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Structural Behavior of Reinforced Concrete Beams enhanced with Hybrid steel-polypropylene fiber under Impact Load

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ABSTRACT

Current research involves study the structural behavior of reinforced concrete beams enhanced with steel and polypropylene fibers under the influence of impact load. It has casting concrete cubes of dimensions (150 × 150 × 150) mm, concrete prisms of dimensions (100 × 100 × 400) mm, concrete cylinders of dimensions (150 × 60) mm, and reinforced concrete beams of dimensions (150 × 150 × 1000) mm, to determine compressive strength, modulus of rupture, and impact strength of both reference and fiber reinforced concrete respectively. It also has studied the effect of adding 3% of super plastisizer, and the combined effect of admixing with silica fume up to 10%, on both reference and fiber reinforced concrete respectively. The results revealed the importance of adding fibers, super plastisizer, and silica fume respectively, on improvement of mechanical properties of both reference and fiber reinforced concrete under the influence of static and impact load at ages of 7 and 28 days.

Keywords : *Impact resistant, polypropylene fiber, silica fume, steel fiber.*

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التصرف الإنشائي للعتبات الخرسانية المسلحة والمعززة بالألياف الهجينة من الفولاذ والبولي بروبلين تحت تأثير الحمل الصدمي

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الملخص

تتضمن الدراسة الحالية دراسة السلوك الإنشائي للعتبات الخرسانية المسلحة والمعززة بألياف من الفولاذ والبولي بروبلين تحت تأثير الحمل الصدمي.تم صب مكعبات بأبعاد (150 *150*150 ملم) ومواشير بأبعاد (100*100*400 ملم) ونماذج اسطوانية بقطر 150 ملم وارتفاع 60 ملم، وأعتاب خرسانية بأبعاد (150*150*1000 ملم)، لحساب مقاومة الانضغاط، معاير الكسر، ومقاومة الصدمات للخرسانة المرجعية والخرسانة المسلحة بالألياف. كذلك تم دراسة تأثير اضافة الملدن الفائق بنسبة 3% والتأثير المشترك للملدن الفائق مع غبار السليكا بنسبة 10%، على الخصائص الميكانيكية للخرسانة المرجعية والمسلحة بالألياف. بينت النتائج اهمية أضافة ألياف الفولاذ والبولي بروبلين، الملدن الفائق وغبار السليكا، في تحسين الخصائص الميكانيكية للخرسانة وللأعمار 7 و28 يوم.

الكلمات الدالة : مقاومة الصدمة، الياف البولي بروبلين، بخار السليكا، الالياف الفولاذية.

1.INTRODUCTION

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads because of its low resistance to crack, where its tensile strength is only approximately one tenth of its compressive strength. As a result of these characteristics, concrete member could not support such loads and stresses that usually take place, majority on concrete beams and slabs. Fiber reinforced concrete (FRC) can be regarded as a composite material with two phases in which concrete represents phase, and the fiber constitutes the inclusion phase.

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The introducing of fiber was brought in as a solution to develop concrete in view of enhancing its flexural and tensile strength, which is a new form of binder that combines Portland cement in the bonding with cement matrices. Fiber is most generally discontinuous, randomly distributed throughout the cement matrices **(Bentur and Mindess 2006)**. Fiber-reinforced concrete (FRC) in the context of this research is conventionally mixed concrete containing discontinuous fibers that initially are randomly orientated in three dimensions in the mixture.

Fiber reinforcement is commonly used to provide toughness and ductility to brittle cementations matrices. Reinforcement of concrete with a single type of fiber may improve the desired properties to a limited level. A composite is termed as hybrid, if two or more types of fibers are rationally combined to produce a composite that derives benefits from each of the individual fibers and exhibits a synergetic response.

