Impact Strength for the 3D Textiles Fiber Reinforced Cementitious Composites Plates

Dr.Waleed A. Abbas[1] **Dr.Ikbal N. Gorgis** [2] **Nadia Moneem** [3]

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Abstract

The use of textile reinforcement made from non-corrosive materials, such as carbon and glass can reduce the required concrete material; this is known as Textile Reinforced Concrete (TRC). This study deals with plate specimens having dimension of 500×500×40mm tested under impact load at 28 and 90 days age under two conditions of ends, simply supported and fixed. Cement mortar with about 60 MPa, 7cm cube compressive strength at 28 days was designed for casting the plates. Plate specimens were divided into four groups, they consist of reference plates (no reinforcement) and plates reinforced with 3D glass fabric having three different thicknesses 6, 10 and 15mm.

The results indicate that using 3D textile glass fabric cause an increase in number of blows, reduce in final stage deflection, an improvement in toughness and energy absorption under impact loads. Using 3D textile glass fiber with 10mm thickness gave higher number of blows for 28 and 90 days as compared with 6 and 15 mm. Plates with slice 6mm 3D textile glass fiber in two way reinforced has significantly enhancement in number of blows, the improvement was about (80 - 125%) and (128.5-114. 3%) for 28 and 90 days respectively. The specimens showed increase in the energy absorption, besides the number and width of cracks was reduced and only few cracks are propagated up to the edge of the plates.

Keywords : 3D Textiles, impact test, self-compact mortars (SCMs), Textile Reinforced Concrete (TRC).

تحمل الصدمة للصفائح السمنتية المركبة والمسلحة بنسيج زجاجي ثلاثي الابعاد

د.وليد عبد الرزاق عباس د.أقبال نعيم كوركيس نادية منعم عبدالحسين

الخلاصة

ان استخدام الالياف اوالنسيج بابعاد ثلاثية مصنوعة من مواد زجاجية اوكاربونية ذات طبيعة كيميائية خاملة يؤدي الى تقليل بكمية المواد السمنتية الداخلة بالخلطة الخرسانية. حيث تضمنت هذه الدراسة قياس تحمل الصدمة لصفائح بابعاد ٥٠٠*٥٠٠*٤٠ ملم وبعمر ٢٨ و٩٠ يوم بواقع نوعين من الشروط الحدودية (بسيطة وثابتة). وتم صب الصفائح باستخدام مونة اسمنتية ذات مقاومة انضغاط ٦٠ ميكاباسكال بعمر ٢٨ يوم. قسمت الصفائح الى اربع مجاميع مؤلفة من صفائح بدون استخدام اي الياف لغرض المقارنة وصفائح مسلحة بثلاث اسماك مختلفة (٦و١٠و١٥ملم) من الياف زجاجية ثلاثية الابعاد.

فحصت الصفائح تحت تاثير حمل الصدمة واظهرت النتائج ان استخدام نسيج زجاجي ثلاثي الابعاد ادى الى تحسن في خواص الصفائح وذلك بزيادة عدد الضربات وتقليل الانحرافات وزيادة في مقدار الطاقة الممتصة. ان استخدام الياف زجاجية بسمك ١٠ ملم تطلب زيادة في عدد الضربات المطلوبة للفشل بعمر فحص ٢٨ و٩٠ يوم مقارنة مع سمك ٦ و١٥ ملم. كما ان استخدام نسيج ثلاثي الابعاد على شكل شراح بطبقتين وبسمك ٦ ملم ابدى قوى ربط اكبر وتحسن بعدد الضربات ، حيث كان التحسن بمقدار ٨٠-١٢٨ % و١٢٨,٥-١١٤,٣% لاعمار ٢٨ و ٩٠ يوم اضافة الى ان جميع الصفائح اظهرت زيادة في امتصاص الطاقة ونقصان في سمك وعدد الشقوق خلال الفحص .

