INVESTIGATE THE BEHAVIOR OF 3D TEXTILES FIBER REINFORCED CEMENTITIOUS COMPOSITES PLATES UNDER IMPACT LOAD

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ABSTRACT

We have proposed a new textile reinforcement which was made from non-corrosive material (smart material: such as steel and glass). That will be effectively reduce the required concrete material, this technique which is called the Textile Reinforced Concrete (TRC). This paper presents a plate specimen with dimension of (500x500x400 mm), to demonstrate the effectiveness of our material we have tested under an impact load during 28 to 90 days with two different conditions simply support and fixed, respectively. Cement mortar with 60 MPa, 7 cm cube shape compressive strength for 28 days has been designed for the casting process of the plate. The reference plate (has 22 sub plates) which is divided into four categories were casted essentially with 3D glass fabric, all these groups have three different thickness (6,10, and 15 mm) indeed a 0.75 volume fraction of the micro steel and ferrocement that is known as mesh chicken wire layers. The simulation and the experimental results demonstrate that, the steel fibre gave higher quality results than the 3D glass fabric and mesh chicken wire, indeed we have proven that the 3D glass fabric with 6 mm gave higher number of blows than the other thicknesses.

Keywords: 3D textiles, impact test, self compact mortars, textile reinforced concrete.

1. INTRODUCTION

Structural elements are commonly subjected to a wide variety of static and dynamic loads. One of the major categories of dynamic load is impulsive or shock loads. These may be caused by missile impact, blast loads on structures, aircraft crashing against a structure, etc [1]. 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 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 [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, which can be broadly grouped into the following categories.

a) Drop weight single or repeated impact test,

b) Constant strain rate test,

c) Weighted pendulum charpy type impact test,

d) Explosion- impact test,

e) Projectile impact test,

f) Instrumented pendulum impact test,

g) Split Hopkinson bar test [3].

Numerous methods have been reported to estimate the impact characteristics of concrete/cement composites. Of these, the simplest and most widely used test is the drop-weight test, which can be used to evaluate the relative performance of composites.

The characteristics of the 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. In construction industry, strength is a primary criterion in selecting a concrete for a particular application. Concrete used for construction gains strength over a long period of time after pouring. Therefore, rapid and reliable prediction for the strength of concrete would be a great significance [4].

The dynamic response to impact is complex and is dependent on many factors such as the velocity of the striker, size of the striker, contact area, size of the target structure, material behavior of the striker and the structure, etc. It is necessary to estimate the maximum dynamic energy that a structure could absorb without failure or to predict the damage that a structure would sustain if it were involved in a collision with another body or subjected to explosive loads. The addition of fibers greatly improves the fracture and impact resistance of concrete [1]. The use of a repeated impact, drop weight test to qualitatively estimate the impact resistance of composites was recommend by [5].

One of the greatest advantages in fiber reinforcement of concrete is the improvement in the impact resistance of concrete. Unfortunately, due to a lack of satisfactory tests for impact resistance of fiber reinforced concrete, it has been difficult for researchers to assess the exact magnitude of improvement. The 3D textile composites have excellent advantages of impact resistance, owing to their more integral microstructure. An experimental investigation was made 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 is observed to be (25 to 30 %) for 120 days and (45 to 55 %) for 180 days compared with 60 days impact strength. The increase in impact strength of glass fiber SCC mixes at 60, 120, 180 days are observed to be (12% to 17 %) when compared with SCC mixes [6].

The behavior of 3D AR- glass fabric cement-based composites under impact loading was investigated by [7]. 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. A linear variable differential transformer (LVDT) with a range of +10 mm was connected to the specimen by means of a lever arm. 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 3D fabric improves the toughness in as high as 200 folds; compared to short fiber composites. 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.

The impact response of fixed ends concrete plate under drop weight was discussed by [8], plate dimensions were (600× 600) mm with thickness varying from 20 to 25mm and 30mm, steel fiber with aspect ratio (l/d) (50,75,100). The impact testing machine consisted of vertical steel pipe fixed by a general steel frame, the pipe used for controlling the drop weight, drop weight represented by cylindrical weight 4.5kg and a stainless-steel ball of 61.5mm and weighs 0.5kg. The inside surface of the steel pipe was lubricated to avoid any friction between the casing and the ball. The whole arrangement was fixed to a vertical steel frame then welded to the base frame that holds the plate. The height of fall of the spherical ball is kept constant for all plates test which is equal to750mm. The results indicate that a maximum displacement was about 50mm for steel fiber 0.5% compared to 1% of plate thickness equal to 20mm, and it was equal to (40 and 35) mm for thicknesses equal to (25, 30) mm respectively. For l/d of fiber 50 to 75, the changing of fiber amount from 0.5 to 0.75% increases the energy absorption about 20%. The energy absorption increases up to 50% for steel fiber amount 1% and l/d equal to (100). The result also shows, the l/d of fiber did not play a significant role in the behavior when the steel fiber amount was less than 0.5%, increasing the steel fiber amount to 0.75% and 1% will increase the impact resistance about 60%. The crack width in steel fiber reinforced concrete plates was much less as compared to cracks in plates without steel fibers.