The polypropylene fiber has a low modulus of elasticity, however. Consequently, they cannot prevent the formation and propagation of the cracks at high stress level. Neither can they bridge large cracks. Steel fibers have a considerably larger length and higher modulus of elasticity as compared to the PP fiber. This leads to an improved potential for crack control. However, volumetric density is high, and steel is conductive in electric and magnetic fields. Therefore, steel fiber content has to be reduced to below a certain level in structures such as tunnels and continuous slabs for high-speed railway systems, where the communication system can be disturbed. Optimization of mechanical and conductivity properties can be achieved by combining different kinds, types, and sizes of fibers, such as in case of PP and steel fibers according to **(Bentur and Mindess (Bentur and Mindess 2006))**. The advantages of hybrid fiber systems are:

1- To provide a system in which one type of fiber, which is stronger and stiffer, improves the first crack stress and ultimate strength, and the second type of fiber, which is more flexible and ductile, leads to improved toughness and strain capacity in the post-cracking zone.

2- To provide a hybrid reinforcement, in which one type of fiber is smaller, so that it bridges micro cracks of which growth can be controlled. This leads to a higher tensile strength of the composite. The second type of fiber is larger, so that it can arrest the propagating macro cracks and can substantially improve the toughness of the composite.

3- To provide a hybrid reinforcement, in which the durability of fiber types is different. The presence of the durable fiber can increase the strength and/or toughness retention after age while another type is to guarantee the short-term performance during transportation and installation of the composite elements. Tension stresses in concrete be at the great value in the farther fiber of the section and they gradually fall to zero in the neutral axis, so for economical purposes fibers put in the tension zone of the section not for the full depth.

Sivakumar and Santhanam (2007): studied the behavior of high strength concrete with hybrid fibers. An experimental investigation carried out on high strength concrete reinforced with hybrid fibers (combination of hooked steel and a non-metallic fibre) up to a volume fraction of 0.5%. They showed that the addition of steel fibers generally contributed towards the energy absorbing mechanism (bridging action) whereas; the non-metallic fibers resulted in delaying the formation of micro-cracks. Compared to other hybrid fiber reinforced concretes, the flexural toughness of steel–polypropylene hybrid fiber concretes was comparable to steel fiber concrete. The incensement in the fiber availability in the hybrid fiber systems (due to the lower densities of non-metallic fibers), in addition to the ability of non-metallic fibers to bridge smaller micro cracks, are suggested as the reasons for the mechanical properties enhancement.

Singh and others (2010): studied the mechanical properties of hybrid fiber reinforced concrete. The results indicate that concrete containing a fiber combination of three quarters steel fibers plus one-quarter polypropylene fibers, can be adjudged as the most appropriate combination to be employed in hybrid reinforced concrete for enhancement in compressive strength, flexural strength and flexural toughness.

This research focuses on the experimental investigation in the properties of hybrid reinforced concrete beam with mineral admixture (silica fume). The experimental tests were carried out to obtain the mechanical properties and behavior of fiber reinforced concrete (FRC), simultaneously compared to the conventional plain concrete. The comparison in mechanical properties and behavior include the compressive strength, flexural strength, toughness, and Impact resistance. The most widely mineral admixture silica fume (SF) is used. Silica fume improves the strength and durability of concrete; furthermore, it improves the bond between the fibers and the cement matrix. This admixture produces denser matrix, resulting in better mechanical properties of fiber reinforced concrete (FRC) **(Chung 2002)**.

Using the super plasticizer as a high range water reducing admixture (HRWRA) in concrete has become of great and beneficial important due to its high performance in reducing water cement ratio (w/c) of concrete, thereby increasing strength and improving its workability. On the other hand, the use of hybrid polypropylene and steel fibers in concrete with optimum dosage of (HRWRA) and (SF) admixture is most likely to ensure optimized

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performance of concrete and to improve compression, tension, flexural toughness and impact resistance over that of ordinary concrete.

The cracks generally develop with time and stresses to penetrate the concrete, thereby impairing the waterproofing properties and exposing the interior of the concrete to the destructive substances containing moisture, bromine, acid sulfate, etc. The exposure acts to deteriorate the concrete, with the reinforcing steel corroding. To counteract the cracks, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibers **(Grzybowski and Shah 1990) (Padron and Zollo 1990)**, and the admixture used to improve mechanical properties of concrete.

2.EXPERIMENTAL WORK

2.1.Materials:

The properties of materials used in concrete mixtures are given below.

Cement: Iraqi ordinary Portland cement Type I, was used in all mixes throughout this work. The chemical and physical properties of this cement are presented in Table.(1). Test results indicate that the adopted cement conformed to the Iraqi specification IQS No. 5/1984.