1. Introductiond

Impact strength is of importance when concrete is subjected to a repeated falling object, as in pile driving, or a single impact of a large mass at a high velocity. The principal criterion is the ability of

[1] *Assist.Professor at the Building and Construction Engineering Department /University of Technology/Iraq/Baghdad.*

[2] *Assist.Professor at the Building and Construction Engineering Department /University of Technology/Iraq/Baghdad.*

[3] *Assist.lecture Civil Department of Najaf Technical Institute at the Furat Al-Awsat Technical University/ Iraq.*

a specimen to withstand repeated blows and to absorb energy. In general, the impact strength of concrete increases with an increase in compressive strength, but the higher the static compressive strength of the concrete the lower the energy absorbed per blow before cracking [1, 2]. The capability to absorb energy, often called ‘toughness’, is of importance in actual service conditions of mesh reinforced composites, when they may be subjected to static, dynamic and fatigue loads. Toughness evaluated under impact loads is the impact strength, impact resistance of any reinforced composite can be measured by using many different test methods, grouped into the following categories; Drop weight single or repeated impact test, Constant strain rate test, Weighted pendulum type impact test, etc. [3]. The simplest and most widely used test is the drop-weight test, which can be used to evaluate the relative performance of composites.

Impact load are different from those of static and seismic loads. Since the duration of loading is very short, the strain rate of material becomes significantly higher than that under static and seismic loading. Also, structural deformation and failure modes will be different from those under static and seismic loading [4]. The addition of fibers greatly improves the fracture and impact resistance of concrete. The use of a repeated impact, drop weight test to qualitatively estimate the impact resistance of composites was recommend by ACI-544-1R [5]. One of the greatest advantages in fiber reinforcement of concrete is the improvement in the impact resistance of concrete. Textiles reinforced cement-based elements (TRC) have been intensively investigated in recent years [5]. 3D fabrics having reinforcement in three or-thogonal directions can limit failure by delamination, enhance shear strength and therefore expected to improve the mechanical properties of cement composites under dynamic and impact loads. Recently 3D spacer fabrics were developed for use in cement–based products.

The 3D textile composites have excellent advantages of impact resistance, owing to their more integral microstructure. An experimental investigation was made by Rao and Sekhar [6] on impact strength of glass fiber reinforced self-compaction concrete (SCC) at 60, 120 and 180 days. The fibers volumes were 0.03 % of concrete volume. The results showed that the growth in impact strength of glass fiber SCC mixes was observed to be (25 to 30 %) for 120 days and (45 to 55 %) for 180 days compared with 60 days impact strength. Peled and Mobashe [7] investigated the behavior of 3D AR-glass fabric cement-based composites under impact loading. An impact test set-up based on a free-fall drop of an instrumented hammer 134 N with a drop height of 152 mm was used. The result shows that 3D fabrics significantly improve the toughness and energy absorption of cement based composites under impact Loading, compared to short AR-glass fibers reinforcement. The energy absorption was highly affected by the thickness of the element. Larger toughness was achieved when the fabric faces were positioned in the direction of the hammer drop.

In this work an experimental program was devoted investigate the structural behavior of reinforced concrete plates subjected to impact load. Simply and fixed end conditions were used to calculate the impact resistance for plate specimens with dimension (500×500×40mm).

2. Experimental Work

Plate specimens with 500×500×40mm dimensions were divided into four groups (according to the fiber reinforcement thickness and layers) cast with self-compact mortar and tested under impact loads for two age 28 & 90 days with two end conditions , as indicated in table (1).

2.1 Materials

Ordinary Portland cement (type I) of KRASTA Factory is used in the present study. Table (2 a&b) 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 [8].

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. 45-1984[9].

Ordinary drinking water was used in this work for both making and curing for all specimens. High Range Water Reduction Agent(HRWRA) based on polycarboxylic technology, which is known commercially as Glenium 54 (produced by BASF Company and conforms to ASTM C494 Type F [10]) is used in this study. The dosage of HRWRA is one liter per 100 kg of material (cement and binder), table 4 shows the properties of Glenium 54.

2.2 Additive or Mineral Admixture

Fly Ash: Class F fly ash (FA) produced from Thermal Power plant in Turkey is used as an additive according to ASTM C618-03[11], cement is replaced by 20% of fly ash by weight of cementitious material. The physical and chemical properties are presented in table (5).

