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Replacing Reinforcing Steel Bars of Continuous Self-Compacting Concrete Slabs with Steel Fibers at Intermediate Support

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Abstract

In this paper, the use of steel fibers instead of the reinforcement steel bars in the continuous self compacted concrete slab panel was experimentally investigated. Tests were carried out on three two-span slab panels under mid span point loads and simply supported at the panels end. The first slab was reinforced by steel bars to resist the negative moments near the internal supports while the other two slab panels were reinforced by steel fibers only of percentage of volume fraction (0.5and 1.0) in this zone, without negative steel bars. The load-deflection relationship for the tested slab spans is determined, the first crack load, failure load and deflections were recorded. Also a comparison between the results obtained from this study and that obtained from other study of two continuous slabs made of normal strength concrete (CC) was made , one of these slabs was reinforced by steel bars near the interior supports and the other is reinforced by steel fibers of (1%) in this zone. The test results show that the use of steel fibers instead of the steel bars in the negative moment zone with steel fiber ratio of (VF=1%) increases the ultimate strength by (39%) and small deflection values at the first loading up to (15kN) while if the steel fiber ratio (VF =0.5%) increases the ultimate capacity by (11.7%) The comparison between the SCC slabs and corresponding CC slabs shows a similar load-deflection curve but the ultimate strength capacity for the SCC slabs with steel fiber gives ultimate strength larger than CC slabs with steel fibers, while the SCC slabs reinforced by steel bars which show an important effect on the first cracking loading in comparison with CC slabs.

1. Introduction

Self compacting concrete (SCC) is one kind of high performance concrete, and has been described as "the most revolutionary development in concrete construction for several decades". The main character of self compacting concrete is that there is no need of vibrating during construction process, and reducing manpower demand in the construction stages of concrete structures.

SCC requires new technologies that allow speedy and economical construction techniques and materials with improved strength, workability and durability. Steel fiber reinforced self-compacting concrete (SFRSCC) increases the tensile and shear strengths of concrete substantially, and reduces the size and the propagation of micro cracks [1]. Such concrete requires a high slump that can easily be achieved by super plasticizer addition to a concrete mixture. However, for such concrete to remain cohesive during handling operations, special attention has to be paid to mix proportioning. To avoid segregation on super plasticizer addition, a simple approach consists of increasing the sand content at the cost of the coarse aggregate content by 4% to 5% by weight[2,3].

2. Experimental Program:

The experimental program of this study consisting of preparation and testing of three slab panels, which are of (2000x250x50)mm dimensions for length, width and height, which is have symmetrically two span and subjected to point load at mid spans. The bottom reinforcement for positive moments is continuous for all panels while the reinforcing steel bars for negative moment are used only for one panel (reference) at mid support only. No shear reinforcement is needed. Steel fiber of ratios (0.5% and 1%) is used for the other panels for the same self compacted concrete mix and cross section dimensions. Figure (1) and (2) show the details of the slab panel.

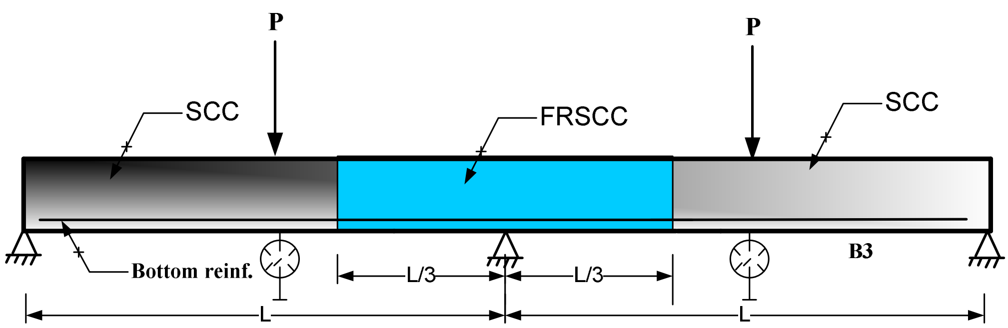


Figure (1) Slab Panel Setup

Figure (2) Slab Panel Details

Table (1) shows the reinforcement of the slab panels.