An experimental program was conducted by [9] on seven intermediate - scale plates (1800×1800×130mm) were constructed and tested to failure under sequential drop weight impacts. Three plates were constructed using plain concrete, and four plated were constructed from a steel fiber reinforced concrete (SFRC) mixture design with varied volumes of end hooked steel fibers. The plates contained longitudinal reinforcing bars and were constructed with steel fiber contents ranging from zero to 1.50% by volume. The plates restrained at their corners and impacted at their centers. The test results showed that the addition of end hook steel fibers was effective in increasing plate capacity, reducing crack widths and spacing, and mitigation of local damage mechanisms, such as mass penetration and concrete scabbing; and increased plate stiffness and capacity.

[10] Investigated the impact resistance and energy absorption properties of reinforced ferrocement plates under impact load. For this a series of five ferrocement plates with dimensions of (450×450×25mm) were casted and tested. The impact loading was applied to the specimens by dropping a 3.5 kg steel ball from a height of 118 mm at the center of plates. The plates were casted with reinforcing bars and different types of reinforcing meshes such as expanded mesh, rectangular welded mesh, and welded mesh light and hexagonal mesh. Polypropylene fiber was used in the mix to produce fibrous concrete jacket to improve the concrete characteristics. The impact energy at initial cracking stage and at failure was determined for all the plates. The results indicated that higher energy absorption is achieved in expanded metal mesh light as they are effective in controlling the developed cracks.

[11] Worked on the behavior of multilayer composite ferrocement plates. The plates include two ferrocement layers with an intermediate rubberized cement mortar (RCM) layer. Different rubber ratios, different thickness of RCM layer. The specimens were cast in (500×500×50 mm), modulus of rupture, and impact resistance were also tested for RCM cubes, prisms, and plate cement mortar specimens to illustrate mechanical properties for using cement mortar. The increase in the RCM layer thickness, with an increase in the crumb rubber ratio, it increases impact energy to cause first a crack and then full perforation. The results show that the rubber content decreases the modulus of rupture by 29 and 50% crumb rubber content decreases the modulus of rupture by about 66 and 52% compared with normal mortar, and 25% containing crumb rubber mortar, respectively, at 7 days. 75% crumb rubber content decreases the modulus of rupture by 80, 72, and 42%, compared with normal mortar, with a 25, and 50% crumb rubber content, respectively. At 28 days, the flexural strength in normal mortar decreased by 58% in mortar with a 25% crumb rubber content, 69% in mortar with a 50 % crumb rubber content, and 94% in mortar with a 75% crumb rubber content. The results also show, when comparing the reference plates (one layer or two layer ferrocement plates) with the plates that contain a rubberized cement layer, we find the effect of the rubberized layer is to increase the impact energy required to cause the first crack and the perforation. This increment depends on the existence of shear connectors, the

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thickness of the rubberized cement layer and the crumb rubber ratio. The failure shape depends on the RCM layer and shear connector. Also, the failure for ferrocement is always local, with no visible yield line from center to corners. There is no major difference in crack pattern as all the cracks start from center and progress to the edges in a winding path.

[12] Investigated ferrocement plates subjected to impact test. A total of twenty-four plates were tested that includes varying materials (ingredients) and different number of reinforcing weld mesh layers. The ferrocement plates were cast in molds of dimension 300 × 300mm with thickness varying from size 25 to 30mm. The mix proportions include variable additive materials for the specimen's preparation and compared with the conventional plate. From the drop weight impact test, it is observed from the results that the number of reinforcing layers improve the impact energy absorption and have influence in confining the fragments mix together. From the comparison the mix containing cement, sand and 10% addition of silica fume (SF) and 40% replacement of cement with ground granulated blast slag (GGBS) to the volume of cement. These specimens showed increase in the energy absorption compared to other mixes. Also, they found, when increasing the layers of weld mesh, the width of the cracks is reduced and only few cracks are propagated up to the edge of the plates. Higher reinforcement content restricts the cracks to propagate and create localized failure i.e., at the point of impact of load, and the failure is characterized by formation initially at the bottom surface of the specimen, propagating to the sides and then widening further. Increase in the volume of reinforcement the energy absorption is also increased when compared to the control mix. The failure pattern in the impact tested plates is found to be punching shear due to higher reinforcement, and the energy absorbed at failure is directly proportional to the volume of the reinforcement provided in the ferrocement plates.

2. EXPERIMENTAL WORK

An experimental program was devoted in this work to investigate the structural behavior of reinforced concrete plates subjected to impact load. For simply and fixed impact Specimens with dimension (500×500×40mm) were divided into multi croups according to the fiber reinforcement thickness, layers, direction of reinforcement, and type of reinforcement. Plates group "one" have self-compact mortar without reinforcement®, group "two" plates reinforce with 6mm 3D glass textile fiber including plates reinforce with one layer, two layers, slice one and two layers, group "three" 10mm 3D glass textile fiber casted with one and two layers, while group "four" are of 15mm 3D glass textile fiber casted with one layer only. This divided for three-dimension glass textile fiber, another groups such as group "five" self-compact mortar reinforced with chicken wire also casted one and two layers, the final group "six" reinforced with micro steel fiber of 0.75% volume fraction, three specimens were casted for each age test (28, 90) days. For impact test, each group three specimen for each age (28, 90) were casted and tested. Details of the specimens are shown in table (1).

2.1 Materials properties

The properties of materials used in the preparation of the tested reinforced and unreinforced self compact mortar are described below.

2.1.1 Cement

Ordinary Portland cement (type I) of KRASTA Factory is used in the present study. Table (2) and show 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 [13].

2.1.2 Fine aggregate

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 [14].

2.1.3 Water

Ordinary drinking water was used in this work for both making and curing for all specimens.

