FLEXURAL BEHAVIOR OF 3D TEXTILES REINFORCED CEMENTITIOUS COMPOSITES PLATES

Nadia Moneem*, Asst. Prof. Dr. Waleed A. Abbas, Asst. Prof. Dr. Ikbal N. Gorgis
*Civil Department of Najaf Technical Institute at the Furat Al-Awsat Technical University
Building and Construction Engineering Department /University of Technology/Iraq/Baghdad

DOI: 10.5281/zenodo.888561

KEYWORDS: 3D glass fiber, Chicken weirs, Micro steel fiber, Mortar, plates, Textiles, Tensile strength.

ABSTRACT

This paper presents the flexural behavior of plate specimens (with dimension 500×500×40 mm) containing 3D glass fabric having three different thicknesses 6, 10 and 15mm with different number of layers and orientation. For comparison plates with one and two layers of chicken wires as well as plates with micro steel fiber of 0.75% volume fraction were casted. All plate specimens were cast with cement mortar having 61.2MPa cube compressive strength at 28 days and tested under flexural.

From the test, it was observed that the load carrying capacities are higher in the case of plates with 3D glass fabric and showed a gradual increase in toughness beyond the ultimate load as compared with non - fibrous plates. The flexural strength was increased significantly the fiber thickness and number of fibers layers was increased. Based on the results a significant increase was indicated with micro steel fiber.

INTRODUCTION

Concrete generally leads to poor; material quality due to in-sufficient; consolidation that eventually weakens the durability of concrete structures. Hence, the need for high workability as self- ; compactibility concrete has been recognized to improve the quality and reliability of built facilities. One of the keys for the achievement of durable concrete structures is the use of self-compacting concrete (SCC), which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. Concrete that must not be vibrated is a great challenge to the construction sector and cost less.

To achieve such behavior, the fresh concrete must show both high flexibility and good cohesiveness at the same time [1]**.** Due to the heterogeneous structure of concrete, it results some undesirable effects such as many internal stress concentration zones, leading to internal micro-cracks. Under the application of externally imposed structural loads and environmental effects, concentration of tensile stresses occurs at the interfaces between aggregates and matrix, causing the growth of micro-cracks in size and number; propagation of interface micro-cracks into matrix and eventual joining of microcracks yield large cracks and lead to failure of concrete. Today it is well known that the benefits of addition fibers to concrete, mainly the enhancements in the residual load-bearing capacity, are influenced by the type, content and orientation of the fibers. Fibers are added not to improve the tensile strength itself, but mainly to control the cracking, prevent coalescence of cracks, and to change the behavior of the material by bridging of fibers across the cracks. The properties of fibers that are usually of interest are fiber concentration, geometry, orientation and fiber distribution [2].

Flexural strength of the structure; depends on several factors such as volume of steel reinforcement, grade of concrete used, water cement ratio (W/C) adopted for mix, quality of materials used etc. The flexural behavior of beams tested under three-point load was conducted on two batches of beams reinforced with straight steel and 3D fibers respectively was studied by **Richardson and Heather** [3], so that flexural strength and post crack toughness could be calculated and compared. A comparison test was carried out between the straight steel fibers and the 3D fibers (3D and straight steel fibers were also embedded in cubes). 3D fiber reinforced specimens showed higher flexural strength and post crack toughness than straight steel samples. 3D fibers continued to stand the rupture plane after initial crack formation during testing, which held together the concrete matrix. These findings suggest 3D fiber reinforced concrete would perform better as a blast protection material as compared to straight steel fiber reinforced concrete.

Ability of production and application of Textile Reinforced Concrete (TRC) elements with the flexible mold has been investigated and studied by Magri and et al. [4]. To determine the suitability of textile reinforcement in the flexible mold and possible practical applications of double curved (TRC) elements. The experiments have been conducted with an alkali-resistant glass (AR-glass) fiber textile with a bi-axial mesh. The concrete that was used had a maximum aggregate size of 1 mm fine grain concrete. For the investigation on the deformation multiple TRC elements were cast and deformed in the flexible mold (400×800×25 with four layers of textile). The results showed that the textile deformed with the concrete but deviations in the positioning of the layers occurred. The layer thicknesses were 2.5 to 7 mm after production, whereas the intended layer thickness was 5 mm. These deviations are a result of the applied production method, from lamination to deforming, and have influence on the flexural strength of the concrete elements. The mechanical properties of TRC are tested with tensile- and four-point bending tests. Both tests showed a strain hardening trajectory after initial cracking of the concrete. The results also proof that not the tensile strength of the textile reinforcement can be utilized but also, the experiments signposted that the reinforcement percentage does not influence the maximum tensile stress of a textile and that the maximum tensile stress of a textile increases under flexural loading.

EXPERIMENTAL INVESTIGATION

The experimental investigation consists of testing of six groups according to the fiber reinforcement thickness, layers, orientation, and type of reinforcement.

First group consist of plates cast with self-compact mortar (SCM) with non-fiber reinforcement, the second group was reinforced with 6mm 3D glass textile fiber, reinforced with one and two layers. Third group cast with10mm 3D glass textile fiber with one and two layers, while the fourth group contains 15mm 3D glass textile fiber casted with one layer only. The fifth plate group consist of SCM reinforced with chicken wire casted with one and two layers, the six-group reinforced with micro steel fiber of 0.75% volume fraction, three specimens were casted for each test age (28 and 90) days. Table 1shows the details the specimens detail, materials used and experimental studied are presented below.

Materials used

Ordinary Portland cement (type I) of KRASTA Factory was used, Table 2 shows the chemical composition and physical properties of the used cement. Test results comply with the requirements of the Iraqi Standard Specification I.Q.S. No.51984 [5].

Natural sand from Najaf sea region was used with 0.6 mm maximum size. The results of physical and chemical properties of the sand are listed in Table 3. Test results comply with the requirements of the Iraqi Standard Specification IQS. No.5-1984 [6].

Ordinary tape water was used in both cast and curing works for all plate specimens. A high-performance concrete superplasticizer (also named High Range Water Reduction Agent HRWRA) based on polycarboxylic technology, which is known commercially as Glenium 54 was used. It is produced by BASF Company and conforms to ASTM C 494 Type F [7], Table 4 shows its properties.

Class F fly ash (FA) produced from Thermal Power plant in Turkey was used as an additive according to ASTM C618 [8], cement was replaced by 20% of fly ash by weight of cementitious material. The physical and chemical properties are presented in Table 5.