Silica Fume: 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 C1240-05 [12] and ASTM C311-05 [13]. The technical specifications of silica fume are presented in table (6).

2.3 3D Textile Glass Fiber

3D textile glass fiber woven fabric consists of two bidirectional woven fabric surfaces, which are mechanically connected with vertical woven piles. Two S-shaped piles combine to form pillar, 8-shaped in the warp direction and I- shaped in the weft direction. An open 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 two direction were drilled (by tool cutters). Plats (1) show the surface, thickness and fibers holes. Tables (7) show typical properties from Fabrics Specifications.

3. Mixing, Casting and curing of self-consolidating mortars (SCM) molds

Several trial mixes were done to indicate the suitable mix proportion for obtaining the required self consolidating mortars (SCM) compressive strength. The proportion of the constituents for the prepared mix is 1:1 (by weight) of ordinary Portland cement and cementitious materials: fine aggregate with 0.6mm maximum size, w/p of 0.36 was selected for this investigation. The mixing procedure used conform to ASTM C305-14 [14] to produce self-compacting mortars (SCM).

Table 1. Details of plate specimens

Group No.	Mix Symbol	Description of plate specimen
1	Ref.	without any fiber
2	F6-1	Plate with glass fiber 6 mm thickness (one layer).
	F6-2	Plate with glass fiber 6 mm thickness (two layers).
	F6-1-S	Plate with glass fiber 6 mm thickness (slice one layer).
	F6-2-S	Plate with glass fiber 6 mm thickness (slice two layer).
	F6-2-S-T	Plate with glass fiber 6 mm thickness (slice two way reinforcement).
3	F10-1	Plate with glass fiber 10 mm thickness (one layer).
	F10-2	Plate with glass fiber 10 mm thickness (two layers).
4	F15	Plate with glass fiber 15 mm thickness (one layer).

Table 2.a Physical properties of the cement

Physical Properties	Test Results	Limits of Iraqi spec. No.5/1984
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 2.b Chemical properties of the cement.

Oxide	%	Limits of Iraqi spec. No.5/1984
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 residue	1.29	< 1.5 %
Free lime (F.L)	0.67	-
Compound Composition	**%**	**I.Q.S. 5: 1984 Limits**
C_3S	58.16	_
C_2S	19	_
C_3A	7.95	_
C_4AF	9.43	_

Table 3. Properties of class (f) fly ash*

Particular	Fly ash (Class F)	ASTM C 618 Class F fly ash
Chemical composition		
Silica (SiO_2%)	65.65	**($SiO_2 + Al_2O_3 + Fe_2O_3$) ≥ 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 4: Typical properties of S.P. (glenium54)*

Form	Viscous Liquid
Chemical composition	Sulphonated melamine and naphthaline formaldehyde condensates
Appearance	Whitish to straw colored liquid
Relative density	1.07 gm/cm3at 20 oC
Chloride content	Nil.
pH	5-8
Alkali content (as NaO2) equivalent	0.26%

*According to manufacturer

Table 5: The technical specifications of silica fume

Structure of material	Silica fume	Limits of ASTM C 1240 -05
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	

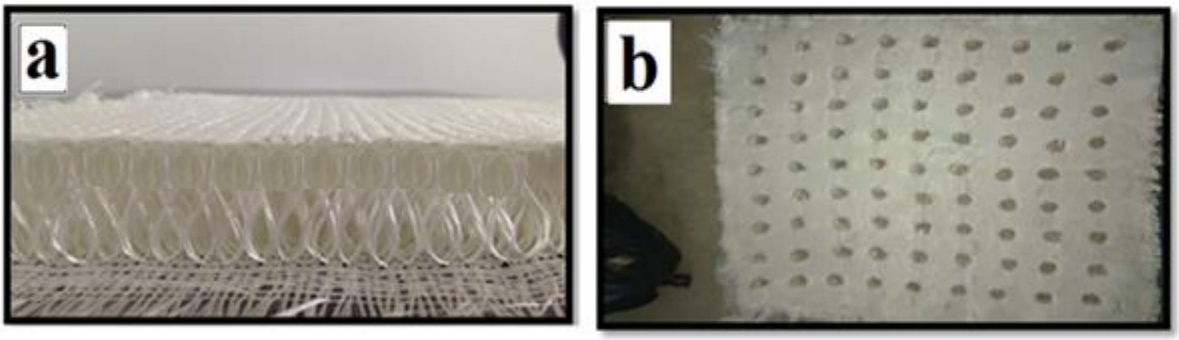
Table 6: Glass fiber woven fabrics specifications*.