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Table.(1): Physical and chemical properties of cement

Oxides composition	Content %	Limit of Iraqi specification No. 5/1984
Silica, SiO_2	13.4 %	21 % Max.
Alumina, Al_2O_3	4.6 %	8 % Max.
Iron oxide, Fe_2O_3	5.2 %	6 % Max.
Magnesia, MgO	4.6 %	5 % Max.
Sulfate, SO_3	1.1 %	2.8 % Max.
Loss on Ignition, (L.O.I)	0.95 %	4 % Max.
Insoluble material	1.05 %	1.5 % Max.
Lim Saturation Factor, (L.S.F)	0.9	(0.66-1.02)

Physical Properties	Test Results	Limit of Iraqi specification No. 5/1984
Specific surface area (Blaine method), (m^2/kg)	301.5	250 m^2/kg lower limit
Setting time (vacate apparatus)		
Initial setting, (hrs : min)	0:55	Not less than 45 min
Final setting, (hrs : min)	7:00	Not more than 10 hrs
Compressive strength (MPa)		
For 3-day	28.7	15 MPa lower limit

Fine aggregate (Sand): Normal weight natural river sand from Al-Tuz region was used as fine aggregate. Before its incorporation into the concrete mix, sand was sieved on 4.75mm sieve. The grading of the sand conformed to the requirements of ASTM C33-01 (ASTM-C33 2004) as shown in Table.(2). Physical and chemical tests results on sand used throughout this work are shown in Table.(3).

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Table.(2): Grading of fine aggregate

Sieve size	Cumulative passing %	Limits of ASTM c33-01
9.5-mm (3⁄8-in.)	100	100
4.75-mm (No. 4)	91.34	95 to 100
2.36-mm (No. 8)	83.8	80 to 100
1.18-mm (No. 16)	67.73	50 to 85
600-µm (No. 30)	20.3	25 to 60
300-µm (No. 50)	2.45	5 to 30
150-µm (No. 100)	0	0 to 10

Table.(3): Chemical and physical properties of the fine aggregate

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01	2.60	
Absorption %	ASTM C128-01	2.2	
Dry loose unit weight, kg/m^3	ASTM C29/C29M/97	1590	
Sulfate content (as SO_3), %	(I.O.S.) No. 45-84	0.08	0.5 (max. value)
Material finer than 0.075 mm% sieve	(I.O.S.) No. 45-84	1.3	5 (max. value)

Coarse aggregate (Gravel): Normal weight natural gravel from Tikrit region was used as coarse aggregate. Before its incorporation into the concrete mix, coarse aggregate was sieved on 25 mm sieve. The grading of the course aggregate conformed to the requirements of ASTM C33-01 (ASTM-C33 2004), as shown in Table.(4), Physical and chemical tests are shown in Table.(5).

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Table.(4): Grading of normal weight coarse aggregate

Sieve size	Cumulative passing %	Limit of ASTM c33-01
37.5 mm (1 1⁄2 in.)	100	100
25.0 mm (1 in.)	95.52	95 to 100
12.5 mm (1⁄2 in.)	33.67	25 to 60
4.75 mm (No. 4)	3.22	0 to 10
2.36 mm (No. 8)	1.09	0 to 5

Table.(5): Chemical and physical properties of normal weight coarse aggregate

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01	2.60	
Absorption %	ASTM C128-01	2.3	
Dry loose unit weight, kg/m^3	ASTM C29/C29M/97	1593	
Sulfate content (as SO_3), %	(I.O.S.) No. 45-84	0.08	0.5 (max. value)

Fibers:

A- High quality monofilament micro short 12 mm polypropylene fiber, shown in Figure.(1) , was used in this investigation. Table.(6), indicates the physical properties of polypropylene fibers used in this work.

B- Steel fibers manufactured by Bekaert - Dramix® ZP305 as shown in Figure.(1), have a ‘trough’ shape with hooks at both ends, had been used in this work. The ZP305 is a cold drawn wire fiber, with hooked ends, and glued in bundles. Steel fibers were 30 mm long And 0.55 mm in diameter (aspect ratio of 55) and possessed a tensile strength of 1100 N/mm^2 the glue dissolved in the water during mixing,thus dispersing the fibers in the mix Specifications of Steel fiber (SF) used in this investigation are shown in Table.(7).