Silica Fume (SF) produced by BASF Company was used as pozzolanic admixture. Cement was replaced by 5% of silica fume by weight of cementitious material. The silica fume used in this work conforms to the requirements of ASTM C-1240-05[9], ASTM C-311-05[10]. The technical specifications of silica fume are presented in Table 6.

3D textile glass fiber woven fabric exported from china consists of two bidirectional woven fabric surfaces, which are mechanically connected with vertical woven piles. And two S-shaped piles combine to form pillar, 8- shaped in the warp direction and I- shaped in the weft direction. For the use of 3D textile as reinforcement in concrete, textile should have an opening mesh allowing the mortar or concrete to penetrate the textile for good bond between the materials, for this reason, 19 mm holes at distance 50mm center to center in both direction were drilled (by tool cutters). This process of preparing with textile fabrics must ensure good penetrability of the cement matrix between the spaces within both the fabric and the bundle filaments that compose the fabric. Plats 1 show the surface, thickness and fibers holes. Tables 7 and 8 shows its typical properties and Fabrics Specifications.

Rhombic shape meshes of reinforcement, fabricated from 0.54mm -nominal diameter steel bars, the opinion in the long and short direction were (10.6 &7.92mm) respectively.

Micro Steel fibers are used in SCM plates to enhance some properties and improve the ductility; it was manufactured by Ganzhou Daye Metallic Fiber Co., Ltd, China. (http//www.gzdymf.com), it conforms to (ISO 9001/2008), the properties are summarized in Table 9.

MIXES

The proportion of the constituents for the prepared mortar mix was 1:1 (cement sand) by weight of ordinary Portland cement and cementitious materials: fine aggregate with 0.6mm maximum size. The superplasticizer (SP) had a dosage of 1liters per 100 kg of material (cement and binder), w/b of 0.36 was selected for this investigation. The mortar was prepared using a small mechanical mixer conforming to ASTM C305-04 [11], the mixing procedure descried blew:

Firstly, add cement, fly ash and silica fume while mixer operating at low speed for 30 sec. until a uniform distribution is reached,

Secondly, add sand and mixing for 1 min. and rotate at medium speed,

Thirdly, first part (2/3) of water was added and mixed thoroughly for 30 sec. at low speed, stop 2 min to clean blades, now, add SP and remainder water and mixing for 2 min. at normal velocity, Stop the mixer and wait for 1 min., and then finalize the process by mixing at normal velocity for 3 min,

Finally, do the discharge and cast the plate specimens with fibers each one as its group. For plates with micro steel fiber (0.75%) volume fraction. after poured first layer of SCM the fiber was randomly distribution by hand.

FRESH MORTAR PROPERTIES

Determination of Slump-Flow:

The slump-flow test was achieved by using mini (slump) cone and a graduated glass plate. The cone has top and bottom diameters of (70mm) and (100mm) respectively with a height of (59mm). The subsequent diameter of the mortar is measured in two perpendicular directions and the average of the diameters is reported as the spread of the mortar. In this test, the truncated cone mold is placed exactly on the (100 mm) diameter graduated circle marked on the glass plate, filled with mortar and lifted upwards. Fresh properties of mortars were evaluated by the mean value of two perpendicular flow diameters in the spread test. Mortars were prepared manually in a container to observe its behavior. The procedure for test was followed as described in [12] see Plate 2.

Determination Flow Time:

Flow time determined in the v-funnel test, the dimension of v- funnel is shown in Figure1.

MECHANICAL PROPERTIES OF HARDENED SELF COMPACT MORTAR

Compressive strength: This test was done on cubes according to the Standard Specification I.Q.S. No.5/1984[5]. A3000kN capacity testing machine was used for compressive test. The average compressive strength of three cubes (77×77×77mm) was recorded for each testing age (7, 28, 90 days).

Flexural Strength: The flexural strength testing was carried out on prisms with (40 × 40 ×160 mm) SCM prisms, the prism was loaded at its center point until failure. Using three mortar prisms for each age (28, 90) days and the average of three results was adopted. A20 kN capacity Beijing United testing machine was used for this test. The flexural strength (modulus of rupture) is calculated, as follows: -

$$fr = \frac{2PL}{3bd^2} \qquad (1)$$

where fr is the flexural strength [which is measured in (MPa), P is the maximum load, measured in (N), L is the clear span length, measured in (mm), b is the width of specimen, measured in (mm), Finally, d is the average depth of specimen, measured in (mm). The mortar prisms were prepared according to ASTM C 348-04[13]. Plates

(4) show the plates of the flexural test.

Tensile Strength of Mortar: Tensile Strength of mortar test was done according to B.S 6319-7:1985[14]. Briquette mold was used for this test, Plate (5) shown mortar tensile test. The average of three samples was used.

Table 1. Details of Test Specimens (unreinforced and Reinforce) Mortar

Group No.	Mix Symbol		Flexural test 500×500×40 mm	
			28 days	90 days
1	Ref.	Without any fiber	3	3
2	F6-1	Glass fiber 6 mm thickness (one layer).	3	3
	F6-2	Glass fiber 6 mm thickness (two layers).	3	3
	F6-1-S	Glass fiber 6 mm thickness (one layer slice).	3	3
	F6-2-S	Glass fiber 6 mm thickness (two layer slice).	3	3
	F6-2-S-T	Glass fiber 6 mm thickness (two way).	3	3
3	F10-1	Glass fiber 10 mm thickness (one layer).	3	3
	F10-2	Glass fiber 10 mm thickness (two layers).	3	3
4	F15	Glass fiber 15 mm thickness (one layer).	3	3
5	FS-1	Mesh chicken wire (one layer).	3	3
	FS-2	Mesh chicken wire (two layers).	3	3
6	M S F	With V_f =0.75 micro steel fiber	3	3

Table 2. Chemical and Physical Properties of the Cement

Oxide	**%**	**I.O.S. 5: 1984 Limits**
CaO	66.11	_
SiO_2	21.93	_
Al_2O_3	4.98	_
Fe_2O_3	3.10	_
MgO	2.0	< 5.0
K_2O	0.75	
Na_2O	0.35	
SO_3	2.25	< 2.8
Loss on Ignition (L.O.I)	2.39	< 4.0
Lime Saturation Factor	0.93	0.66 - 1.02
(L.S.F) Insoluble residual	1.29	< 1.5 %
Free lime (F.L)	0.67	-
Compound Composition	**%**	**I.O.S. 5: 1984 Limits**
C_3S	58.16	_
C_2S	19	_
C_3A	7.95	_
C_4AF	9.43	_
Physical Properties	**Test Results**	**I.Q.S.5:1984 [5] Limits**
Fineness, Blaine, cm^2/gm	3300	>2300
Setting Time:		
Initial hrs.; min	1;08	≥45 min
Final hrs.; min	4;00	≤10hrs
Compressive Strength (MPa)		
3-days	20,0	≥15
7-days	25,0	≥23