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 7: 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
Woven	parabeam
Construction	Two layers and one hollow spacer



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

Steel molds for mortar properties and plate specimens with (500×500×40mm) were prepared. After mixing process completing, molds were treated with oil before casting the mortar.
Plate specimens with multi layers of fibers, the first layer of mortar was poured into the mold followed by placement of first layer of (400×400mm) fiber or (400×100mm) slice reinforcement (3D textile glass fiber), the procedure was repeat for the other layers of reinforcement. All the specimens were covered with a nylon sheet to prevent evaporation of water. After (24hr) the specimens were remolded and soaked in water for 28 days in the laboratory. Then plates extracted from water and left in laboratory condition until the testing age. All specimens were cleaned and painted with white paint on both surface to achieve clear visibility of cracks during testing and easily noticed.

4. Properties of Self-Compacting Mortar

Determination of Slump-Flow and V- Funnel: The test apparatus for measuring the flow and viscosity of mortar comprises a mini frustum (slump) cone and a graduated glass plate. Mini slump cone has top and bottom diameters of (70mm) and (100mm) respectively with a cone 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. Fresh properties of mortars were evaluated by the mean value two perpendicular flow diameters in the spread test. The procedure for slump test v-funnel test was followed as described in EFNARC [15].
Compressive Strength: This test was done on cubes according to the Standard Specification I.Q.S. No.5/ 1984[8]. A3000kN capacity testing machine was used for compressive test. The average compressive strength of three cubes (70×70×70mm) was recorded for each testing age (7, 28 and 90) days.
Flexural Strength: The flexural strength testing is carried out on a (40 × 40 ×160mm) self-compact mortar prism. The prism is then loaded at its center point until failure. Using three mortar prisms for each age (28 and 90) days and the average of three results is adopted. A20kN capacity Beijing United testing machine was used for this test. The modulus of rupture is calculated, as follows – :

$$f_r = \frac{2PL}{3bd^2} \tag{1}$$

where: fr is the modulus of the rupture [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 C348-14 [16].
Tensile Strength: Tensile Strength of mortar test was test according to B.S 6319-7:1985[17]. Briquette molds was used for this test. The average of three samples was used.

5. Impact Test for Plate Specimens

A steel frame was manufactured for this test to allow free falling of steel 5000gm mass in the center of plate specimens, the instrument was presented in Plate (2). The test procedure was achived using two boundary end conditions (simply and fixed supports) the steel mass was released from a height of (1000 mm) repeatedly, which would come in contact with the top surface of the center point of plates. The number of impact blows until the appearance of first visible crack was recorded. Deflection under the central point of the plates was recorded by using a linear variable differential transformer (LVDT) instrument, which was calibrated before using. The loading was then continued and the number of blows until failure was recorded. In average, three plates are adopted in this instrument with two ages of (28 and 90) days. The energy absorption value was obtained by :

$$E = N \times (w \times h) \qquad (2)$$

Where; E is the energy in joules, w is weight in Newton, h is the drop height in meter and N is the blows in numbers. Plates (2) shows Impact Test instrument.

a) Frame of fixed impact test

b) Hammer weight

c) Impact Test instrument.

d) During simply impact test.

Plate (2): Impact test set-up for sample test.

6. Result and Discussion

6.1 Fresh SCMs Properties

The test results relevant to the slump flow diameter, V-funnel flow time are presented in table (9). The results show the mix had slump flow diameter, V-funnel flow time conforming to ref. [10]. 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.

