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FLEXURAL BEHAVIOR OF STEEL FIBER-SELF COMPACT CONCRETE SLABS

Murtada A. Ismael
Lecturer, Civil Engineering Department, College of Engineering, University of Diyala
murtadaameer13@yahoo.com

ABSTRACT: - Self-compacting concrete (SCC) is one of the most important developments in concrete technology. Although SCC has high performance, but it like normal concrete in being brittle material with low tensile strength and poor fracture energy, therefore, steel fibers can be added to SCC to increase tensile strength, improve stiffness, improve fracture energy and improve flexural and shear strength. This research presents experimental study to investigate flexural behavior of steel fiber-self compacting concrete two way slabs. The experimental program include testing eight slabs to study effect of steel fibers volumetric ratio on normal and high strength SCC, effect of flexural steel reinforcement ratio and effect of compressive strength of SCC on flexural behavior. It is found experimentally that, the improvement in high strength SCC in terms of first crack load, ultimate load and ultimate deflection is less efficiency than that of normal strength SCC, however, as steel fiber increases from 0% to 0.8% in normal strength SCC, the first crack load, the ultimate flexural strength and the ultimate deflection increased with percentages (51.4%, 24.7%, and 30.8%) respectively, as compared with nonfiberous SCC slab, while the increases in high strength SCC were(18.2%, 19.2%, and 17.1%) respectively. Also the results showed that steel reinforcement and compressive strength has significant effect on flexural behavior of steel fiber-SCC slabs.
KEYWORD: Flexural Behavior, Self-Compacting Concrete, Steel Fibers and Slabs

1- INTRODUCTION

Self-compacting concrete (SCC) has been described as the most revolutionary development in concrete technology for the last two decades. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. Although SCC has high performance, it like normal concrete in being brittle material with low tensile strength and poor fracture energy; therefore, steel fibers can be added to SCC to increase tensile strength; improve stiffness, improve fracture energy and improve flexural and shear strength [1].

Few researches were presented dealt with using steel fiber with self-compacting concrete, some of them studied mechanical properties[2,3 and 4] and others studied structural behavior of beams[5,6,7, 8 and 9] , corbels[10],one way slabs[11] and, punching shear of two way slabs [12], but there are no studies investigate effect of steel-fibers self-compacting concrete on flexural behavior of two way slabs ;therefore, this research presents experimental study to investigate flexural behavior of steel fiber-self compacting concrete two way slabs under static load.

2. Experimental program

The experimental program consists of testing eight slabs using self compacting concrete with steel fibers to study effect of steel fiber volumetric ratio (V_f) in normal strength SCC , effect of steel fiber volumetric ratio (V_f) in high strength SCC, effect of steel reinforcement ratio (ρ) and effect of compressive strength (f_c') on flexural behavior of two way slabs. The slabs were divided into four groups as listed in Table (1). All slabs have the same dimension (450mm length, 450mm width and 50mm thickness) as shown Figures (1) and (2). The slabs were designed to have appropriate dimensions that can be manufactured, handled and tested as easy as possible.

3. MATERIALS

3.1 Cement

Ordinary Portland cement (Type I) supplied from Iraq, Sulymania, Tasloga factory is used in this study. Test results indicated that the chemical and physical properties of this cement conform to the requirements of the Iraqi specification No.5/1984 [13].

3.2 Fine aggregate

Natural sand from Al-Ukhaider region is used in concrete mix of this research. Before using it, the sieve analysis is performed at Material Laboratory in Engineering College of Diyala University. The fineness modulus is 2.7. The test results indicated that this type of fine aggregate grading conform to the requirements of the Iraqi specification No.45/1984 [14].

3.3 Coarse aggregate

Coarse aggregate or crushed gravel of maximum size 10 mm from Al-Niba'ee region is used. Before using it, the sieve analysis is performed at Material Laboratory in Engineering College of Diyala University to ensure its validity for mixing and choosing the primary proportions of mix materials. The test results indicated that this type of coarse aggregate grading conform to the requirements of the Iraqi specification No.45/1984 [14].

3.4 Limestone powder

Limestone powder is locally named "Al-Gubra" has been used as a filler in SCC. The particle size of the limestone powder is less than 0.125 mm (Sieve No.200), which satisfies EFNARC 2005recommendations [1].

3.5 High range water reducing admixture (Superplasticizer S.P.)

Superplasticizers (also known as high range water reducers) are chemical materials used as admixtures to reduce w/c ratio of concrete with keeping good workability [15]. In this study Superplasticizers based on sulphonated naphthalene which is known commercially as SP was used. SP can be used with all types of portland cement, including sulphate resisting and complies with ASTM C494type A&Fb[16].

3.6 Steel fibers

Macro straight steel fibers with aspect ratio of 52 (L/d=13mm/0.25mm) and yield stress of 1130 MPa were used. This type of steel fiber satisfied the requirements of ASTM A820/A 820M-04 [17]. Figure (3) shows steel fiber used in this study.

3.7 Steel reinforcing bars

Two sizes of deformed steel reinforcement bar were used (Ø6 mm with yield stress of 328MPa and Ø10 with yield stress of 418MPa) to form three types of bottom mesh reinforcement (flexural reinforcement) (4Ø6, 3Ø6 and 4Ø10 in each way in the two way slab) of steel reinforcement ratios (0.00679, 0.01496 and 0.01994) respectively. Figure (4) shows one of the mesh reinforcement used in this study. The test results of bars (ϕ6mm) and (ϕ10mm) satisfy ASTM A615 requirements [18].

4. CONCRETE MIX PROPORTIONS AND MIXING

Two types of concrete (normal strength SCC and high strength SCC) were used in this study. The classification of normal and high strength concrete followed ACI 363R6[19] in which the high strength concrete is the concrete has compressive strength more than 41MPa. Many mix proportions were tried to get the required compressive strength for each type of concrete. The materials proportions of each mix are listed in Table (2). Mixing and casting processes are performed at the Structural Laboratory of Engineering College in Diyala University. Figure (5) shows stages of materials mixing.