Table 3. Properties of the Fine Aggregate

Physical properties*	**Test results**	**Iraqi specification. 45/1984[6]**
Specific gravity	2.65	-
Sulfate content	0.3 %	Not more than 0.5%
Absorption	1 %	-
Bulk density(kg/m^3)	1560	-

Table 4. Typical Properties of (GLENIUM54) *

*According to manufacturer

Table 5. Physical and Chemical Properties of Class (F) Fly Ash*

Particular	Fly ash (Class F)	ASTM C 618 Class F fly ash [8]
Chemical composition		
Silica (SiO_2%)	65.65	$(SiO_2 + Al_2O_3 + Fe_2O_3) \geq 70$
% Alumina (Al_2O_3)	17.69	
Iron Oxide (Fe_2O_3)%	5.98	
Lime (CaO)%	0.98	
Magnesia (MgO)%	0.72	
% Sulphur Trioxide (SO_3)	0.19	Max. 5.0
Loss on Ignition	3.1	Max. 6.0
Na_2O	1.35	
K_2O	2.98	
Physical properties		
Specific gravity	2.12	
Fineness (cm^2/gm)	3600	Min. 2250cm^2/gm

* Chemical and Physical testing laboratory in Iraq Geological Survey

Table 6. The Technical Specification of Silica Fume

Structure of material	Silica fume	Limits of ASTM C 1240-07[9]
Color	Dark gray	
Density	0.55-0.7 kg/m^3	
Chlorine amount	< 0.1 %	
Specific surface area (cm^2/gm)	> 150000 cm^2/g	≥ 150000 cm^2/g
SiO_2	> 85 %	≥ 85 %
CaO	< 1 %	
Activity index*	156 %	≥ 105 %
Specific gravity	2.2	

Table 7. Glass Fiber Woven Fabrics Specifications*

Area Weight (g/m^2)	Core (mm)	Density of Warp (ends /cm)	Density of Weft (ends /cm)	Tensile Strength (MPa) Warp (n/50mm)	Tensile Strength (MPa) Weft (n/50mm)
900	6	15	10	5500	9400
1480	10	15	8	6800	12000

1650	15	12	6	7200	13000

*According to manufacturer

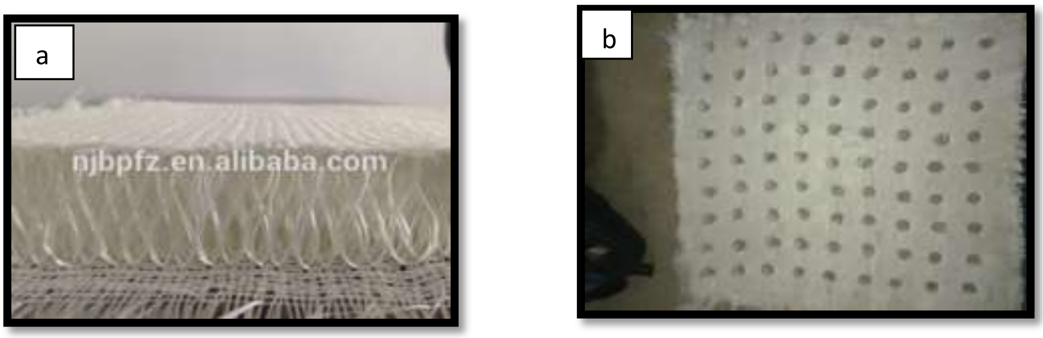
Table 8. Typical Properties 3D Textile Glass Fiber Woven Fabrics Specifications

Weight/ area	From 820 to 2580g/m^2
Surface Treatment	Silicon Coated
Width	1.3m or Made to order
Weave Type	Plain Woven
Yarn Type	E-Glass
Alkali Content	Alkali Free
Standing Temperature	260 °C
Color	White
Specific stiffness	Extremely High
Woven	parabeam
Acoustic insulation	Excellent
Wave transmittable	Well
Construction	Two layers and one hollow spacer

*Table 9. Specification of Micro Steel Fiber**

Property	Specification
Type	WSF 0213
Surface	Brass coated
Tensile Strength	2850 MPa
Length	15mm
Diameter	0.2 mm
Aspect ratio	65

* Adopted by manufacturer



Plates 1. 3D textile glass fiber made in china; a) Zoom view. b) Holes made in 3D glass fiber

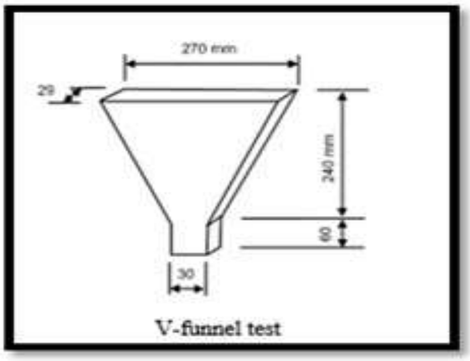


Figure1. V-funnel apparatus.

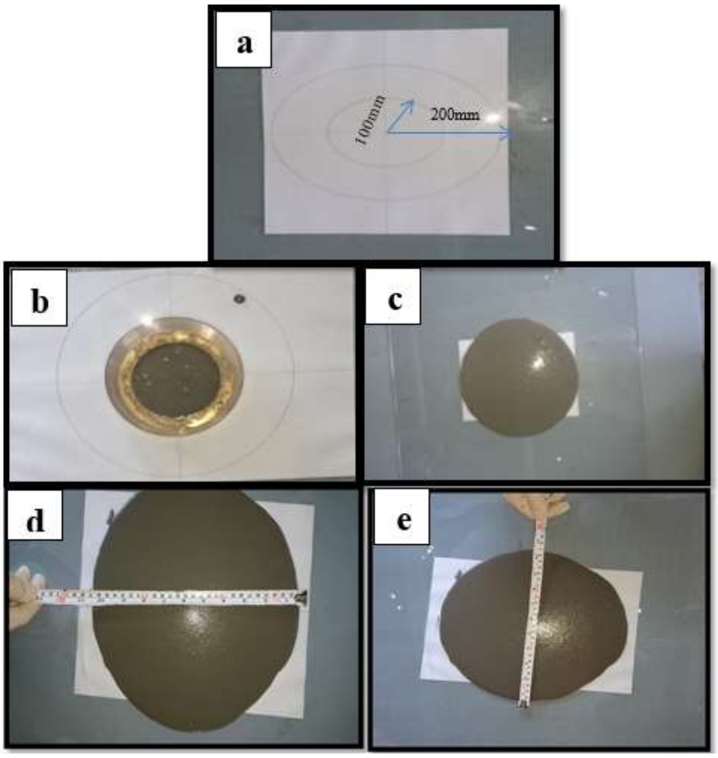


Plate 2. a) draw two circle (10&20) cm. b) mini slump cone filled with mortar test. c) Flow of mortar. d) And e) measured appendicular diameter.