Table (1) Identification of the Slab Panels

Slab Designation	Reinforcement	
	Positive	Negative
SCC1	2 10mm Steel reinforcing bars at bottom	2 10mm Steel reinforcing bars at top of the interior supports
SCC2		Hocked end Steel Fiber (0.5%)
SCC3		Hocked end Steel Fiber (1%)

2-1 Materials

Table (2) and (3) show the properties of the materials used in the concrete mixture, while the Details of the mix proportions adopted are shown in Table (4).

Table (2) Description of Materials Properties

Material	Description
Cement	Ordinary Portland Cement (Type I)
Sand	Natural Siliceous Desert Sand from Al-Ukhaider region with maximum size (4.75)mm
gravel	Crushed Gravel with maximum size (12mm)
Limestone	Crushed Limestone with a fineness 3100cm^2 /gm(100%) passing sieve (0.075mm)[4]
Super plasticizer	Gelnium 51 conformed to the requirements of type A and F of ASTM 494 Standard
Reinforcing Bars	10mm deformed steel bars having yield strength fy=410MPa

Table (3) Fiber Properties

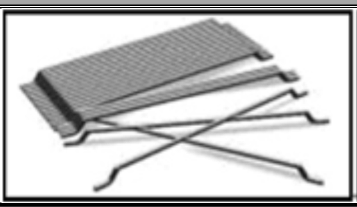
Steel Fiber	Description
	Hocked-ends Mild carbon steel fibers with average length of (50mm), nominal diameter of (0.5mm), aspect ratio of (100) and yield strength (1130MPa)

Table (4) Mix Proportion

W/C ratio	Water (kg/m^3)	Cement (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	Limestone (kg/m^3)	Super plasticizer (kg/m^3)
0.74	**185**	**250**	**739**	**870**	**250**	**2**

2-2 Test Measurements and Instrumentation
Hydraulic universal testing machine (MFL system) has been used to test the slab specimens as well as the cubes and cylinders. Central deflection has been measured by means of (0.01mm) accuracy and (30mm) capacity dial gauges . They have been placed at mid span of each span panel.

2-3 Compressive Strength Test
Two types of specimen shapes were tested to determine the concrete compressive strength. The concrete compressive strength was determined in accordance to ASTM C39 and BS1881. These types of specimens investigated were:

1. 150x300mm. cylinders.
2. 150x150x150mm. cubes.

The concrete compressive strength of each strength of mix represents the average of three specimens are tabulated in Table (5). The concrete specimens were tested at age 28 days of water curing.

2-4 Splitting Tensile Strength Test
Splitting tensile strength tests were conducted in accordance to ASTM C496 on cylinder of 150x300mm size. The splitting tensile strength of each mix is shown in Table (5) which represents the average of three specimens at the age of 28 days of water curing.

Table (5): Compressive Strength and Spliting Tensile Strength

mix	Fiber %	f_{cu} (MPa)	f'_c (MPa)	f_t (MPa)
SCC	0	29	23	2.75
	0.5%	31.2	25	3.8
	1%	33	26.5	7.5

2-5 Test Procedure
The slab panels have been tested using a universal testing machine (MFL system) by applying monotonic loading up to the ultimate state. The slab spans rest on a simple support over effective spans of 950mm and loaded with a single point load at midspans.

The slabs have been tested at ages of (28) days by placing them on the testing machine and adjusting so that the centerlines, supports, point loads and dial gauges were in the correct locations.

Loading has been applied slowly in successive increments, and the corresponding deflections were recorded with the observation of the crack developments until the slab failure.

3- Results and discussion
The obtained results from the experimental work are recorded to compare the failure loads of the slabs reinforced with negative reinforcement consist of steel reinforcing bars , (0.5%) and (1%) steel fibers. Also the load-deflection relationship for the tested slabs was drawn. It must be mentioned here that the compressive strength of the specimen CC (without steel fibers) equal (22MPa) is approximately the same value of SCC (without steel fibers) which is equal (23MPa).

3-1 First Cracking Loading, Ultimate Strength and Failure modes
It was observed that the crack pattern in all SCC slabs are similar in nature. Initially, hair line cracks were formed at the first crack load, then the increment of load caused the cracks to be greater and the slabs showed a tension flexural failure.

Table (6) shows the values of the first cracking loads, failure loads and mode of failure for the continuous self compacted concrete slabs tested in this paper and for the continuous conventional concrete slabs of Ref.[5].

Fig.(3 to 5) shows the failure forms of tested SCC slabs.