Table 9: Fresh properties of SCMs

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

6.2 Hardened SCMs Properties

The hardened properties of the mortars were summarized in table (10) the strength increased with ages.This development in compressive strength, tensile strength and flexural strength can be attributed to the fact of continuous hydration process (C-S-H), also 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: 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**

6.3 Impact Resistance

The ability to absorb energy is of importance in real service conditions of reinforced composites, when they may be subjected to static, dynamic and fatigue loads. The results of all tested specimens were listed in tables (11 - 15).

6.3.1 Effect of Boundary conditions

Simply and fixed supports were used to achive the impact test the results were listed in tables (11 and 12). The results indicate that the number of blows required to first and failure crack at age of (28 and 90 days) are the same or nearly the same for simply and fixed support condition of SCMs plates reinforced with one or two layers of 3D textile glass fiber. This mean that type of support has no effect on number of blows, although increase in fiber content leads to an increase in the capacity strength of SCMs. Although the deflections of plates (at initial and final stages) with simply supported were slightly larger than those for plates with fixed supports by a range of (5.3- 20.4%) and (2- 21.1%) for the tested plate specimens at 28 and 90 days.

Figures (1 and 2) indicate that inducing fiber in plates specimens cuase a reduction in initial deflection values for all plate specimens, this decrease was about (27- 90.4%), (34- 90.7%) and (9.9- 92.2%), (19- 92.8%) at 28 and 90 days for simply and fixed support respectively. The results of final maximum deflection shows different performance for both test ages and both end support which depend on number of blows, with higher number of blows the value of maximum deflection incrased, this is due to fiber effect and produceing higher toughness.

6.3.2 Effect of Thickness and Number of Fiber Layers

An enhancement was indicated in the number of blows up to ultimate failure at (28, 90) days for simply and fixed support condition. An increasing in thickness and number of fiber layers cause increased in number of blows as compared with refernce plate. The increase in number of blows was about (40 - 220%) and (50 - 250%) at 28 days for simply and fixed support condition respectively. While the improvement at 90 days was about (14.3-128.6%) and (28.6-142.9%) for simply and fixed support condition respectively. Using 3D textile glass fiber with 10mm thickness gave higher number of blows for 28 and 90 days as compared with 6 and 15 mm 3D textile glass fiber thickness. Plates with slice 6mm 3D textile glass fiber in two way reinforced has significantly enhancement in number of blows, the improvement was about (80 - 125%) and (128.5- 114. 3%) for 28 and 90 days.

The maximum deflection has decreased by increase number of layers of 6 mm 3D textile glass fiber, it has decreased by about (5 - 7%) and (16 - 17.6%) at 28 and 90 days for simply and fixed support respectively. Also, the maximum deflection has been decreased by increasing number of 10 mm 3D textile glass fiber layers by about (21.1- 28.5%) and (25- 31%) at 28 and 90 days for simply and fixed support respectively.

Regarding SCMs plate reinforced with 6mm 3Dtextile glass fiber slice (one, two) layers shows the same behaviors (maximum deflection) has been decreased (see Figure 1 and 2), the decrease was about (29- 38.6%), (59.6- 62%) and (40.7- 41%), (54.6- 87.6%) for one and two layers of 6mm 3D textile glass fiber at 28 and 90 days for simply and fixed support respectively.

Table (11): Number of blows and deflection results for specimens under impact test at 28 days

Mix ID	Simple support				Fixed support			
	Initial	Max Deflection (mm)	Failure	Max Deflection (mm)	Initial	Max Deflection (mm)	Failure	Max Deflection (mm)
R	1	1.847	5	29.796	1	1.7	4	27. 96
F6/1	1	1.347	7	25.12	1	1.15	6	24.657
F6/2	2	1.28	8	30.56	2	1.074	7	29.9
F6/1/S	1	1.31	7	33.12	1	1.043	7	31.24
F6/2/S	2	0.746	8	26.175	2	0.645	10	24.673
F6/2/S/T	2	0.176	9	14.067	3	0.158	9	20.134
F10/1	2	1.19	11	33.228	2	1.12	10	26.43
F10/2	2	0.938	16	26.341	2	0.801	14	24.301
F15	2	1.26	8	37.01	2	1.02	9	33.65

Table (12) : Number of blows and deflection results for specimens under impact test at 90 days