Flexural Strength Test of SCM plate specimens (f_r)

Flexural strength test (modulus of rupture) is carried out by using three molds with dimension (500×500×40mm) plate was casted and tested for ages (28, 90) days, the dimension of base frame (510×510×310mm), two support clamping by two bolts for each edge of the top of the base frame to provide support, for this test 1000 kN universal testing machine with rate 0.2 kN/s was used. The load was applied until failure, the test is carried out according to ASTM C1186-08 [14].

The central displacement, was measured by using a linear variable differential transformer (LVDT) was supported below the center of the specimen and connected to output screen, fixed to frame by another angle steel section from the same type which welded at the mid span of the below frame part; the test continued till failure, with failure mode and crack patterns were noticed and recorded, digital camera was used to recorded the result data during test. To evaluation the flexural strength three plates for each age and the average of three results was adopted, the modulus of rupture is calculated, as equation described in section (4.2), the total length of plate was equal to (500mm) and the effective flexural span was equal to (450mm).

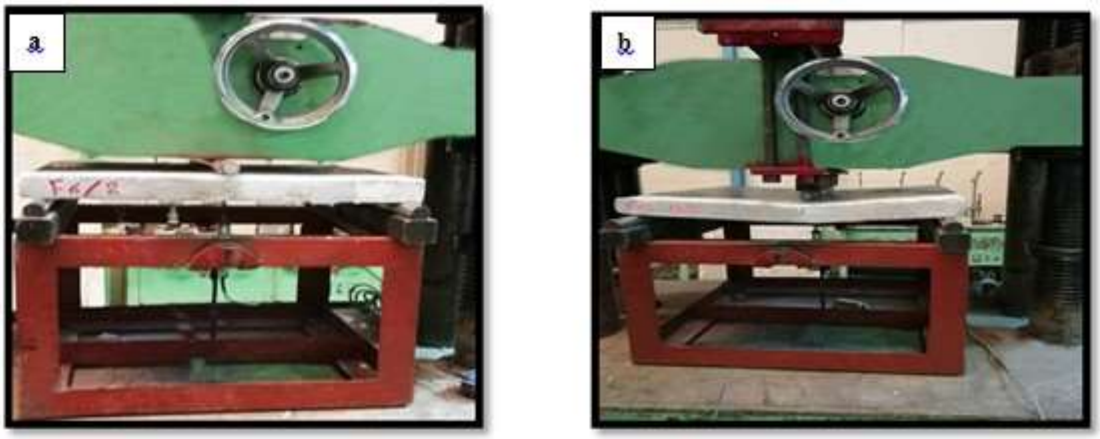


Plate 3. Flexural test: a) flexural test. b) After failure occurred.

SUMMARY OF RESULTS AND CONCLUDING REMARKS

Fresh Mortar Properties

The test results relevant to the slump flow diameter, V-funnel flow time are presented in Table 10. From result it was indicated that the mixture had slump flow diameter, V-funnel flow time conforming the specifications [12]. Where **Dm** is the mean value of the two perpendicular diameters, measured in (mm); **D0** is the initial diameter of the base of the cone, measured in (mm), and finally, the **t** represents the time of flow in the v-funnel, which is measured in second.

Hardened SCMs Properties

The hardened properties of the mortars were summarized in Table11. The strength was increased with time for all specimens, this development in compressive strength, tensile strength and flexural strength can be attributed to the fact of continuous hydration process (C-S-H). Beside present of silica fume tends basically to consume the calcium hydroxide crystals released from the hydration process leading to the formation of further calcium - silicate- hydrate (secondary C-S-H).

Table 10. Fresh Properties of SCMs

SCMs	Slump Flow Diameter (cm)	V-funnel time (s)	$G_m = \left(\frac{Dm}{D_0}\right)^2 - 1$	$R_m = \frac{10}{t}$
	25.4	9.5	5.45	1.05
Acceptance criteria of SCMs suggested by [12]	24-26	7-11	-	-

Table 11. Results of Hardened Properties of SCMs

Type of Test	Compressive Strength (MPa)			Tensile Strength (MPa)		Flexural Strength (MPa)	
Test Age (days)	7	28	90	28	90	28	90
	45.7	61.22	77.9	3.3	5.1	5.3	9.12

Flexural behavior of plate specimens

Flexural tests have been carried out on SCMs plate's specimens under a bending load. Multiple specimens on a three-point bending test were used to determine the flexural strength. A total of 72 plates have been tested under flexural loading. Table 12 indicates the test results and failure mode is presented in Figures from 2 through 7.

The relationship between applied load and the deflection at the center of the plates was typical for all tested plates, an approximate linear increase behavior followed by a nonlinear behavior until failure.

From Table 12 and Figure 2, it is worthwhile to note that the fibrous SCMs plates really stand out higher in the flexural strength when compared to the non-fibrous SCMs plates. The non-fibrous plate exhibited brittle failure mechanism while the fibrous SCMs plates were quite ductile, with fibers that bridged the cracks and failed in bond, in flexural strength tests. Observations of the fractured surface of fibrous SCMs revealed that almost the fibers were pulled out of the mortar and very rarely were seen broken. The results indicated that non-fibrous SCMs plates and several types of fiber reinforced SCMs plates specimens exhibited continuous increase in flexural strength with increasing age.

Reinforced SCMs plates with fibers showed significant improvement in flexural strength at all ages relative to the reference plates without fibers. This is mainly due to the increase in crack resistance of the composite and to the ability of fibers to resist forces after the concrete matrix has cracked. The increase in flexural strength was found to be increased with the increase in thickness and layer numbers of 3D textile glass fiber, and layer number of chicken wire mesh.