2.1. 4 High range water reducing admixture (Superplasticizer SP.)

A high performance concrete super plasticizer (also named High Range Water Reduction Agent HRWRA) based on polycarboxylic technology, which is known commercially as Glenium 54. It is produced by BASF Company and conforms to ASTM C 494 Type F [15], is used in this study. The dosage of 1 liter per 100 kg of material (cement and binder). Table (4) shows the properties of Glenium 54.

VOL. 13, NO. 4, FEBRUARY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-1. Details of test specimens (unreinforced and reinforce) mortars.

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 thicknesses (one layer).
5	FS-1	Mesh chicken wire (one layer).
	FS-2	Mesh chicken wire (two layers).
6	M S F	Micro steel fiber with 0.75 volume fraction.

2.1.5Additive or mineral admixture

2.1.5.1 Fly ash

Class F fly ash (FA) produced from Thermal Power plant in Turkey is used as an additive according to ASTM C 618 [16], cement is replaced by 20% of fly ash by weight of cementitious material. The physical and chemical properties are presented in Table-4.

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 (L.S.F)	0.93	0.66 - 1.02
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[13] Limits
Fineness, Blaine, cm^2/gm	3300	>2300
Setting Time: Initial hrs.; min	1;08	≥45 min
Setting Time: Final hrs.; min	4;00	≤10hrs
Compressive Strength (MPa) 3-days	20,0	≥15
Compressive Strength (MPa) 7-days	25,0	≥23

2.1.5.2 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 C-1240-05 [17], ASTM C-311-05 [18]. The technical specifications of silica fume are presented in Table (5).

2.1.6 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. 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 a textile as reinforcement in concrete, textile should have 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 for vertical and horizontal direction were drilled (by tool cutters) for the 3D textile glass fiber glass woven; 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

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that compose the fabric. Plats (1) show the surface, thickness and fibers holes). 3D glass fiber textile woven export from china. Tables (6, 7 and 8) shows typical properties, Fabrics Specifications.

2.1.7 Mesh chicken wire

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

2.1.8 Micro steel fiber

Steel fibers are used in self compact mortars (SCMs) to enhance some properties and improve the ductility; it was manufactured by Ganzhou Daye Metallic Fiber Co., Ltd, China. (http//www.gzdymf.com), it is subjected to (ISO 9001/2008) the properties are summarized in Table-9. After poured first layer of self compact mortars; micro steel fiber (0.75%) volume fraction was randomly distribution by hand.

Table-3. Properties of fine aggregate.

Physical properties*	Test results	Iraqi specification. 45/1984[14]
Specific gravity	2.65	-
Sulfate content	0.3 %	Not more than 0.5%
Absorption	1 %	-
Bulk density(kg/m^3)	1560	-

Table-4. Physical and chemical properties of class (F) fly ash.

Particular	Fly ash (Class F)	ASTM C 618 Class F fly ash [16]
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

Table-5. The technical specifications of silica fume.

Structure of material	Silica fume	Limits of ASTM C 1240-05 [17]
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 specification.

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

VOL. 13, NO. 4, FEBRUARY 2018 ISSN 1819-6608
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Table-7. 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-8. 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

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

2.2 Mixes

The proportion of the constituents for the prepared concrete mix is 1:1 (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 mixing procedure used to produce self-compacting mortars was as described:

*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. 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, adding 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.

2.3 Mortar test apparatus

2.3.1 Determination of slump-flow

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. 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 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 [19].

2.3.2 Determination flow time

Flow time determined in the v-funnel test, the dimension of v- funnel is show in Figure-1.

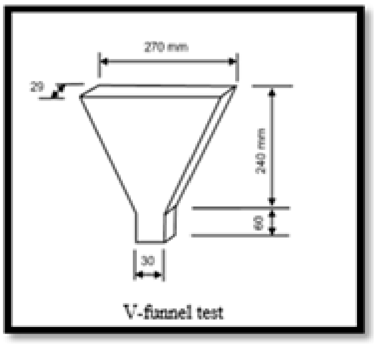

Figure-1. V-funnel.

2.4 Molds preparation

Steel molds (500×500×40mm) are fabricated for casting the one hundred ninety-two unreinforced and reinforced self-compact mortars plats impact load. The molds are made of (4 mm) thickness steel and their side pieces are connected by bolts which can simply be removed and fastened.

2.4.1 Casting, curing of SCMS molds

After mixing process completing, molds were treated with oil before casting the mortar, the mortar are cast in molds without any vibration. When used multi layers the first layer of mortar is poured into the mold, followed by placement a layer of (400×400mm) plate or (400×100mm) slice reinforcement (3D textile glass fiber, chicken wire), this procedure is repeat for two-layer reinforcement, micro steel fiber was distribution by hand after first layer of mortar poured, then the mold fills with mortar, the molds easily and permeates between reinforcing without any segregation. Then, after casting, the specimens are covered with a nylon sheet to prevent evaporation of water. After (24hr), the specimens are remolded, all specimens were marked and soaked in water for 28 days in the laboratory. Then specimens extracted from water and left in laboratory condition until the testing age. Before the testing day, all specimens were cleaned and painted with white paint on both surface to achieve clear visibility of cracks during testing and easily noticed.

3. MECHANICAL PROPERTIES OF HARDENED SCMS

3.1 Compressive strength

This test was done on cubes according to the Standard Specification I.Q.S. No.5/1984[13]. 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, 90 days).