5. TESTS AND RESULTS OF FRESH SCC

In order to verify the fact that the concrete used in this research is SCC, the fresh concrete of each mix were tested according to three standard tests: Slump flow, T50 cm slump flow and L-box as shown in Figure (6) and Figure (7). Table (3) illustrates the results of the three tests and the comparisons with the standard limitations mentioned in EFNARC [1] . It can be noted that the results of all mixes tests satisfy the requirements of EFNARC [1].

6. MECHANICAL PROPERTIES OF HARDENED SCC

The mechanical properties of SCC for each mix are listed in Table (4) the compressive strength (**f_c'**) tests were carried out on cylinders (100x200mm) in accordance with ASTM-C39 [20]. Flexural strength (**f_r**) (modulus of rupture) tests were carried out on prisms (50x50x500mm) in accordance with ASTM C78 [21], while the indirect tensile strength (**f_t**) (splitting tensile strength) tests were carried out on cylinders (150x300mm) in accordance with ASTM C496 [22].

7. TESTING OF SLABS

All the slabs were taken out from the curing water tank at the age of 28 days after casting, left to dry, and then painted with white color so that cracks can be easily detected. The machine which is used in the tests is a universal hydraulic machine with (2000kN) capacity available in the Structural Engineering Laboratory, College of Engineering, Diyala University as shown in Figure (6). The slabs are simply supported along all edges by using solid steel frame of 50mm diameter. The slabs were loaded with one-point static load. The load was applied to the center of the top surface through a circular steel column of diameter (100mm) under hydraulic jack as shown in the Figure (7). The loads were applied in successive increments up to failure. A dial gauge of 0.002 mm accuracy was attached firmly to the center bottom face of the slabs to record center deflection as shown in the Figure (8). In every load step the central deflection was recorded.

8. RESULTS OF SLABS TESTS

8.1General behavior

Steel fiber-SCC slabs tests showed general behavior for all the slabs under flexural loading can be described as follows: at early stage of loading, the first cracks initiate at the center of bottom face, the load in this stage is known as first crack load. With increasing loads, radial cracks start to extend from the center toward the slab edges. At the same time the cracks increase in number and become wider. A complete failure occurred by increasing the load and all tested slabs were failed in flexure by yielding of the steel reinforcement.

Effects of four parameters on flexural behavior of steel fiber-SCC two way slabs in terms of first cracking load, ultimate flexural load, ultimate deflection, load-deflection curves and cracks pattern at the failure were studied and discussed in the following articles:

8.2 Effect of steel fibers volumetric ratio (V_f) on flexural behavior of normal strength and high strength SCC slabs

The results of these two parameters are listed in Table (5). It can be noted that when the steel fibers ratio increased from 0% (slab S1) to 0.4 % (slab S2) and 0.8% (slab S3), the first crack load (P_{cr}) increases to 4.8kN and 5.6kN which represents an increase percentages 29.7% and 51.4% respectively as compared with the nonfibrous slab (S1). Also for the same increase in the steel fibers ratio, the ultimate flexural load (P_{ult}) increases with percentages 16.9% and 24.7% respectively. While for high strength SCC slabs, Table (5) reveals that increase steel fibers ratio from 0% (slab S4) to 0.4% (slab S5) and 0.8% (slab S6) , the first cracking load (P_{cr}) increases with percentages 7.6% and 18.2% respectively as compared with the nonfibrous slab (S4). Also for the same increase in the fibers ratio, the ultimate load (P_{ult}) increases with percentages 11.2%and 19.2% respectively. The improvement in first crack and ultimate load with increase steel fiber ratio for normal and high strength SCC can be attributed to the fact that steel fibers provide obstruction for initiating and expansion of the cracks and contribute in carrying tensile stress of flexural loading.

On the other hand, Table (5) reveals that the ultimate central deflection (Δ_{ult}) increased by adding steel fibers, however, for normal strength SCC slabs , the increase percentage as compared with ultimate deflection of nonfibrous SCC slab (S1) was 14.1% for slab S2 (0.4% steel fiber) and 30.8% for slab S3 (0.8% steel fiber). While for high strength SCC slabs, the increase percentage of ultimate central deflection as compared with the nonfibrous SCC slab (S4), was 5.4% for slab S5 (0.4% steel fiber) and 17.1% for slab S6 (0.8% steel fiber). This behavior is attributed to the ability of steel fibers in limitation of cracks spreading ;therefore, steel fibers rather maintain the bearing capacity of slab throughout the post-cracking stages, hence, slabs could carrying greater loads and deflection before failure. Effect of steel fiber ratio on load-central deflection curves for normal strength and high strength SCC slabs are shown in the Figure (9) and Figure (10). It is clear from these figures that the curves had two portions with small transition zone; the first portion is linear elastic zone until the first crack load and the second portion began beyond first crack load until failure occurs in which steel reinforcement suffer from yielding. It can be also noted that effect of steel fibers on the linear elastic portion is very little but the effect become significant beyond the first crack load due to contribution of steel fibers in carrying tension stresses. Also these figures reveals that ,at all stages of loading the deflection decreases as the steel fibers increased ,this behavior belong to the improvement of slabs rigidity due to the increase compressive strength, modulus of elasticity and tensile strength. Furthermore, the area under load increase with increase steel fiber; thus, the toughness which consider index of ductility increase and the slab become more ductile. This property is very important for structural members since it prevents sudden collapse by giving warning before failure.

The above results reveal that, the improvement due to adding steel fibers in high strength SCC slabs in terms of first crack load, ultimate load and ultimate deflection is less efficiency than that of normal strength SCC slabs**,** this can be attributed to the tendency of high strength concrete to be more brittle than normal strength concrete; therefore, high strength concrete will suffer from a lot of cracks as compared with normal strength concrete, thus the contribution of steel fiber in restrict the cracks will be less efficiency than that of normal strength concrete which exhibits less cracking.