For group 2 (6mm) 3D textile glass fiber, the increase in flexural strength at 28,90 days were (32, 68.5, 39.5,84.2,94.56%) and (31.12, 44.26, 34.43, 54.08, 79.57%) for reference SCMs reinforced with one layer, two layers, one layer slice, two layer slice and slice two way reinforcement respectively relative to the corresponding non-fibrous SCMs plates of group 1. By comparing group 3 (10 mm) 3D textile glass fiber with non-reinforce plates of group 1, the increase in flexural strength at 28, 90 days were (34.19, 40.49%) and (18.67, 35.21%)for reference SCMs reinforced with one layer, two layers respectively relative to the corresponding SCMs plates of group 1. While plates of group 4 (15mm) 3D textile glass fiber, the increase in flexural strength was (50.6, 36.18%) at 28, 90 days respectively relative to the corresponding non-fibrous SCMs plates of group 1.

From Figure 2, wire chicken mesh of group 5 showed the same behavior as 3D textile glass fiber, the increases in flexural strength was (36.3, 51.85%) and (26.33, 33.65%) at 28, 90 days respectively relative to the corresponding non-fibrous SCMs plates of group 1.

Plates of group 6 with 0.75 volume fraction of micro steel fibers also increases the flexural strength of plates and become sensible as compared to those without fibers by about (126.9, 119.8%) at 28, 90 days respectively relative to the corresponding non-fibrous SCMs plates. This might be due to comparatively higher bond strength of fibers.

The increase in fiber content (thickness, layer number) causes an increase in flexural strength. This introduce the role of fibers in releasing fracture energy around crack tips which is required to extent crack growing by transferring it from one side to another side [15].

As well as to fibers help to bridge cracks in the whole plates volume and transfer tensile stress through the opposite face of cracks until the fibers are completely pulled - out or broken. For this reason, in stage of initiation and propagation of cracks, tensile zone of plates reinforced with fiber still sustains more loads. Increasing the thickness and number of layers of fibers layers significantly increases the ductility and capability to absorb energy of the plates.

All plates showed a gradual and ductile behavior beyond the maximum load in comparison with non - fiber SCMs of group 1, from this result it could be noticed that the flexural strength in terms of ultimate load increased significantly. The flexural behaviors of SCMs plates were almost close to the maximum load as shown in Figure 3, though the 3D textile glass fiber thickness was varied.

Table 12. Overview of results flexural strength

Group No.	Mix ID	Flexural strength at 28 days (MPa)	Flexural strength at 90 days (MPa)
1	R	8.1	10.3
2	F6/1	10.7	13.5
	F6/2	13.65	14.83
	F6/1/S	11.3	13.82
	F6/2/S	14.92	15.84
	F6/2/S/T	15.76	18.46
3	F10/1	10.87	12.2
	F10/2	11.38	13.9
4	F15	12.2	14
5	S/1	11.04	13
	S/2	12.3	13.74
6	MSF	18.4	22.6

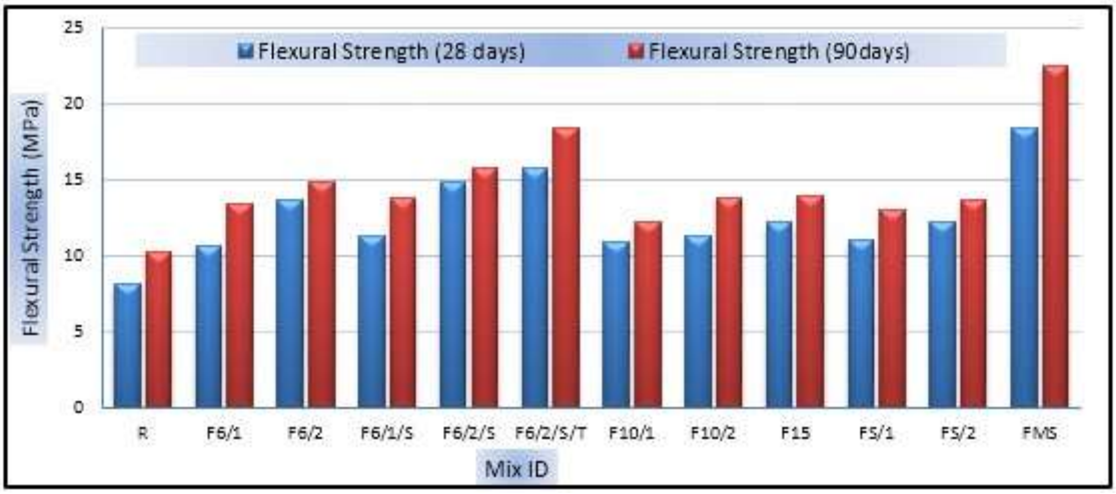


Figure 2. Flexural strength at 28, 90 days.

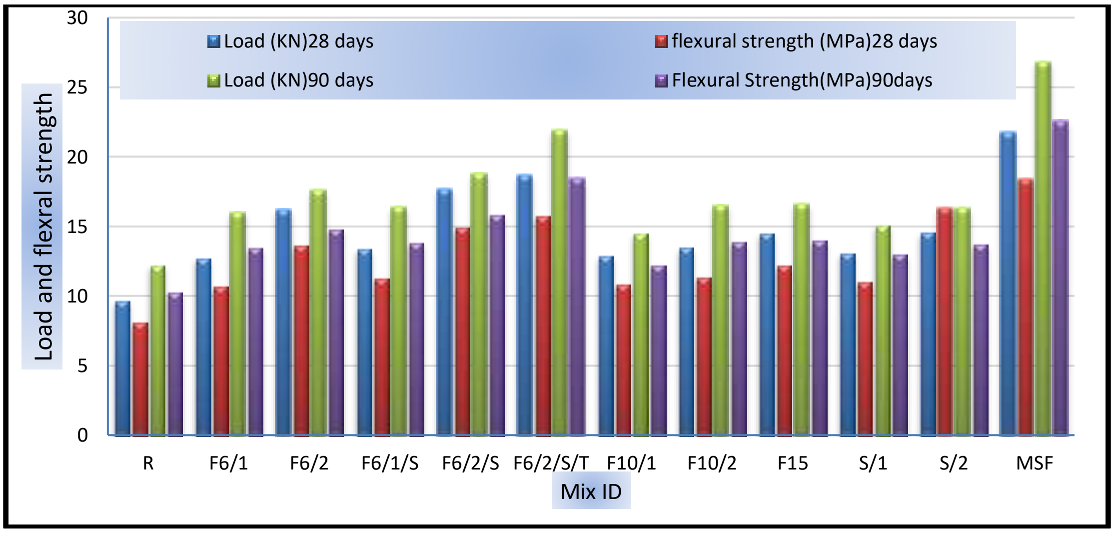


Figure 3. Load Vis flexural strength for reference ®, one layer and two layer reinforcement at 28, 90 days.