Table (6) Cracking, Ultimate loads and Modes of Failure of the Slabs

Specimens Designation	SCC1F(0%)	SCC2(F0.5%)	SCC3(F1%)	CC1(F0%)	CC2(F1%)
Pcr	18	21	25	8	10
Pu	34	38	48	31	43
Mode of Failure	Tension Failure	Tension Failure	Tension Failure	Tension Failure	Tension Failure

From the table above, it is seen that when the steel fibers is used by ratio (0.5%) instead of the reinforcing steel bars for the SCC specimens the first cracking load (Pcr) increases by (11.7%), while when this ratio increases to (1%) the value of Pcr increases by (39%) this is due to the ability of the steel fibers to reduce micro cracks and crack propagations, the use of (1%) steel fibers is more effective than the value of (0.5%).
It can be noticed that the value of Pcr in the CC with reinforcing steel bars is less than the corresponding slab of SCC by (56%), while the value of Pcr in the CC with (1%) steel fibers is less than the corresponding slab of SCC by (60%), the reason is the SCC slab had fewer pores and better bond with reinforcement and it usually spalled in smaller pieces than CC slabs.

Also the above table shows that the failure load of the SCC slabs that uses steel fibers of (0.5%) increases by (11.7%) when using reinforcing steel bars, while the failure load increased greatly by (41%) when the steel fibers is (1%), the ultimate strength of the SCC slabs with comparison with the corresponding CC slabs is increases by (9.6%) and (11.7%) when the reinforcing steel bars and steel fibers (1%) in the negative moments near internal supports of the slab spans is used respectively.

Fig.(3) Failure 0f SCC without Steel Fibers

Fig.(4) Failure of SCC with Steel Fibers (0.5%)

Fig.(5) Failure of SCC with Steel Fibers (0.5%)

3-2 Load-Deflection Relationships

Figures (6 to 8) show the load-deflection relationship at the mid span of the right and left spans of the tested slabs, it is seen from these figures that the SCC slab with reinforcing steel bars deflects with the increase of the load in the same manner of the SCC slabs if steel fibers is used, the curve for the right and left span for a specified slab is approximately the same. It is seen that the load-deflection curves for (1%)VF SCC in the right and left spans are identical. Fig.(9 to10) show a comparison of the load-deflection curve of the three tested slabs for each span, it is clearly observed that the ultimate load capacity of the slab increases largely when replacing the reinforcing steel bars with (1%) steel fibers content due to the good tensile strength of the fiber reinforced SCC, while there is no important effect on the deflection increment. It may be noted that the ultimate strength increases as the fiber content increases from (0.5 to 1%), while the increase in the ultimate strength is less important when replacing the reinforcing steel bars with (0.5%) steel fibers content.

Fig.(11 to 12) show a comparison between the two tested SCC slab spans (reinforcing steel bars and 1% steel fibers content) with the corresponding CC slab spans, it is observed from these figures that the SCC slabs and CC slabs have the same manner. Also it is noted that the ultimate strength of the SCC slabs increases in comparison with the CC slabs because of the good bond strength between the SCC materials, it is very clear that the difference in the strength capacity between the CC slabs and SCC slabs reinforced by (1%) steel fibers is large and more important in addition that the deflection values in the SCC slabs is less than the CC slabs which leads to recommend to use SCC with steel fibers in the continuous slabs in the negative moments zone.