8.3 Effect of steel reinforcement (ρ)

Three ratio of steel reinforcement (ρ) (0.00679, 0.01496 and 0.01994) were used to investigate the influence of steel reinforcement ratio on flexural behavior of SCC two way slabs with 0.4% steel fibers. Table (6) list the results of this parameter. It can be observed that steel reinforcement ratio has very significant effect on first crack load and ultimate flexural strength. However, as steel reinforcement ratio increased from 0.00679 (slab S7) to 0.01496 (slab S2) and 0.01994 (slab S8) the first crack load increase with percentages 26.3% and 81.6% respectively. The increases in first crack load belong to the enhancement the crack control due to increase steel reinforcement and prevention the flexural micro cracks from further widening. On the other hand, as steel reinforcement increase with the same ratios, the ultimate load strength increased with percentages 27.6%, 79.8% respectively. The increases in the ultimate flexural loads belong to the fact that increase steel reinforcement ratio leads to increase tensile force, hence, the internal bending moment capacity of slab increases.

On the other hand, increase steel reinforcement ratio from 0.00679 to 0.01496 and 0.01994 results in increase the ultimate central deflection with percentages 31.0% and 25.5% respectively. The disproportionate relationship between steel reinforcement ratio and ultimate deflection belong to the fact that presence steel reinforcement enhance the stiffness and rigidity of the slabs and this enhancement make the slabs able to carry high loads until the failure occurs and these loads caused more deflections for slabs which became more ductile due to presence steel fibers with ratio (0.4%).

Figure (11) shows effect of steel reinforcement on load-central deflection curves. It can be observed that at all stages of loading, the deflections decreases as steel reinforcement ratio increase. Also effect of increase steel reinforcement begun from the first portion of the curves on the contrary with of effect steel fibers which appear significant after first crack, this belong to the difference between the effect mechanism of steel fibers and steel reinforcement, since steel fibers become active after cracking while steel reinforcement provide crack control and increase in the rigidity before cracking.

8.4 Effect of compressive strength (f_c')

Effect of compressive strength (concrete strength type) (f'_c) on first crack load, ultimate load and ultimate central deflection between the slabs which have the same steel fiber ratio are detailed in Table (7). It can be noted from the table that the improvement in first crack load and ultimate load capacity due to increasing compressive strength from normal to high strength decrease with increasing volumetric steel fiber ratio. However, the improvement in first crack load due to increase compressive strength from normal to high strength are with percentages (78.4%, 47.9% and 39.3%) for the steel fibers ratio (0%, 0.4% and 0.8%) respectively, while the improvement for ultimate load are with percentages (55.1%, 47.6% and 32.5%) respectively. It can be noted also from the Table (7) and Figures (12), (13) and (14) that the ultimate deflection decrease with increased compressive strength. On the other hand the reduction in ultimate deflection increased with percentages (5.7% ,12.9% and 15.6%) with increasing steel fibers from (0% to 0.4% and 0.8%) respectively. This reduction belong to the increase of compressive strength and flexural rigidity (EI) of the slabs.

9. CRACK PATTERNS

In all the tested slabs, concrete cracks initiate at the center of the tension face (bottom face) of the slabs and extend radially to the edges as shown in Figures. (15), (16) and (17) which show photographs of the crack patterns for the slabs at the failure. Effect of steel fiber ratio in normal strength SCC slabs on crack patterns can be seen from Figure (15), it can be seen that, as steel fiber increase from 0% (slab S1) to 0.4%(slab S2) and 0.8%(slab S3) the cracks become narrow and more numerous, this is attributed to the crack arrest mechanism of the steel fibers as it holds the parts of the crushed concrete and prevents its disintegration. Figure (16) shows the cracks at failure of high strength SCC slabs, it can be recognized that the nonfiberous (slab 4) has very wide cracks as compared with the cracks of slab S1 (normal strength SCC) and the increase steel fiber ratio to 0.4% (slab S5) and 0.8% (slab S6) make the cracks narrow due to the same reason mentioned above. Figure (17) shows effect of steel reinforcement ratio, it can be seen that slab S7 (ρ=0.00679) has few and wide cracks, while the cracks of slabs S2 and S8 (ρ=0.01496 and ρ=0.01994 respectively) are narrow, this attribute to the crack control of steel reinforcement which increase with increasing steel reinforcement ratio. Thus, although the mechanism of steel fibers different from that of steel reinforcement in arresting the cracks but their increasing effect on crack pattern at the failure is approximate.

10. CONCLUSIONS

Based on experimental results of this study it can be concluded that:

1. Adding straight steel fibers of aspect ratio L/d= 13/0.25 with volumetric ratio reach to 0.8% for SCC did not effect on their ability to filling, passing and segregation resistance.
2. Adding steel fibers to normal strength SCC slabs and high strength SCC slabs results in improvement its flexural behavior in term of first crack load, ultimate flexural load and the ultimate deflection. However, as steel fibers ratio increases from 0 to 0.8% the increases for normal strength SCC slabs are with percentages (51.4%, 24.7%, and 30.8%) respectively. While for high strength SCC slabs, the increases are with percentages (18.2%, 19.2%, and 17.1%) respectively.
3. The improvement in high strength SCC slabs due to adding steel fibers in terms of first crack load, ultimate load and ultimate central deflection of slabs is less efficiency than that of normal strength SCC slabs. This can be attributed to the tendency of high strength concrete to be more brittle than normal strength concrete; therefore, high strength concrete will suffer from a lot of cracks and crashing as compared with normal strength concrete, thus the contribution of steel fibers in restrict the cracks will be less efficiency than that of normal strength concrete which exhibits less cracking.
4. Steel reinforcement ratio has a significant effect in improvement first crack load and ultimate flexural load of steel fiber-SCC slabs. However, as steel reinforcement ratio increases from 0.00679 to 0.01496 and 0.01994 the first crack load and ultimate flexural load increase with percentages 26.3% and 27.6% respectively for the slab of tensile steel ratio 0.01496 and with percentages 81.5% and 79.8% respectively for the slab of tensile steel ratio. But the ultimate deflection in disproportionate relationship with increase steel reinforcement ratio.
5. The improvement in first crack load, ultimate load and ultimate deflection due to increasing compressive strength from normal to high strength, become less with increasing steel fiber ratio.
6. Increasing steel fibers ratio lead to decrease the central deflection of the slabs under flexural loading in all stages of loading although the ultimate deflection increase, this refer to increase the toughness and the ductility of the slabs due to extend the area under load-central deflection curve.
7. In all the tested slabs, the concrete cracks initiate at the center of the tension face (bottom face) of the slabs and extend radially to the edges. Although the mechanism of steel fibers different from that of steel reinforcement in arresting the cracks but their increasing effect on crack pattern at the failure is approximate in making the concrete cracks narrow and multiple.