Mix ID	Simple support				Fixed support			
	Initial	Max Deflection (mm)	Failure	Max Deflection (mm)	Initial	Max Deflection (mm)	Failure	Max Deflection (mm)
R	1	1.576	7	36.14	1	1.42	7	34.01
F6/1	2	1.32	8	28.012	1	0.982	9	30.67
F6/2	2	1.10	13	28.078	2	0.809	11	24.819
F6/1/S	1	0.934	10	32.94	2	0.837	7	31.797
F6/2/S	2	0.716	10	25.01	2	0.176	12	24.5
F6/2/S/T	4	0.122	16	33.09	4	0.102	15	26.108
F10/1	2	1.04	14	32.67	2	1.0	12	30.90
F10/2	3	0.78	16	28.87	3	0.69	17	28.45
F15	2	1.196	10	30.143	2	1.076	10	26.301

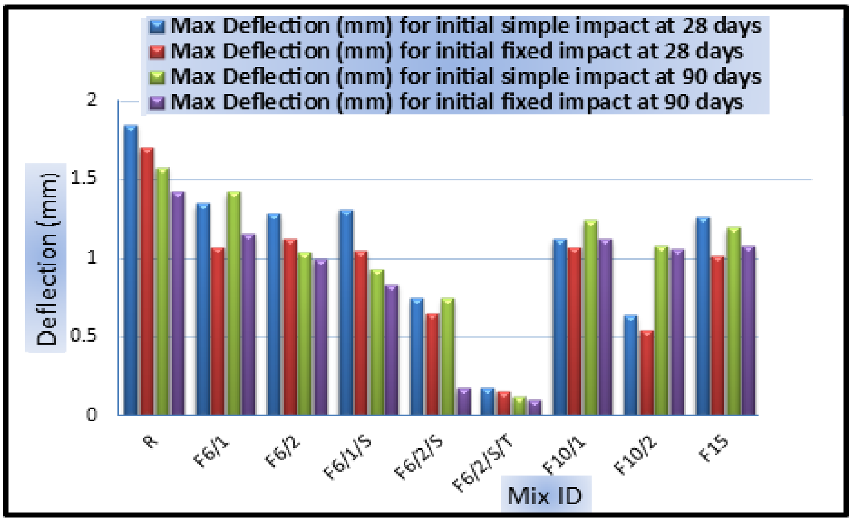


Figure (1): Max deflection for initial simple and fixed impact at (28, 90) Days.

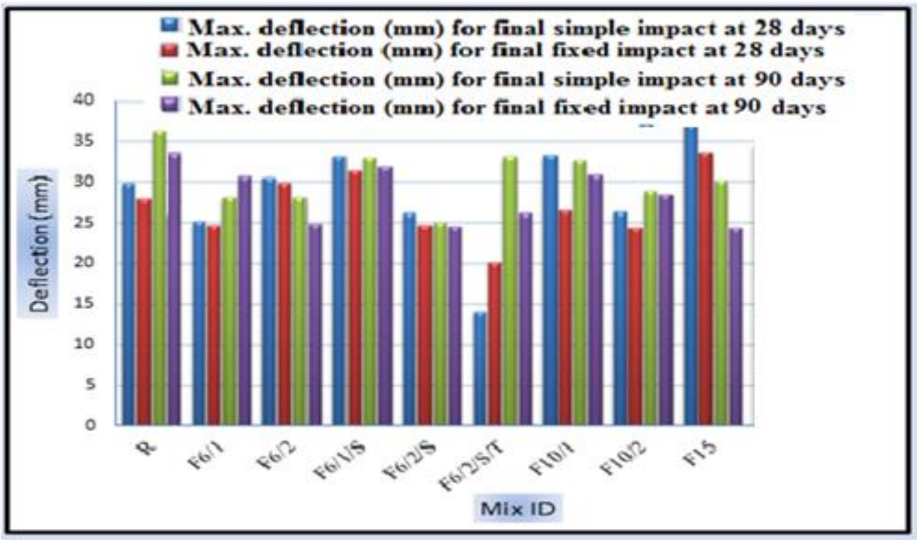


Figure (2): Max deflection (mm) for final simple and fixed impact (28, 90) Days.