3.2 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, 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:

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

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 [21].

3.3 Tensile strength; test of mortar

Tensile Strength of mortar test was test according to B.S 6319-7:1985 [22]. Briquette molds was used for this test. The average of three samples was used.

3.4 Manufacturing impact test instrument

The main difficulty is the absence of standardized test technique for testing concrete under impact. Many researchers have used different impact machines, specimen configuration, geometry and instrumentation and have also adopted different analysis schemes. The impact test procedure is the infant stage, that not only there is no available impact testing instrument, but also clear lacking national researches that concern dynamic load; hence, it is found that is convenient to manufacture Impact Testing Instrument in order to cover the present study requirements. A repeated impact drop - weight test adopted as a dynamic test procedure implemented in the present work, the impact instrument design specially to allow drop free falling mass to affect concrete plate specimen with dimension (500 × 500× 40 mm) in the center. The impact instrument mainly consists of five parts as listed below:

a) Main instrument structure.

b) The impact masses or strikers.

c) Vertical guide for the falling mass.

d) Counter unit.

e) Supporting frame.

The instrument structure generally manufactured using steel members. It was constructing with three-dimensional structure as that appear in Figure-2. The instrument detail was described below.

The outside dimension of structure is (550×550×2000 mm). Equal leg angle section with size (500×500×40 mm) is use in manufacturing. Four vertical members are use as main columns of the structure. The length these columns are (2000 mm) and the distance between any two Contiguous columns is (550 mm). Iron welding is used to joining the columns together at the top and the bottom. Joining columns with others done by use horizontal members from the same section of leg with length (550 mm). The main structure fixed to the ground by using four roll bolts. The roll bolts Types are (M10). It done by use hummer drill to getting holes in the concrete ground and install the main structure of the instrument in the rigid base to prevent any sides' way during the test. In addition, the instruments provided with braced members jointed between the columns diagonally. The advantage of braced members is to avoid skewing that might cause due to eccentric loading or reaction of impact. Equal leg angles size (70×70×4 mm) used in two levels. The first level located at the distance of (300 mm) from top main structure while the second level located at distance (1000 mm) also from top main structure. The braced done by use iron welding the horizontal members with the main columns. A steel hummer with cylindrical shape and spherical end was use as impact hummer. The mass of this hummer is (5000gm) and the net diameter is (50 mm) and length (250 mm). It is free falling from a height of (1000

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mm). The hummer suspended up and allowed to drop by use steel wire. The diameter of wire is (3 mm). The hummer pulls up by means of wire through vertical guide. This guide is composed of a hollow tube member with internal diameter (53 mm). The tubes placed vertically; and pass through the braced members then well welding with them. The wire that pulled the drop hummer pass over two steel rollers fixed at the upper end of the guiding tube and the other fixed at the corner of the instruments in top side. The advantage of these two rollers to allow wire moves without friction. The other end of wire jointed with crowbar allowed pulling up and freely falling the mass manually. It is installing at the right-hand side at the top of the main structure. In addition, the instrument provided with digital counter use to number of drops required to get the concrete plat failure due to impact load. It is consisting of two parts, the first one is digital screen work by electrical power (220 volt) and other part is count switch (limit switch). it has electrically wired to gathers. This switch installed at the second level of braced members. The guide slotted longitudinally at this position to allow the limit switch spindle to touch the doped mass when move down. At the distance, equal to (600mm) from the top of main structure, the left columns provided with hinge joints and the base of structure also provide means allow to ease tightens and opens the lower part of the structure to insert the supporting frame inside the structure between columns. The supporting frame manufactured by using the same equal leg angle section that used in the main structure. The supporting frame used to bearing the concrete plate specimen during the test. It manufactured as like parallelogram shape. The dimensions of frame are (500×500×250 mm). It is providing with means at the bottom used for catching the linear variable differential transformer (LVDT). This frame jointed to the main structure by use two bolts with size (13mm) in each edge. So the frame provided with framework in top. The framework is use of support the concrete plate and simulate the case of fixed end support in the truth. In addition, the supporting frame provided with two simple support means, where two rectangular hollow sections with dimension (60×40×3mm), it is jointed to the supporting frame by using two bolt size (13mm) on two parallel edges, which is used to test a simply impact test; also, rubber layer (50×50×4.3mm) is inserted above and below the concrete plate specimen in impact test for simply support and fixed support. The rubber helps to reduce the damping the effect of impact wave on support. The test procedure adopted is as (5000gm) steel mass was released from a height of (1000 mm) repeatedly, which would come in contact with the top surface of the center of plates. Figure-2 shows the impact instrument Schematic diagram.

The number of impact blows until the appearance of first visible crack was recorded. 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, 90) days. The energy absorption value was obtained by:

$$E = N \times (w \times h). \quad (2)$$

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.

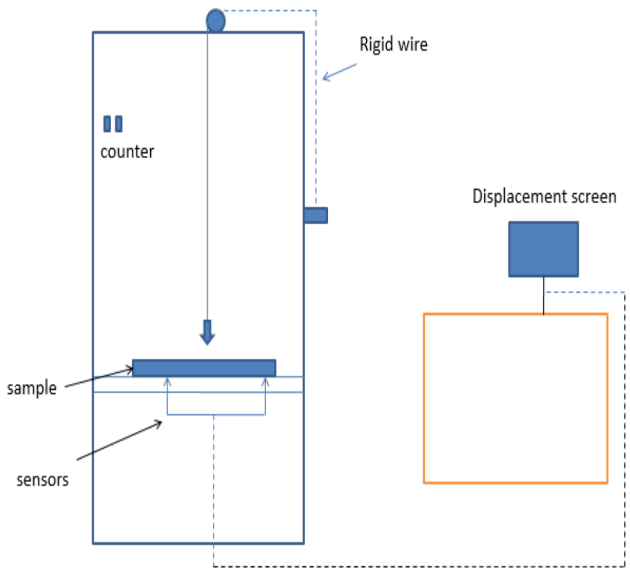

Figure-2. Schematic diagram.