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Table (1) the parameters and slabs details

Group No.	Parameter	Slab	V_f%	ρ	Compressive stress(concrete strength type)
1	Effect of steel fibers volumetric ratio (V_f) in normal strength SCC	S1	0	0.01496	Normal
		S2	0.4	0.01496	Normal
		S3	0.8	0.01496	Normal
2	Effect of steel fibers volumetric ratio (V_f) in high strength SCC	S4	0	0.01496	High
		S5	0.4	0.01496	High
		S6	0.8	0.01496	High
3	Effect of steel reinforcement ratio (ρ)	S7	0.4	0.00679	Normal
		S2	0.4	0.01496	Normal
		S8	0.4	0.01994	Normal
4	Effect of compressive strength (concrete strength type) on steel fiber-SCC	S1	0	0.01496	Normal
		S2	0.4	0.01496	Normal
		S3	0.8	0.01496	Normal
		S4	0	0.01496	High
		S5	0.4	0.01496	High
		S6	0.8	0.01496	High

Table (2): Proportions of SCC mixes used in this study per cubic meter

Mix type	Mix name	Cement (kg)	Limestone Powder (kg)	Water (liter)	Sand (kg)	Gravel (kg)	S.P* (liter)	Steel fibers
Normal strength SCC without fibers	M1	394	172	188	770	767	7.5	0
Normal strength SCC with 0.4% fibers	M2	394	172	188	770	767	8.5	31.4
Normal strength SCC with 0.8% fibers	M3	394	172	188	770	767	10	62.8
High strength SCC without fibers	M4	547	51	166	845	775	20	0
High strength SCC with 0.4% fibers	M5	547	51	166	845	775	22	31.4
High strength SCC with 0.8 % fibers	M6	547	51	166	845	775	25	62.8

*__Super plasticizer__

Table (3) Results of fresh SCC for slump flow and L-box tests

Mix name	Slump flow (mm)	T50 (sec)	L-box (H2/H1)
M1	780	2.0	0.98
M2	740	3.5	0.96
M3	710	4.5	0.89
M4	750	3.5	0.95
M5	700	4	0.97
M6	680	5	0.84
Limits of EFNARC[1]	650-800	2-5	0.8-1

Table (4) Mechanical properties of SCC mixes

Normal Strength SCC					
N0.of mix	Mix type	Steel fiber V_f%	f_c'(MPa)	f_r(MPa)	f_t(MPa)
1	M1	0	25.2	3.4	3.0
2	M2	0.4	28.7	4.6	3.8
3	M3	0.8	31.0	5.2	4.4
High Strength SCC					
N0.of mix	Mix type	Steel fiber V_f%	f_c'(MPa)	f_r(MPa)	f_t(MPa)
4	M4	0	56.2	5.4	4.8
5	M5	0.4	60.4	6.1	5.7
6	M6	0.8	62.6	6.4	6.2

Table (5) Effect of steel fiber ratio on flexural behavior of normal and high strength SCC slabs

Effect of Steel Fiber Volumetric Ratio (V_f) in Normal Strength SCC slabs			
Slab No.	**S1**	**S2**	**S3**
Mix	**M1**	**M2**	**M3**
f_c' (MPa)	**25.2**	**28.7**	**31.0**
Steel fiber (V_f) %	**0%**	**0.4%**	**0.8%**
ρ	**0.01496**	**0.01496**	**0.01496**
P_{cr}^* kN	**3.7**	**4.8**	**5.6**
$(P_{cr}-P_{crS1})/P_{cr\ S1}\times100$	**0**	**29.7%**	**51.4%**
P_{ult}^{**}kN	**17.8**	**20.8**	**22.2**
$(P_{ult}-P_{ultS1})/P_{ult\ S1}\times100$	**0**	**16.9%**	**24.7%**
Δ_{ult} mm***	**1670**	**1905**	**2185**
$(\Delta_{ult}-\Delta_{ultS4})/\Delta_{ult\ S4}\times100$	**0**	**14.1%**	**30.8%**
Effect of Steel Fiber Volumetric Ratio (V_f) in High Strength SCC slabs			
Slab No.	**S4**	**S5**	**S6**
Mix	**M4**	**M5**	**M6**
f_c' (MPa)	**56.2**	**60.4**	**62.6**
Steel fiber (V_f) %	**0%**	**0.4%**	**0.8%**
ρ	**0.01496**	**0.01496**	**0.01496**
P_{cr}^* kN	**6.6**	**7.1**	**7.8**
$(P_{cr}-P_{crS4})/P_{crS4}\times100$	**0**	**7.6%**	**18.2%**
P_{ult}kN	**27.6**	**30.7**	**32.9**
$(P_{ult}-P_{ultS4})/P_{ultS4}\times100$	**0**	**11.2%**	**19.2%**
Δ_{ult} mm**	**1575**	**1660**	**1845**
$(\Delta_{ult}-\Delta_{ultS4})/\Delta_{ult\ S4}\times100$	**0**	**5.4%**	**17.1%**