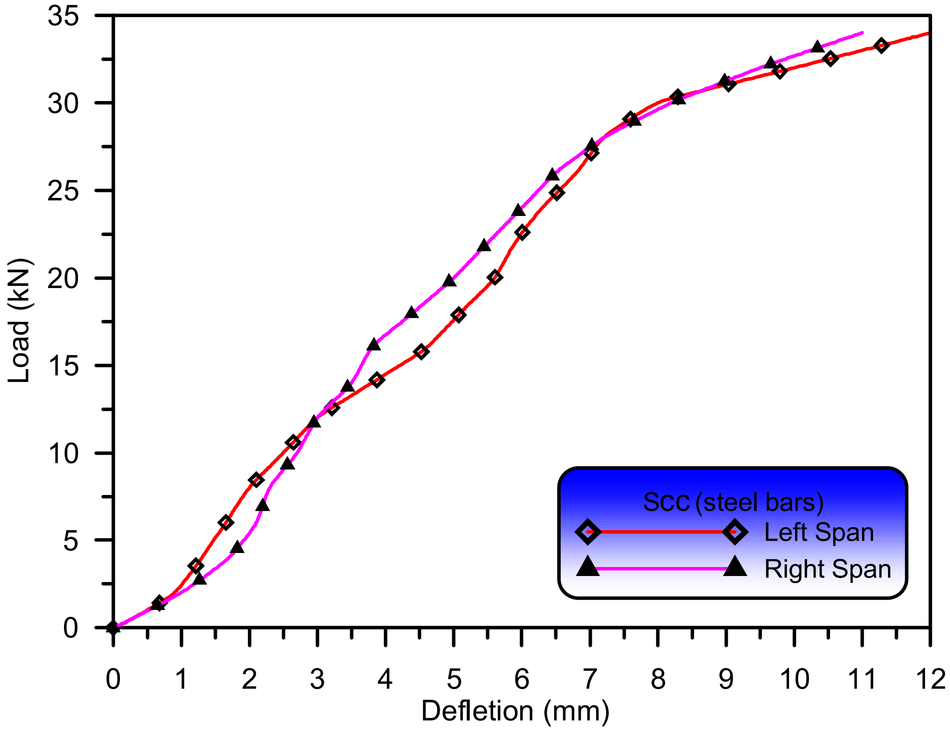


Fig.(6) Load-Deflection Curve of the SCC Slab with Reinforcing Steel Bars

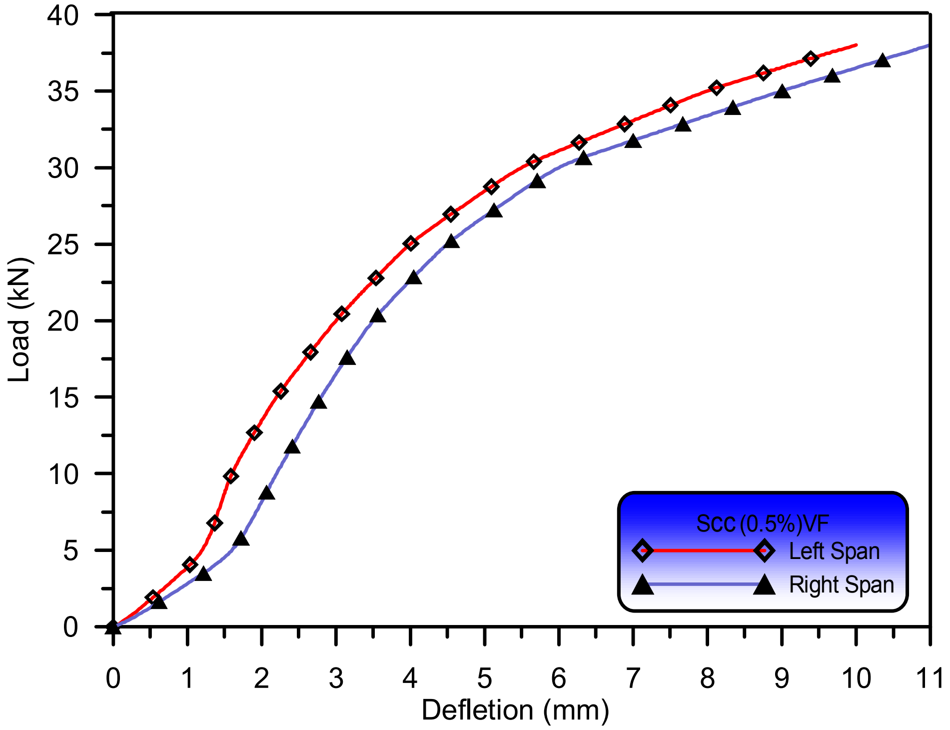


Fig.(7) Load-Deflection Curve of the SCC Slab with (0.5%) Steel Fibers Content

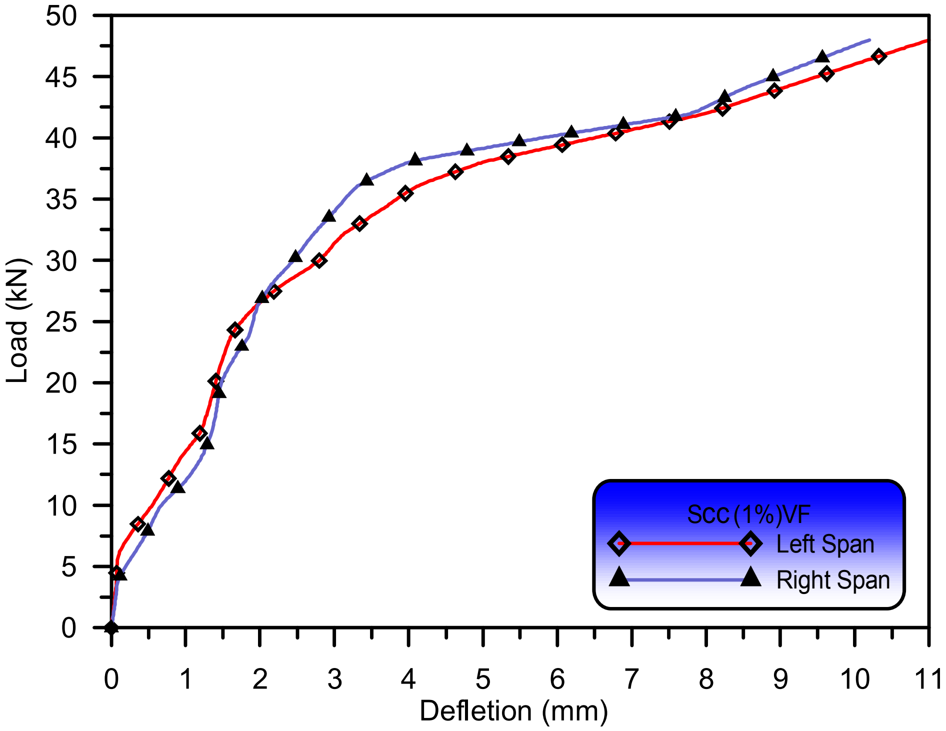


Fig.(8) Load-Deflection Curve of the SCC Slab with (1%) Steel Fibers Content

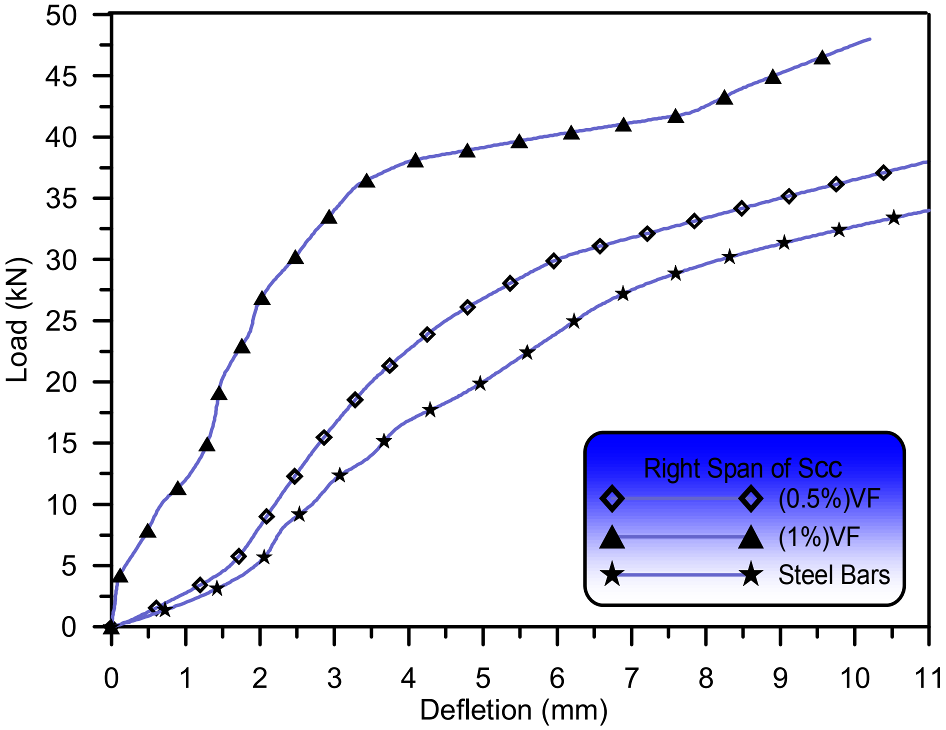


Fig.(9) Comparison of Load-Deflection of the Right Span of Tested SCC Slabs

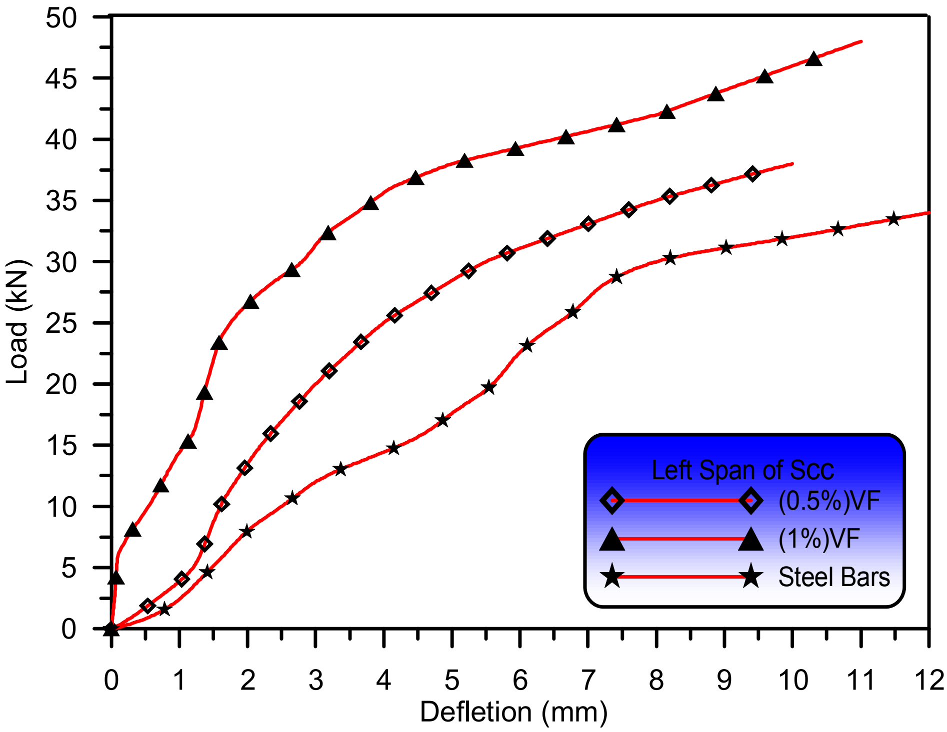


Fig.(10) Comparison of Load-Deflection of the Left Span of Tested SCC Slabs

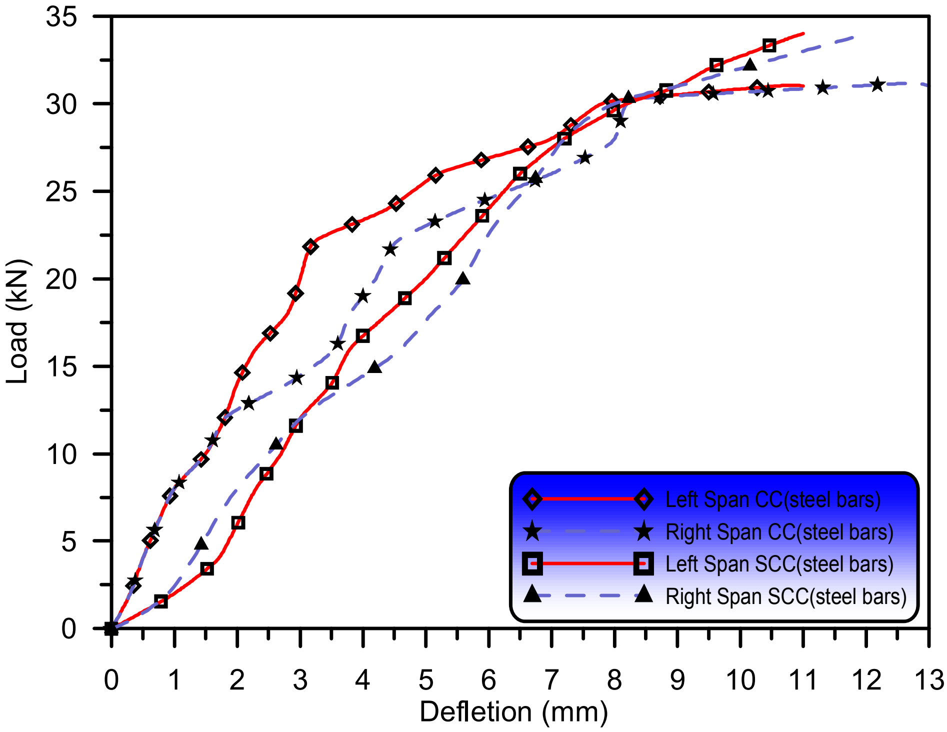
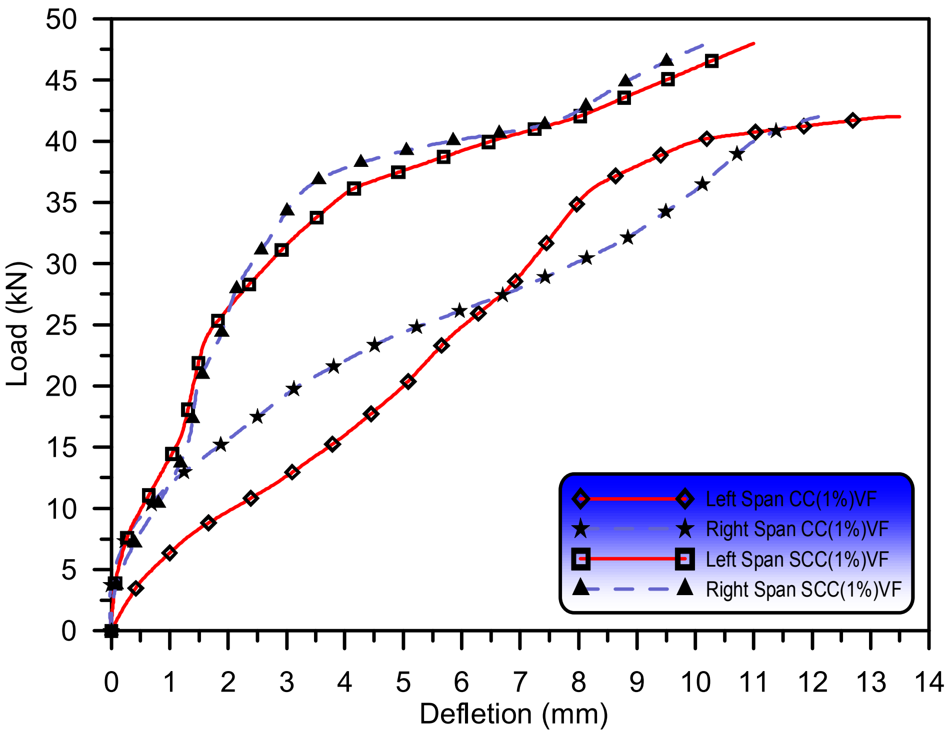