Plate-2. a) Frame of fixed impact test. b) Hammer weight. c) Impact test instrument. d) During simply impact test.

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4. RESULTS AND DISCUSSIONS

4.1 Fresh mortar properties

The test results relevant to the slump flow diameter, V-funnel flow time are presented in Table (9). From result show the mixture had slump flow diameter, V-funnel flow time conforming [19]. 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)	$G_m = \left(\frac{Dm}{D_0}\right)^2 - 1$	$R_m = \frac{10}{t}$
	25.4	**9.5**	**5.45**	**1.05**
Acceptance criteria of SCMs suggested by [19]	24-26	7-11	-	-

4.2 Hardened SCMs properties

The hardened properties of the mortars were summarized in Table-10. From results showed in Table-10, the strength increased with ages. This development in compressive strength, tensile strength and flexural strength can be attributed to the fact continuous the 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. Result 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

4.3 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. Impact resistance of any reinforced composite can be measured by using many different test methods, which can be generally grouped into the following categories:

a) Drop weight single or repeated impact test.
b) Constant strain rate test,
c) Projectile impact test,
d) Weighted pendulum charpy type impact test,
e) Explosion- impact test,
f) Instrumented pendulum impact test,
g) Split Hopkinson bar test [3].

Several methods have been reported to evaluate the impact characteristics of cement composites. The simplest and most widely used test is the drop weight test, which can be used to evaluate the relative performance of composites. The impact resistance of plates with (500×500×40 mm) cast with self- compact mortar (SCM) was determined as the number of blows required causing complete failure for two end conditions; in which simply supported at two ends and fixed all around edges. The mass of (5000gm) was repeatedly dropped for a (1000 mm) height up to failure of plates. Two sets of number of blows were recorded depending on the mode of failure, the first number was for first crack and the second was for failure. The results of number of blows required to first and failure crack at age of (28, 90 days) are present in Figures (3) to (6). If careful has been undertaken Figures (3) through (6), several points can be obtained and as shown in the following points: -

*The number of blows at (28, 90) days for simply and fixed support condition of SCMs plates reinforced with one or two layers fiber (3D textile, chicken wire mesh), cause first crack same or nearly to the number of blows caused first crack for unreinforced reference plates. This mean increase in fiber content leads to an increase in the capacity strength of SCMs.

*Increase the number of blows up to ultimate failure at (28, 90) days for simply and fixed support condition of SCMs plates with increasing thickness and number of fiber layers, the increase was about (40 - 220%), (50-250%) at 28 days for simply and fixed support condition respectively. While the improvement at 90 days was about (14.3-128.6%), (28.6-142.9%), for simply and fixed support condition respectively.

*Regarding the result of chicken wire mesh, there was an increase in number of blows up to ultimate failure at 28 days for simply supported plates with increasing the number of layers, the increase was about (16.7%) and (25%) at 90 days for simply support condition respectively.

*By comparing with unreinforced plate®, significant improvement in number of blows for plates reinforced by micro steel fiber for first crack and ultimate failure, the increase was about (500%) and (500-542%) for 28 and 90 days respectively.

*With respect to the initial maximum deflection, presence of fibers with three diverse types used, cause a decrease in deflection. This decrease was about (27-90.4%), (34-90.7%) and (9.9- 92.2%), (19- 92.8%) at 28, 90 days for simply and fixed support respectively.

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*Final maximum deflection has decreased by fibers introducing, it has decrease about (15.7- 52.8%), (11.8-27.9%) and (8.9- 44.6%), (6.5- 44%) at 28, 90 days for simply and fixed support respectively. By comparing with reference SCMs plate the maximum deflection has decreased by increase number of layers of 6 mm 3D textile glass fiber, it has decreased about (5, 7%) and (16, 17.6%) at 28, 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, 90 days for simply and fixed support respectively.

*Regarding micro steel fiber reinforced SCMs plate, the initial deflection has significant reduction. The reduction was about (68.6, 67.7%) and (68.4, 64.9%), and the final deflection shows the same behavior and cause reduction by about (12.7, 11.8%) and (33, 34.4%) at 28, 90 days for simply and fixed support respectively.

*In spite of different and increased in number of blows caused initial and ultimate failure. The deflections of plates with simply supported condition 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, 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, 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 3Dtextile glass fiber at 28, 90 days for simply and fixed support respectively. From Tables (12,13) and figures (3,4), 6mm 3Dtextile glass fiber slice two way reinforced has significantly enhancement in number of blows, the improvement was about (80, 125%) and (128.5, 114.3%), also max deflection was reduced, the reduction was about (90.5, 90.7%) and (92.3, 92.8%) at 28, 90 days for simply and fixed support respectively.

*With respect to the maximum deflection has been decreased by increasing number of layers of 10 mm 3D textile glass fiber, it has decreased about (21.1, 28.5%) and (25, 31%), while the reduction in deflection about (3.5, 8.5%) and (9.1%) at 28, 90 days for simply and fixed support respectively.