*** P_{cr} :First crack load**
**** P_{ult} :Ultimate load**
*****Δ_{ult} : Ultimate deflection**

Table (6) Effect of steel reinforcement ratio on flexural behavior of SCC slabs

Effect reinforcement ratio (ρ) on SCC slabs			
Slab No.	S7	S2	S8
Mix	M2	M2	M2
f_c' (MPa)	28.7	28.7	28.7
Steel fiber (V_f) %	0.4	0.4	0.4
ρ	0.00679	0.01496	0.01994
P_{cr} kN	3.8	4.8	6.9
$(P_{cr} - P_{crS7})/P_{crS7}\times100$	0	26.3%	81.6%
P_{ult} kN	16.3	20.8	29.3
$(P_{ult} - P_{ultS7})/P_{ultS7}\times100$	0	27.6%	79.8%
Δ_{ult} mm	1454	1905	1825
$(\Delta_{ult}-\Delta_{ult\ S7})/\Delta_{ult\ S7}\times100$	0	31.0%	25.5%

*** P_{cr} :First crack load ** P_{ult} :Ultimate load ***Δ_{ult} : Ultimate deflection**

Table (7) Effect of compressive strength (f_c') on flexural behavior of steel fiber-SCC slabs

Effect of compressive strength with 0.0% steel fiber		
Slab No.	S1	S4
Mix	M1	M3
f_c' (MPa)	25.2	56.2
ρ	0.01496	0.01496
P_{cr}^{*} kN	3.7	6.6
$(P_{cr}-P_{crS1})/P_{cr\ S1}\times100$	-	78.4%
P_{ult}^{**}kN	17.8	27.6
$(P_{ult}-P_{ultS1})/P_{ult\ S1}\times100$	-	55.1%
Δ_{ult} mm***	1670	1575
$(\Delta_{ult}-\Delta_{ultS1})/\Delta_{ult\ S1}100$	-	-5.7%
Effect of compressive strength with 0.4% steel fiber		
Slab No.	S2	S5
Mix	M2	M4
f_c' (MPa)	28.7	60.4
ρ	0.01496	0.01496
P_{cr}^{*} kN	4.8	7.1
$(P_{cr}-P_{crS2})/P_{crS2}\times100$	-	47.9%
P_{ult}kN	20.8	30.7
$(P_{ult}-P_{ultS2})/P_{ultS2}\times100$	-	47.6%
Δ_{ult} mm**	1905	1660
$(\Delta_{ult}-\Delta_{ultS2})/\Delta_{ult\ S2}\times100$	-	-12.9%
Effect of compressive strength with 0.8% steel fiber		
Slab No.	S3	S6
Mix	M3	M6
f_c' (MPa)	31.0	62.6
ρ	0.01496	0.01496
P_{cr}^{*} kN	5.6	7.8
$(P_{cr}-P_{crS3})/P_{crS3}\times100$	-	39.3%
P_{ult}kN	22.2	32.9
$(P_{ult}-P_{ultS3})/P_{ultS3}\times100$	-	32.5%
Δ_{ult} mm**	2185	1845
$(\Delta_{ult}-\Delta_{ultS3})/\Delta_{ult\ S3}\times100$	-	-15.6%

* P_{cr} :First crack load ** P_{ult} :Ultimate load ***Δ_{ult} : Ultimate deflection

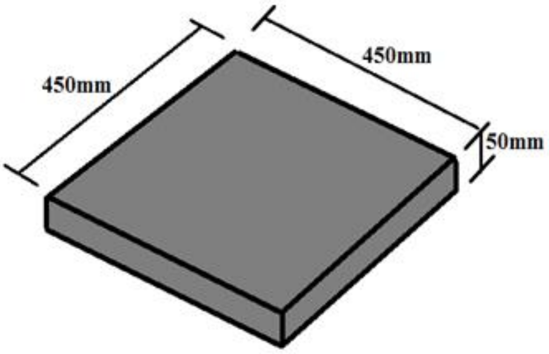

Figure (1) Dimensions of the slabs

Figure (2) One of the slabs specimens

Figure (3) Steel fiber used in this study

Figure (4) One of the mesh steel reinforcement

Figure (5) Stages of SCC materials mixing

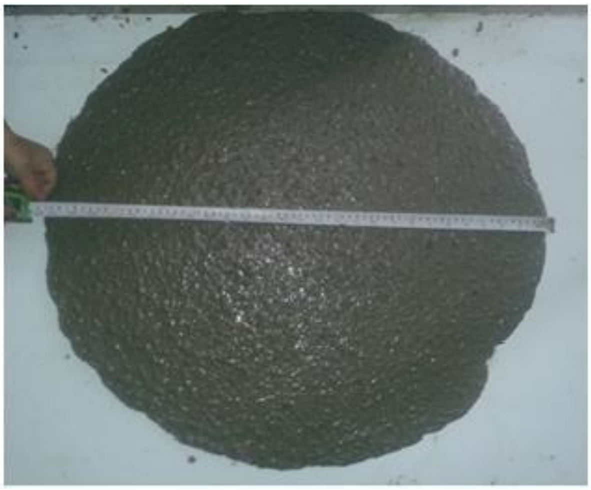

Figure (6) Flowing SCC in L-box test **Figure (7)** Spreading SCC in slump flow test