6.4 Energy Absorption

The energy absorption can be obtained by using formula described by equation (2). The ratio of energy absorbed up to the failure of specimens to the energy absorbed at initiation of first crack is defined as the "Residual Impact Strength Ratio"(Irs). The energy absorption capacities of all SCMs plates at initial crack and at ultimate failure stages are presented in tables (13 and 14). The results indicate that the number of layers and increase in thickness of 3Dtextile glass fiber improve the impact energy absorption compared to the reference plates.

The energy absorbed is directly proportional to the volume of the 3D textile glass fiber (thickness, layers number) provided in the SCMs plates. Figure (3) indicates that the energy sbsorbed was signifactntly improved in final stages with increasing the layer of 6 and 10mm 3D textile glass fiber thickness and reduces with 15mm thickness. This is due to good bond between the matrix and fiber with thickness 6 and 10mm thickness and easily saperation was indicated with 15mm thickness.

Table (13): Energy absorption capacity of SCMs plates at 28 days

Mix ID	Impact energy observed (Joules) Simple support		Residual impact strength ratio (I_{rs})	Impact energy observed (Joules) Fixed support		Residual impact strength ratio (I_{rs})
	Initial	Final		Initial	Final	
R	49.05	245.25	5	49.05	196.2	4
F6/1	49.05	343.35	7	49.05	294.3	6
F6/2	98.1	392.4	4	98.1	343.35	3.5
F6/1/S	49.05	343.35	7	49.05	343.35	7
F6/2/S	98.1	392.4	4	98.1	490.5	5
F6/2/S/T	98.1	441.45	4.5	147.15	392.4	2.67
F10/1	98.1	539.55	5.5	98.1	490.5	5
F10/2	98.1	784.8	8	98.1	686.7	7
F15	98.1	392.4	4	98.1	294.3	3

Table (14): Energy absorption capacity of SCMs plates at 90 days

Mix ID	Impact energy observed (Joules) Simple support		Residual impact strength ratio (I_{rs})	Impact energy observed (Joules) Fixed support		Residual impact strength ratio (I_{rs})
	Initial	Final		Initial	Final	
R	49.05	343.35	7	49.05	343.35	7
F6/1	98.1	392.4	4	49.05	441.45	9
F6/2	98.1	637.65	6.5	98.1	539.55	5.5
F6/1/S	49.05	392.4	8	98.1	343.35	3.5
F6/2/S	98.1	490.5	5	98.1	588.6	6
F6/2/S/T	196.2	784.8	4	196.2	735.75	3.75
F10/1	147.15	686.7	4.7	98.1	588.6	6
F10/2	147.15	784.8	5.3	147.15	784.8	8
F15	98.1	490.5	5	98.1	490.5	5

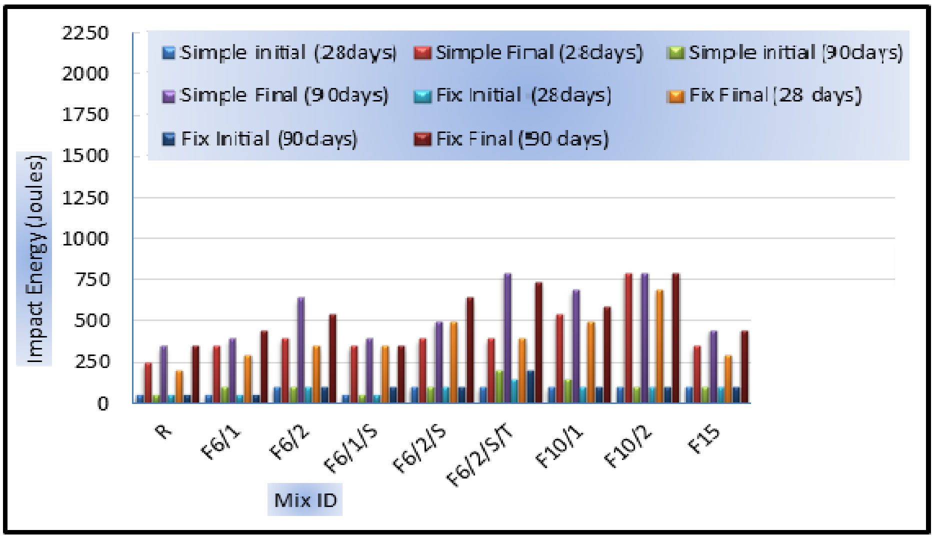


Figure (3): Energy absorption capacity at (28, 90) days for fixed and simply support.