*The number of blows up to ultimate failure at (28, 90) days for simply and fixed support condition of SCMs plates enhancement 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.

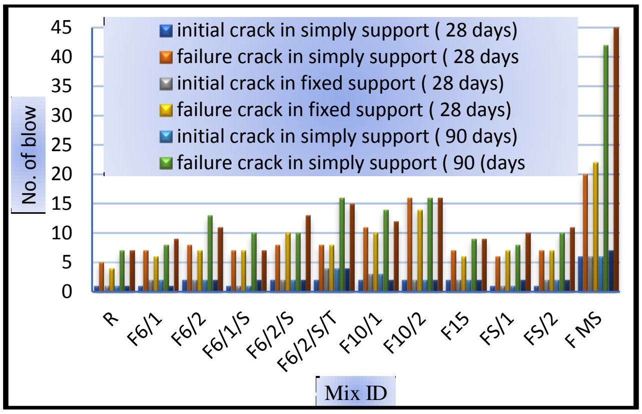

Figure-3. Number of blows to first and failure crack of fixed and simply support at (28, 90) days.

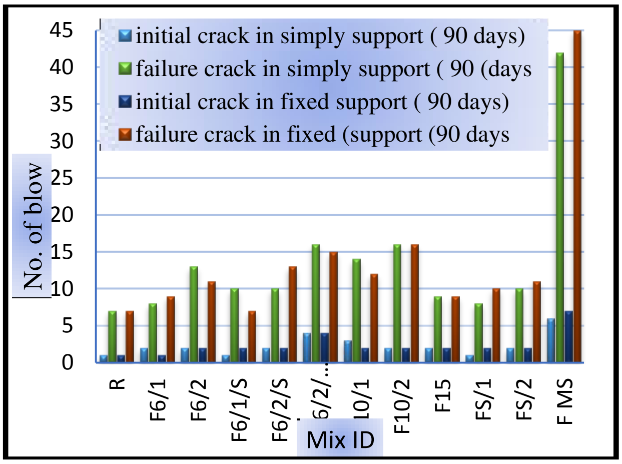

Figure-4. First and failure number of blows at ages (28, 90 days).

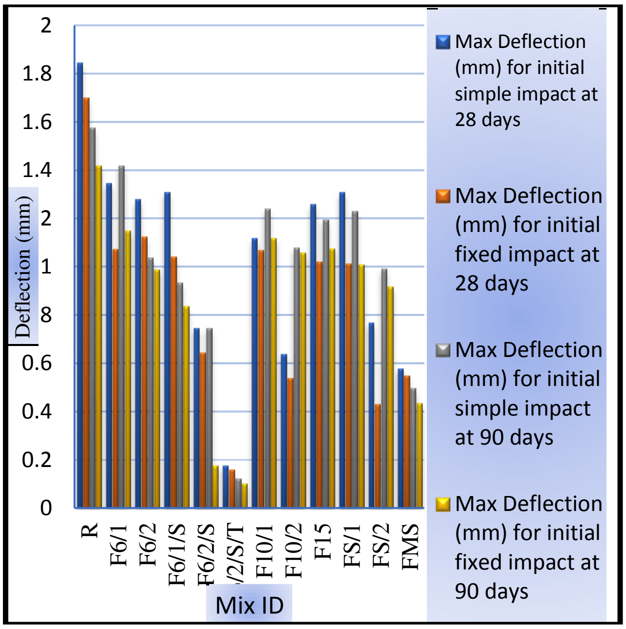

Figure-5. Max deflection for initial simple and fixed impact at (28, 90 days).

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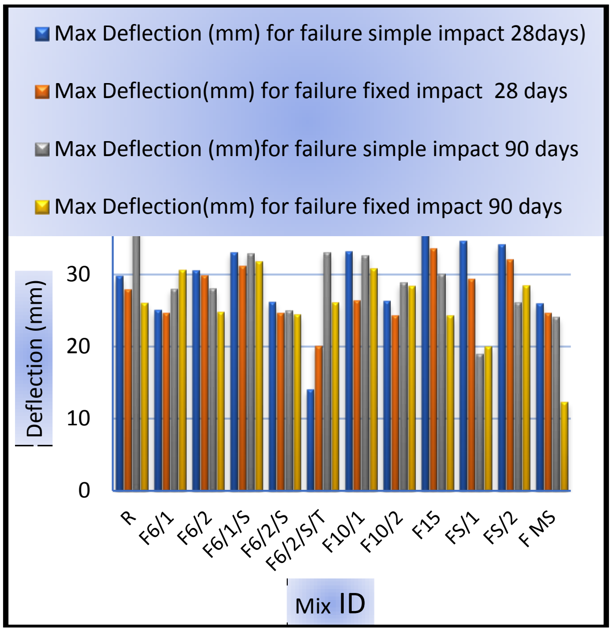

Figure-6. Max deflection (mm) for final simple and fixed impact (28, 90 days).

4.4 Energy absorption

The total energy absorbed by the SCMs plates when struck by a hard impact or depends on the local energy absorbed both in contact zone and by the impact or. The energy absorption can be obtained by using formula described in section (3.4).