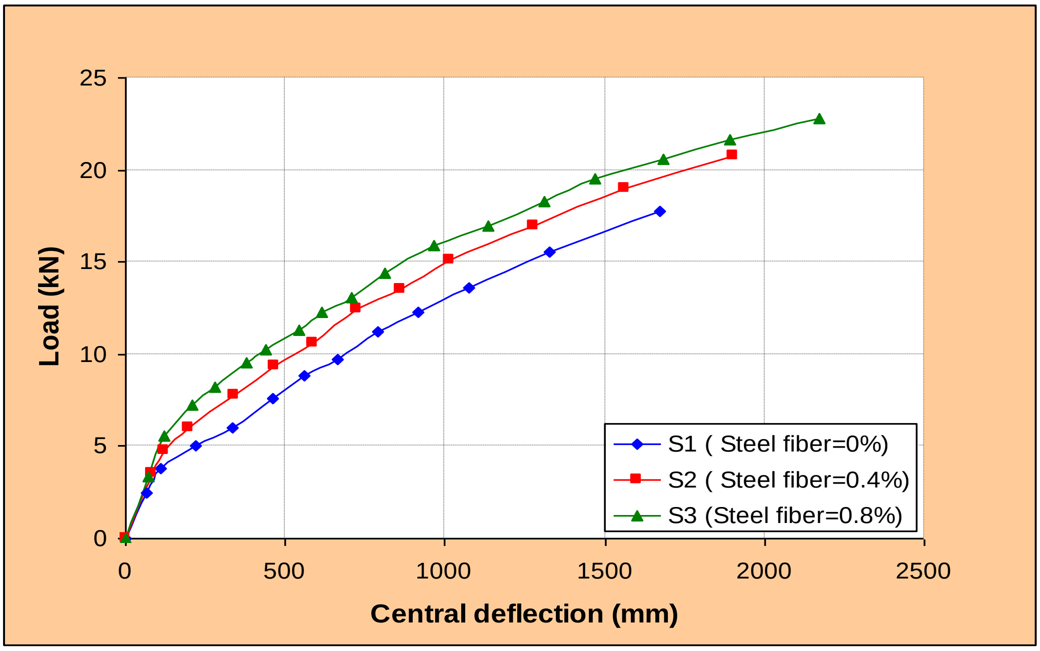

Figure (9) Effect of steel fiber volumetric ratio on load-central deflection curve of normal strength SSC slabs

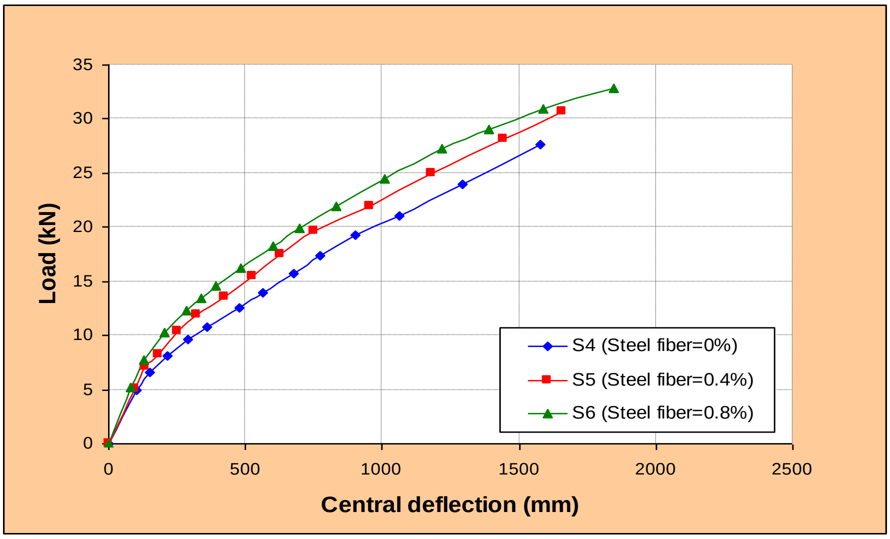

Figure (10) Effect of steel fiber volumetric ratio on load-central deflection curve of high strength SSC slabs

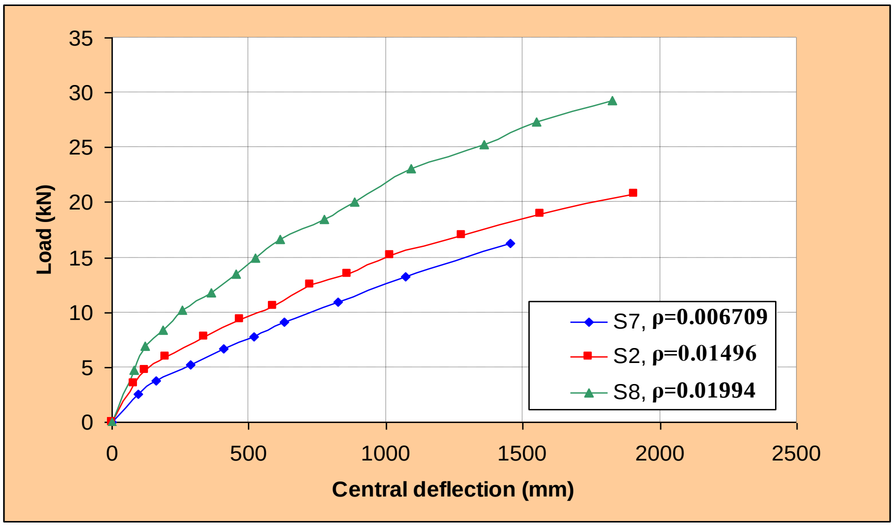

Figure (11) Effect of steel reinforcement ratio on load deflection curve of steel fiber-SCC slabs

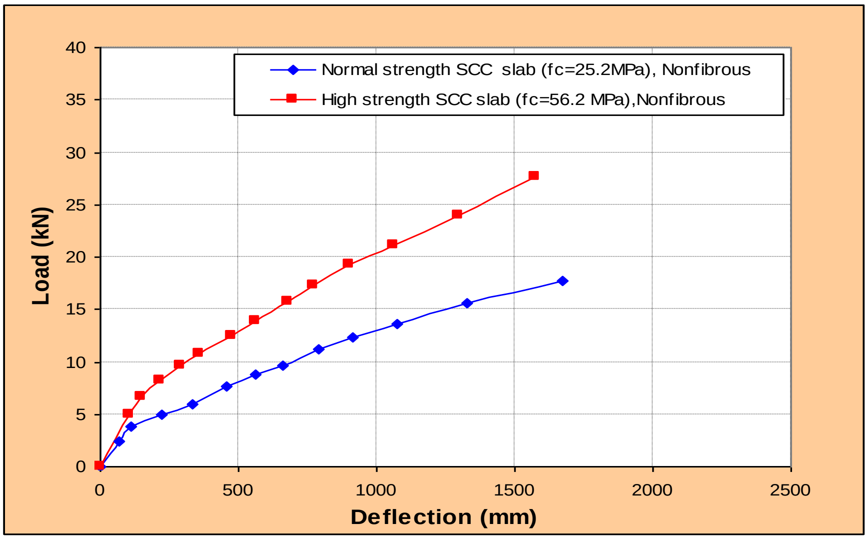

Figure (12) Effect of compressive strength with 0.0% steel fiber on load-deflection curve of SCC slabs