Fig.(11) Comparison of Load-Deflection with Bar Reinforcement of the CC and Tested SCC Slabs



(12) Comparison of Load-Deflection with Fiber Reinforcement of the CC and Tested SCC Slabs

3. Conclusions

The following conclusions may be listed based on the experimental results:

1. Replacing reinforcing steel bars with steel fibers in the continuous SCC slab panels at the interior supports increase the first cracking load from (18) to (25kN) if the steel fiber percentage of volume fraction is (1%) while it increases to (21kN) if the steel fiber percentage of volume fraction is (0.5%).
2. The ultimate strength of the slab increases from (34) to (48kN) if steel fibers of percentage (1%) is used instead of steel bars by (39%), while the increase in the strength is (11.7%) if steel fibers of percentage (0.5%) is used.
3. The load-deflection curves for the tested slab panels have the same manner, but when using steel fibers of percentage (1%) the deflection values are very small up to loading value of (15kN) .
4. In comparison with the CC slab panels, the load-deflection curves of the SCC slab panels show the similar behavior of the CC slabs.
5. When a comparison is made between the CC slabs and SCC slabs reinforced by steel bars in the negative moment zone, it is seen that the ultimate strength of the SCC slab increases by (9.6%) and the first cracking load increases by (56%).
6. The ultimate strength of the SCC slabs reinforced by (1%) steel fibers increases by (11.7%) more than the ultimate strength of the CC slabs and the first cracking load increases by (60%), while the flexural stiffness of the SCC is more better than that of CC slabs.
7. The use of the steel fibers of percentage of volume fraction of (1%) instead of steel bars at the interior supports of the continuous slab panels has a great benefit in improvement of the strength and much better than the use of the steel fibers of percentage of volume fraction of (0.5%).

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