Micro steel fiber (Group 6) also increases the ductility of plates and decreases the central displacement tendency as compared to other groups. The maximum displacement was decreased with the increase of the fiber layers from one to two and increasing the thickness, Figures from 4 to 7 shows that, in all plats, as the number of layers fiber and thickness increases the deflection reduces for the same load.

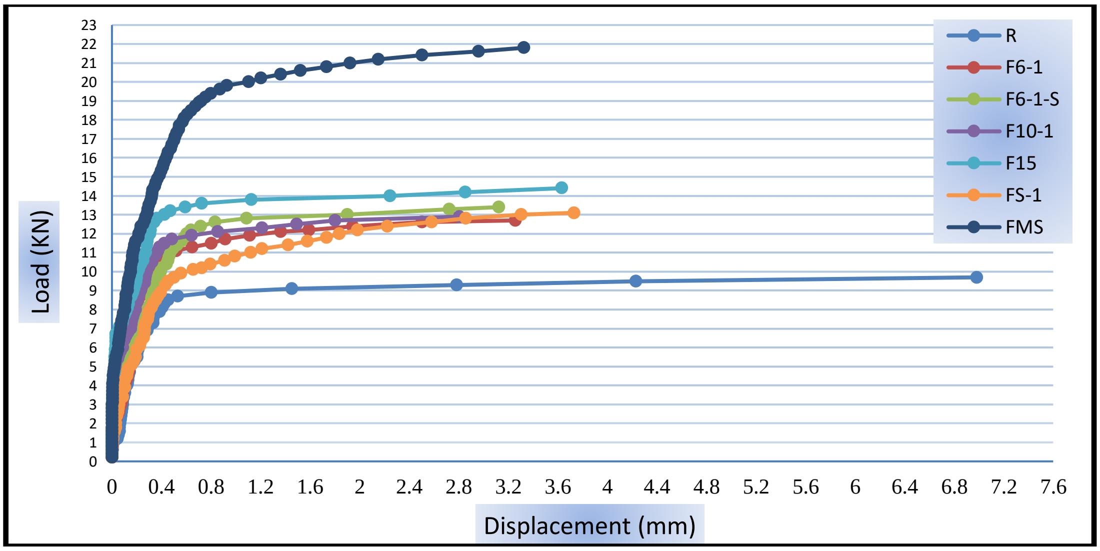


Figure 4. Load Vis displacement for reference ® and one layer reinforcement at 28 days.

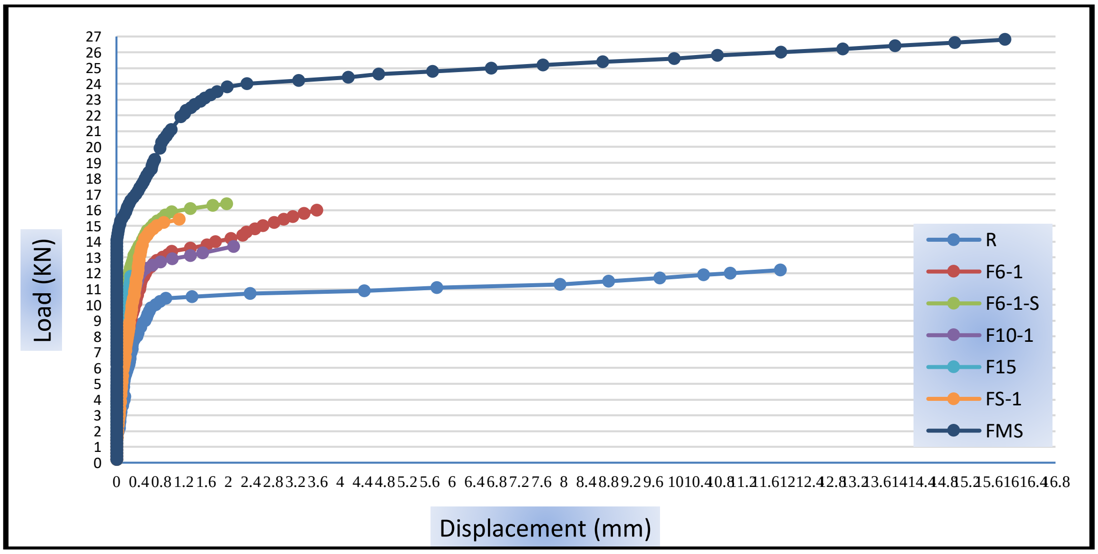


Figure5. Load Vis displacement for reference ® and one layer reinforcement at 90 days.

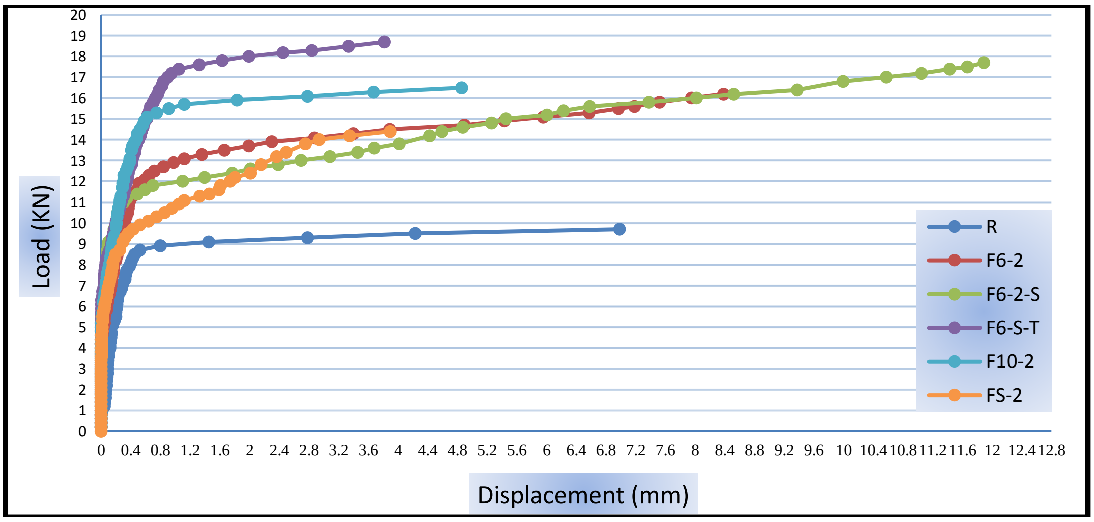


Figure6. Load Vis displacement for reference ® and two layer reinforcement at 28 days.