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"(I_{rs}). The energy absorption capacities of SCMs plates at initial crack and at ultimate failure stages and residual impact strength are presented in Figures (7, 8). From the results that the energy absorbed increase with increase the number of layers and increase in thickness of 3Dtextile glass fiber improve the impact energy absorption compared to the no reinforcement plates ®. The energy absorbed at failure is directly proportional to the volume of the reinforcement (thickness, layers number) provided in the SCMs plates. Of the three types of reinforcement, micro steel fiber, 3D textile glass fiber (10mm thickness and 6mm slice two-way reinforcement) have absorbed higher energy compare to the other types. This may be due to the higher ductility embrittlement of reinforcement.

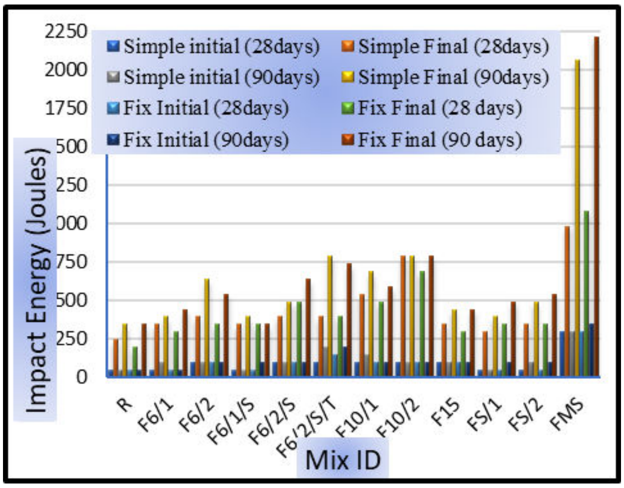

Figure-7. Energy absorption capacity at (28, 90) days for fixed and simply support.

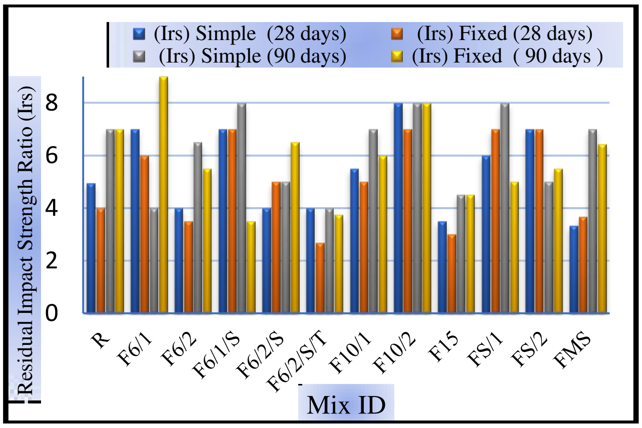

Figure-8. Residual impact strength at (28, 90) days for fixed and simply support.

4.5 Crack patterns

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 to towards the supports. In present study, the crack patterns for all SCMs plates were in diagonal direction and start from center point (mean the center of plate where mass is falling) then propagation in all direction in lines perpendicular to its edges, the width of cracks were different from plat specimen to another where they depend on plat stiffness. From result shown in Figure-9, the following points describe the cracks formation and propagation after impact load:

*The SCMs plate which has no reinforcement ® was strongly influenced by impact load and significant cracks has propagated rapidly.

*Average crack width has decreased by introduced different type of fibers (3D textile glass, chicken wire mesh, micro steel).

*Average crack width has decreased by increasing the thickness and layer numbers of 3D textile

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glass fiber reinforce SCMs plate, also increase number of chicken wire mesh from one to two layers and micro steel fiber in reinforced SCMs plate decreased the average crack width.

*Regarding the average crack width, crack propagation in micro steel fiber reinforced SCMs plates was much less as compared to cracks in plates without micro steel fibers. The cause of that result may be due to the influence of mixing action the fiber are uniformly distrusted fibers disallow the micro crack from developing into macrocracks and potential troubles, in addition these fibers bridge and therefore hold together the existing macro crack thus reinforcing the concrete against disintegration.

Smaller crack pattern for all plates are shown in plates (3) through (6), 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, hence, the behavior of the normal concrete in this point seems look like the behavior of SCMs plate. It is clear that increasing thickness and fiber layers numbers, also introduce micro steel fiber and chicken wire mesh will increase the capacity of SCMs plates and this is a cause why the maximum deflection has decreased. On the other hand, micro steel fiber is highly influenced not only on cracks width, but also affected on the number of cracks, this perhaps reverts that micro steel fiber is sufficient to make bridging amongst the invisible cracks, in other meaning, micro steel fibers have disallowed cracks propagating.

Finally, it is suitable to show that (Trevor and Frank, 2014) [22] studied the effect of steel fiber in reinforced normal concrete plate under impact load, they concluded that increasing micro steel fiber decreases the cracks width and change the plate behavior from the localized punching to global response, hence, the behavior of the normal concrete in this point seems look like the behavior of SCMs plate simply support, but not agreement with they for fixed support, the failure is local with very few visible yield line from center to corner.

The behavior of SCMs plate that had amounts of micro steel fiber is better than other those plate specimens because they have not only reduced the deflection significantly, cracks width, mitigating local damage under impact and spacing but also the number of cracks was too few, in other words, micro steel fiber increasing plate capacity, and created bridging better than other fiber reinforced SCMs plates. The failure pattern at the point of contact of the drop weight and no fragments detached from the plates specimens as the various layers of the fiber reinforcement assisted to hold the different fragments together. It can thus infer that several types fiber used as reinforcement SCMs plates, play a significant role in not only enhancement the impact energy absorption, but also retain various fragments together. All the cracks reached from center to edge of the plats. The increasing in thickness and number of layers, multiple cracks with small crack width propagated up to the edge and cracks are interconnected like network.