6.5 Crack Pattern

A high quality Portable microscope designed for measuring crack widths in concrete members was used to measured initial and final crack width, the larger cracks were measured by used Vernier caliper . The fact of crack patterns and failure modes in impact load often depend on position of striker and plat towards the supports. In present study, the crack patterns for all SCMs plates were in diagonal direction and start from center point of plate where mass is falling, then propagation in all direction in lines perpendicular to its edges. The width of cracks varies for plate specimens, which depend on 3D textile glass thickness, table (15) indicates the following points describe the cracks formation and propagation after impact load. The reference plates which was strongly influenced by impact load and significant cracks has propagated rapidly.

- Average crack width has decreased by 3D textile glass fiber introduceing, this is due to sufficient bridging amongst the invisible cracks and disallowed cracks propagating.
- Average crack width has decreased by increasing the thickness and layer numbers of 3D textile glass fiber.

The failure mode was punching with truncated cone shape, the increasing in thickness and number of fiber decreases the cracks width and change the plate behavior from the localized punching to global response, as indicated in plates (3) and (4). The increasing in thickness and number of layers cause multiple cracks to start with small crack width propagated up to the edge and cracks are interconnected like network.

Table (15): Crack width for all SCMs specimens tested.

Mix ID	Simple support (28 days)		Fix support (28 days)		Simple support (90 days)		Fix support (90 days)	
	Initial crack width (mm)	Failure crack width (mm)	Initial crack width (mm)	Failure crack width (mm)	Initial crack width (mm)	Failure crack width (mm)	Initial crack width (mm)	Failure crack width (mm)
R	0.953	4.48	0.815	4.17	0.75	3.23	0.675	2.72
F6/1	0.86	3.87	0.81	2.98	0.33	4.07	0.31	2.17
F6/2	0.565	3.8	0.46	2.43	0.212	2.33	0.197	2.1
F6/1/S	0.8	3.23	0.76	2.75	0.686	2.93	0.241	2.35
F6/2/S	0.74	3.055	0.7	2.26	0.66	2.17	0.375	1.25
F6/2/S/T	0.31	1.31	0.27	1.1	0.18	0.729	0.075	0.119
F10/1	0.51	4.59	0.46	3.34	0.237	2.11	0.156	1.7
F10/2	0.5	4.31	0.41	2.7	0.21	1.61	0.066	0.86
F15	0.46	2.33	0.367	2.21	0.467	3.21	0.22	0.71


a) Crack width measuring by Portable Microscope.


b) Crack width measuring by Vernier Caliper

Plate (3) Crack width measuring.

a) Initial Crack of Fixed Support. **b) Final Crack of Fixed Support.**

Plate (4) Crack pattern of plate specimens with 3Dtextile glass fiber.

7. Conclusions:

Based on this work *in* can be concluded that 3D textile glass fiber can be beneficial as reinforcement for cement-based composites, which significantly improve the impact strength and toughness . The following conclusion could be drawn from the results of this work:

1- The number of blows up to ultimate failure at (28 and 90) days for simply and fixed support condition of SCMs plates were enhanced with increasing thickness and number of fiber layers, this mean increase in fiber content *and* leads to an increase in the capacity strength of SCMs.

2- The deflections of plates (at initial and final stages) with simply supported were larger than those for plates with fixed supports by a range of (5.3- 20.4%) and (2- 21.1%) for the tested plate specimens at 28 and 90 days.

3- The energy absorption was highly affected by the thickness and number of layers of 3D textile glass fiber, energy *sbsorbed* was signifactntly improved in final stages with 6 and 10mm 3D textile glass fiber.

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