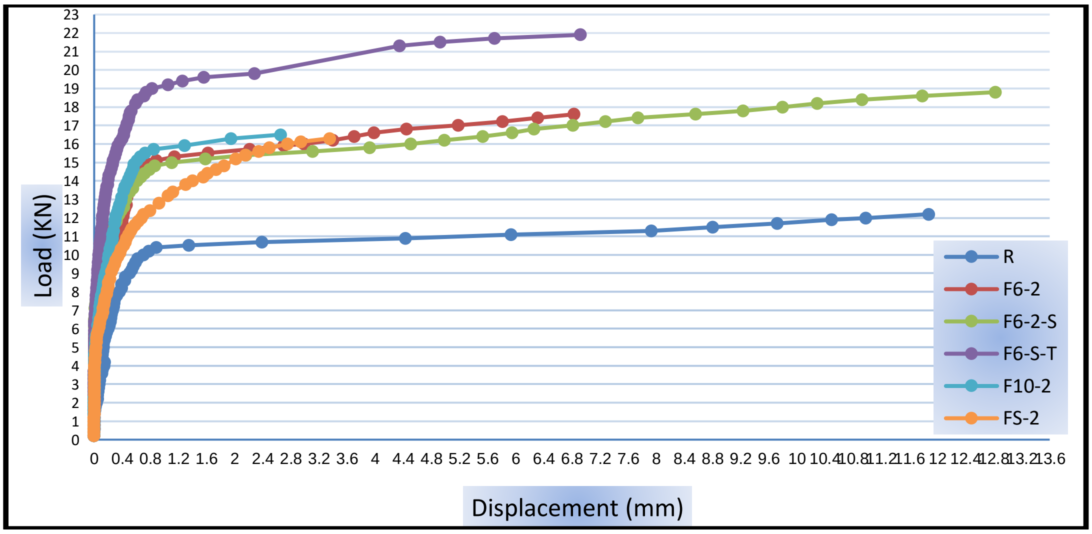
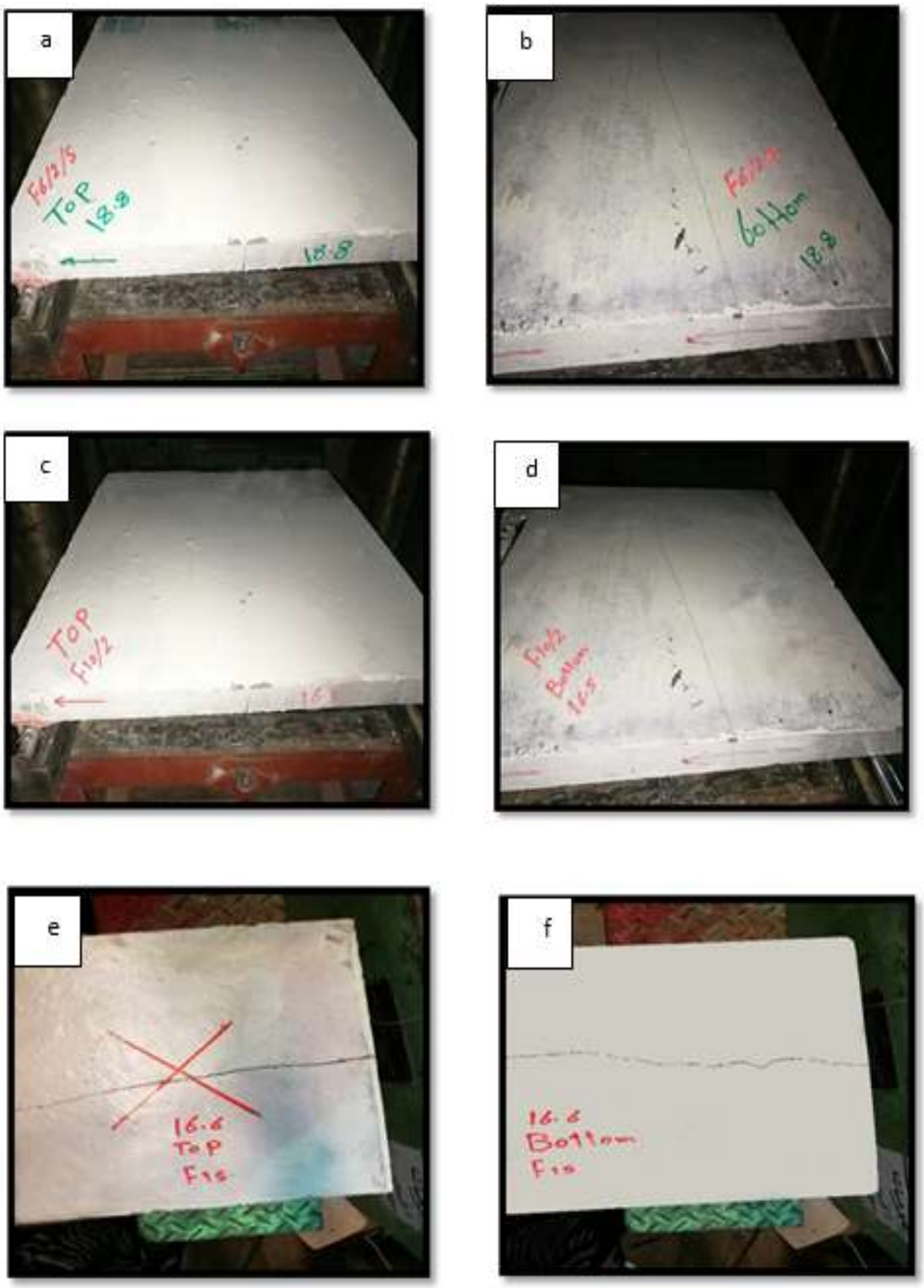


Figure7. Load Vis displacement for reference ® and two layer reinforcement at 90 days.