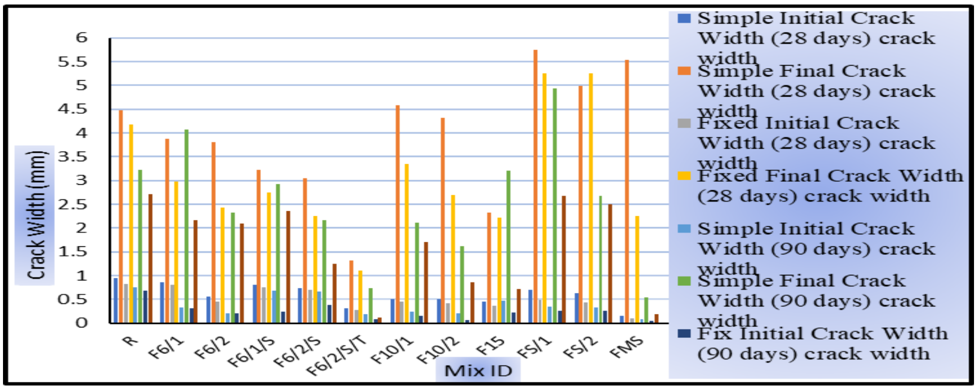

Figure-9. Initial and final crack width for simply and fixed support at (28, 90) days.

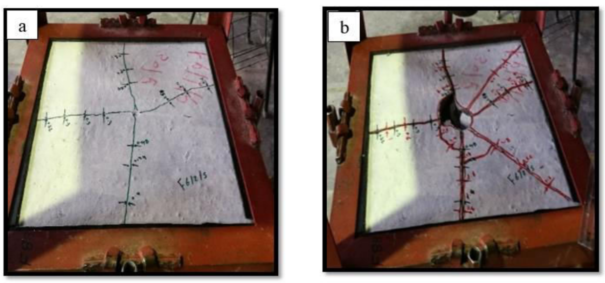

Plate-3. Crack pattern of micro steel fibre: a) initial crack of simply support. b) final crack of simply support.

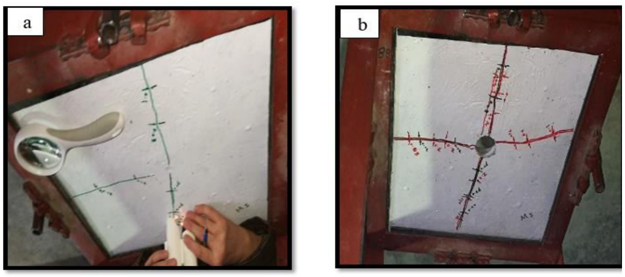

Plate-4. Crack pattern of micro steel fibre: a) initial crack of simply support. b) final crack of simply support.

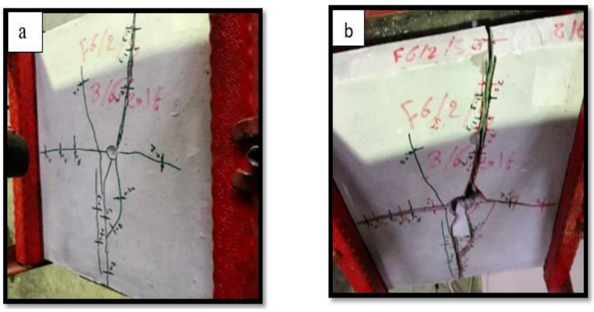

Plate-5. Crack pattern of micro steel fibre: a) initial crack of simply support. b) final crack of simply support.

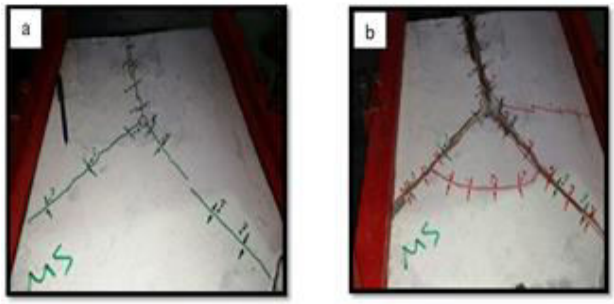

Plate-6. Crack pattern of micro steel fibre: a) initial crack of simply support. b) final crack of simply support.

5. CONCLUSIONS

a) The maximum deflection has been decreased by increasing the thickness and number of layers fiber, it has decreased while the maximum deflection was reduction at 28, 90 days for simply and fixed support.

b) The number of blows up to ultimate failure at (28, 90) days for simply and fixed support condition of SCMs plates enhancement with increasing thickness and number of fiber layers and introduce micro steel fiber.

c) The energy absorbed increase with increase the number of layers and increase in thickness of 3Dtextile glass fiber improve the impact energy absorption compared to the no reinforcement plates ®.

d) The SCMs plate which has no reinforcement ® was strongly influenced by impact load and significant cracks has propagated rapidly.

e) Average crack width has decreased by introduced different type of fibers (3D textile glass, chicken wire mesh, micro steel).

f) Average crack width has decreased by increasing the thickness and layer numbers of 3D textile glass fiber reinforce SCMs plate, also increase number of chicken wire mesh from one to two layers and micro steel fiber in reinforced SCMs plate decreased the average crack width.

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