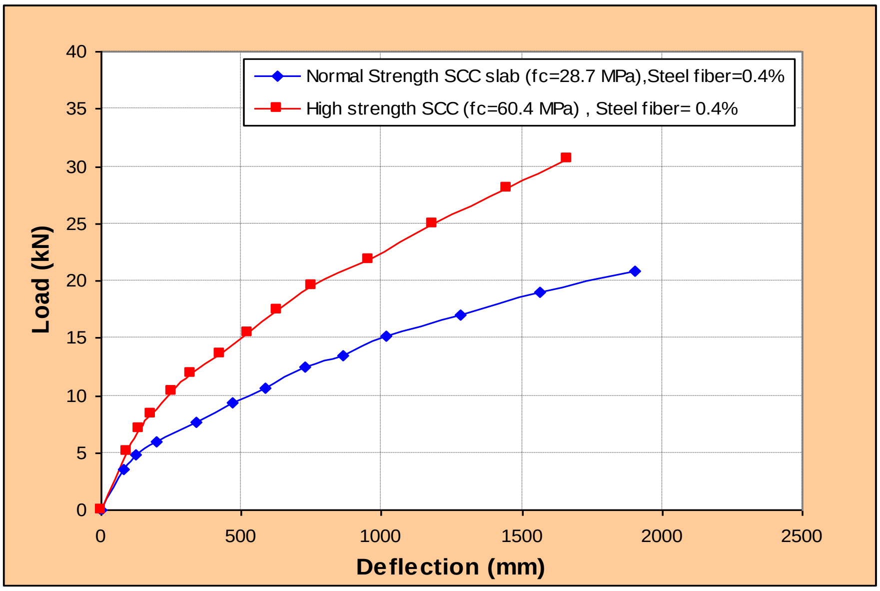

Figure (13) Effect of compressive strength with 0.4% steel fiber on load-deflection curve of SCC slabs

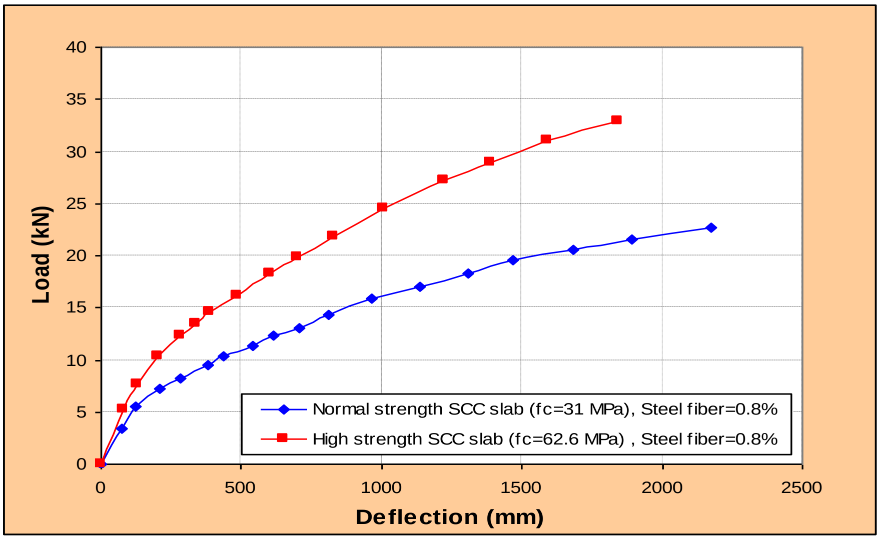

Figure (14) Effect of compressive strength with 0.8% steel fiber on load-deflection curve of SCC slabs

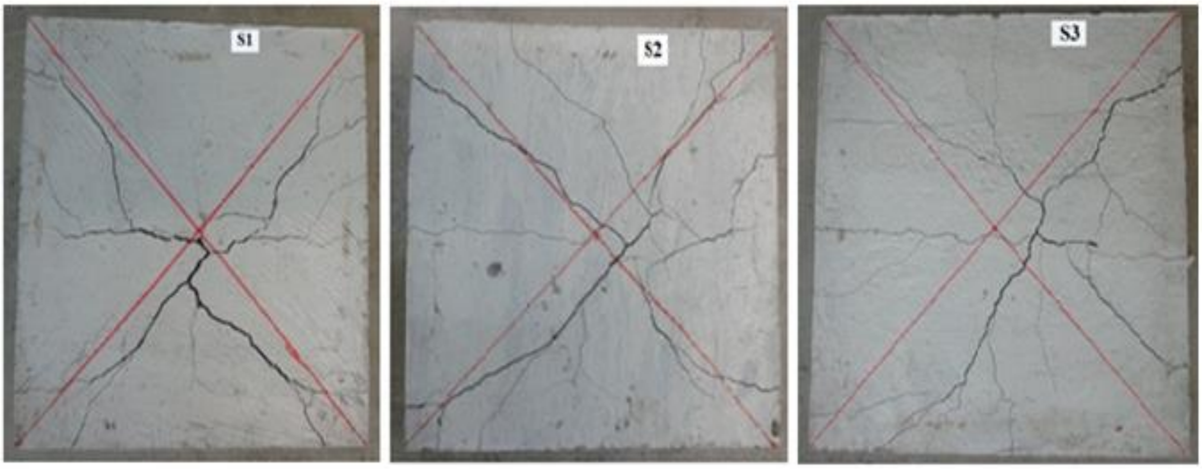

Figure (15) Effect of steel fiber volumetric ratio on crack pattern of normal strength SCC slabs