All tested plates were failed in flexure tensile mode, due to formation of cracks in the tensile stress zone (bottom and side faces). Cracks started to appear as the load was increased, and extended from that perimeter under the loading line (due to the bending moment toward the supported edges) and became wider at the center region parallel to the line of applied loads for all plate specimens.

Plate 4, showed the failure mode of some SCMs plates, from test result the micro steel fibers improved significantly SCMs ductility.


a
F6/2/5
ToP
18.8
18.8
b
F6/2/5
bottom
18.8
c
ToP
F10/2
16
d
F10/2
Bottom
16.5
e
16.6
ToP
F15
f
16.6
Bottom
F15

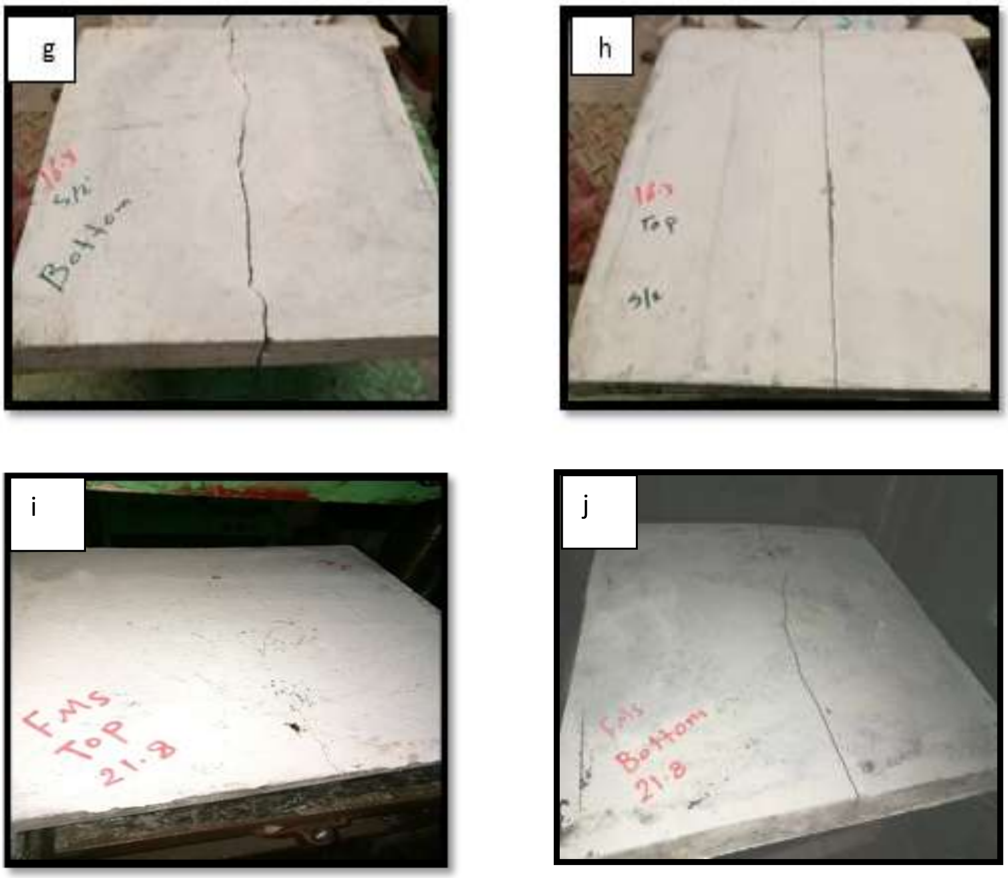


Plate 4. failure mode of some SCMs plates: a, b represents group 2. c, d represents group 3. e, f represents group 4. g, h represents group 5. I, j represents group 6.

CONCLUSION

The following conclusions can be drawn based on the results of the present study for the flowing ability of self-compact mortars reinforced with diverse types of fibers:

1. All plates showed a gradual and ductile behavior beyond the maximum load in comparison with non - fiber SCMs, the flexural strength in terms of ultimate load increased significantly.
2. The increase of the flexural strength becomes sensible with of SCMs reinforced by micro steel fiber.
3. The maximum displacement was decreased with the increase of the fiber layers from one to two and increasing the thickness.
4. The same failure mode was observed; the failure crack was located under the loads.

REFERENCES

1. Corinaldesi, V., Moriconi, G., “Durable fiber reinforced self compacting concrete”, Cem Concr Res, 34, 249–54, 2004.
2. Sahmaran, M., Yaman, I.O., “Hybrid fiber reinforced self compacting concrete with a high volume coarse fly ash”, Construct Build Mater, 21, 150–6, 2007.
3. Alan Richardson, Marcus Heather "Improving the performance of concrete using 3D fibers" Non-Circuit Branches of the 3rd Nirma University International Conference on Engineering (NUiCONE 2012).
4. IG, Magri A, Zani G, Colombo M, Prisco M. "Textile Reinforced Concrete: Experimental Investigation on Design Parameters". Mater Struct; 46(11): 1933–51, 2013.

5. Iraqi standard specifications of number (5/1984) "Portland cement”, Central Organization for Standardization and Quality Control in Iraq,1-10.
6. Iraqi standard specification of number (5/1984) "Ruins the natural resources used in concrete construction", Central Organization for Standardization and Quality Control in Iraq,1-16.
7. ASTM C-494/C 494M-05 "Standard Specification for Chemical Admixtures for Concrete", ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States, 2005, pp. 1-10.
8. American Society for Testing and Materials, “Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete", ASTM C 618, 2003.
9. ASTM C-1240-07 "Standard Specification for the Use of Silica Fume as a Mineral Admixture in Hydraulic Cement Concrete, Mortar, and Grout", Vol. 04.02, pp. 1-7, 2007.
10. ASTM C-311-05 "Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete", ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States, pp. 1-7, 2005.
11. ASTM C305-04 "Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic consistency". Annual book of ASTM standards vol.04.01. Philadelphia, USA: American Society for Testing and Materials; 2004.
12. EFNARC, "Specification and Guidelines for Self-Compacting Concrete". London”, UK: Association House, February, 32pp, 2002.
13. ASTM C348-14, "Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars" standard by ASTM International, 2014.
14. ASTM C1186-08 " Standard Specification for Flat Fiber Cement Sheets" standard by ASTM International,2012.
15. Teng Y.S. and Shah S.P., "Crack Propagation in Fiber Reinforced Concrete", Journal of Structural Engineering, Vol. 112, No. 1, pp. (19-34), 1986.