exceeded it. The increase due to RPC splice reached up to 15.2% as compared with NC splice region.
3. It was observed that increase of the volumetric ratio of steel fibers from 1% to 2% for the reactive powder concrete of splice region was efficient to minimize the cracks width and meanwhile it will reduce the possibility of corrosion of steel reinforcement of spliced girders.

4. It is noticed that, the increasing of steel fibers volumetric ratio led to enhance the overall behavior of spliced girders, because these fibers restrained cracks and increased the stiffness and consequently reduced the deflection of the spliced girders.

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