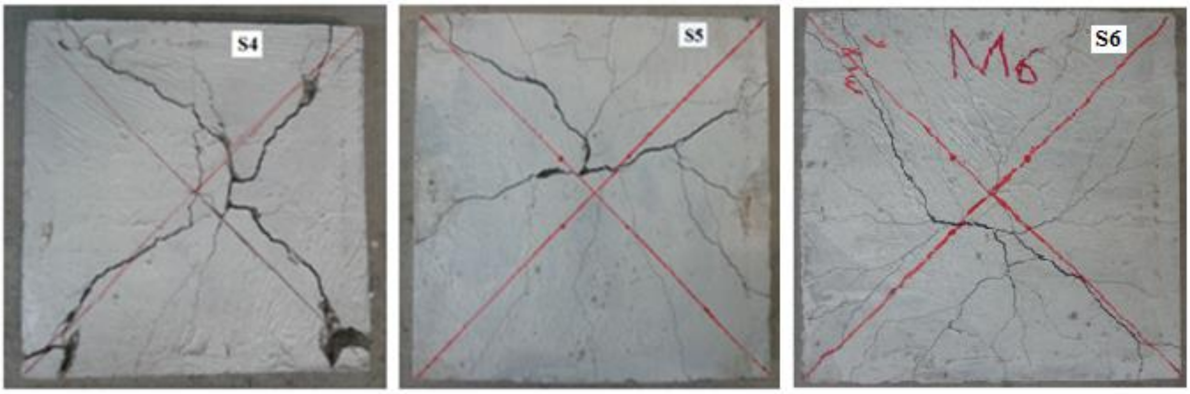

Figure (16) Effect of steel fiber volumetric ratio on crack pattern of high strength SCC slabs

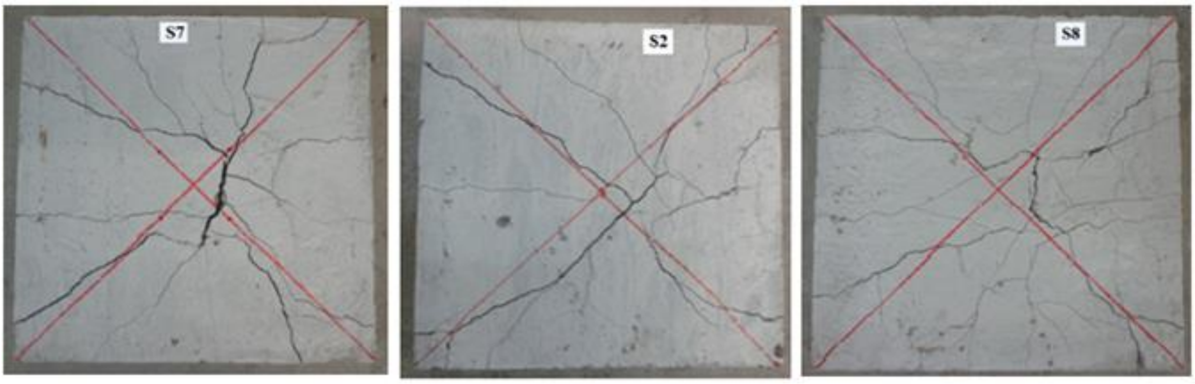

Figure (17) Effect of steel reinforcement ratio on crack pattern of steel fiber SCC slabs

سلوك الانثناء لبلاطات الخرسانة ذاتية الرص الحاوية على الياف الحديد

الخلاصة:

الخرسانة ذاتية الرص هي واحدة من اهم التطورات في تكنولوجيا الخرسانة. بالرغم من ان الخرسانة ذاتية الرص تمتلك اداءا عاليا لكنها تشبه الخرسانة العادية في كونها مادة هشة مع مقاومة شد منخفضة وطاقة كسر قليلة لذلك يمكن اضافة الياف الحديد لهذه الخرسانة لزيادة مقاومة الشد ,تحسين الصلابة , تحسين طاقة الكسر وتحسين مقاومة القص والانثناء.هذا البحث يقدم دراسة عملية لتحري سلوك الانثناء للبلاطات ثنائية الاتجاه ذات الخرسانة ذاتية الرص الحاوية على الياف الحديد. البرنامج العملي تضمن اختبار ثمانية بلاطات لدراسة تأثير كل من النسبة الحجمية لالياف الحديد على الخرسانة ذاتية الرص ذات المقاومة العادية والمقاومة العالية وكذلك تاثير نسبة حديد تسليح الانثناء وايضا تأثير مقاومة الانضغاط على سلوك الانثناء. لقد وجد عمليا بأن التحسن في سلوك الانثناء من حيث زيادة حمل التشقق الاولي ، الحمل الاقصى و الهطول الاقصى نتيجة اضافة الياف الحديد بالنسبة للخرسانة ذاتية الرص ذات المقاومة العالية كان اقل من التحسن على الخرسانة ذاتية الرص ذات المقاومة العادية. حيث ان زيادة الياف الحديد من ٠٪ الى ٠,٨٪ للخرسانة ذاتية الرص ذات المقاومة العادية أدت الى زيادات بالنسب (٥١,٤٪ ،٢٤,٧٪ و ٣٠,٨٪) على التوالي بالمقارنة مع البلاطة غير الحاوية على الالياف بينما كانت الزيادات للخرسانة ذاتية الرص ذات المقاومة العالية بالنسب (١٨,٢٪،١٩,٢٪ و ١٧,١٪) على التوالي. كذلك بينت النتائج ان حديد التسليح ومقاومة الانضغاط ذات تاثير مهم على سلوك الانثناء لبلاطات الخرسانة ذاتية الرص الحاوية على الياف الحديد.