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Figure.(1): Steel Fibers and Polypropylene Fibers

Table.(6): Physical properties of polypropylene fibers (PPF) used in research.

Physical Properties	100% Virgin Polypropylene Fiber
Specific gravity	0.91 g/cm^3
Alkali content	Nil
Sulfate content	Nil
Chloride content	Nil
Air entrainment	Air content of concrete will not be significantly increased
Fiber thickness	(18 and 30) microns
Young modulus	~ 4000 MPa
Tensile strength	350 MPa
Melting point	160 °C
Fiber length	12 mm

Table.(7): Specifications of Steel fiber (SFRC) used in research.

Fiber type	Supplier	Brand name	Aspect ratio	Length (mm)	Diameter (mm)	Configuration	Tensile strength (MPa)
ZP305	Bekaert	Dramix®	55	30	0.55	Hooked ends	1100

Table.(8): Technical description of high range water reducing admixture (Sikament® FFN)

Main Action	Concrete Super plasticizer
Form	Viscous Liquid
Color	Brown homogenous liquid
Relative Density	1.20 – 1.24 kg/l, at 20°C
pH value	6.42
Freezing point	-5°C
Total Chloride Ion Content	Max. 0.1%, Chloride-free
Equivalent Sodium Oxide as % Na2O	Max. % 7

Admixture:

A- High Range Water Reducing Admixture (HRWRA)**:** Sikament® FFN had been used in this work as a substantial water reducing agent for promoting high, early and ultimate strengths or as a highly effective super plasticizer for production of free flowing concrete. Sikament® FFN does not contain chlorides or other ingredients promoting corrosion of steel reinforcement. It is therefore suitable for reinforced and prestressed steel. Table.(8) indicates the technical description of the aqueous solution of super plasticizer used throughout this work.

B- **Silica Fume:** Silica fume, SikaFume® HR/TU is a concrete additive based on powered Sika Silica Fume Technology. It is a highly reactive pozzolanic material suitable for high quality concrete. It contains extremely fine latently reactive silicon dioxide. The presence of this additive significantly improves the internal cohesion and water retention properties of fresh concrete. During the hydration process the silica fume forms a chemical bond with the free lime. The physical properties are given in Table.(9).

Table.(9): The physical properties of silica fume

Physical Properties	Silica Fume (SF)
Density	0.5 ± 0.1 kg/l (dry bulk)
Form	Powder
Appearance / Color	Grey

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2.2.Mixture proportions:

Ordinary Portland cement of 410 kg/m^3 content, coarse aggregate of 1235 kg/m^3, fine aggregate of 561 kg/m^3 and water content of 193 kg/m^3 were used in this work.

It's important to mentioned that during the experimental concrete mixing works there is some difference in water content in order to keep the same workability for all mixes, therefore the slump test (according to ASTM C143M-03 results for all mixes kept between 70 mm and 100 mm. So, many quantities from water differ to what calculated in mix design procedures, had been add to concrete mix. High range water reducer HRWRA and silica fume (SF) has obvious effect on water demands in concrete mixes, therefore, different quantities of water demands had been used in our mixes. The water demand of concrete containing silica fume increases with increasing amounts of silica fume. This increase is due to primarily the high surface area of the silica fume.

Each volume percentage of FRC contains three mixes. As an example, for (0.5%) Volume fraction percentage (V_f), Hybrid steel-polypropylene fiber reinforced concrete mix had been achieved. That is mean three FRC mixes were introduced for these three volume percentages as described in Table.10, in addition to the reference mixes.

Table.(10): References and Fiber mixes details for (0.05 m^3) batch

Item	Group #	Water (kg)	CA (kg)	FA (kg)	Cement (kg)	Silica Fume (SF) %	HRWRA %	Vf %	Vf %	slump (mm)
1	Reference	12.18	128.52	53.76	41.36	10	3	*0*	*0*	76
2	HSPPFRC 0.5	17.6	160.65	67.2	51.7	10	3	*0.5*	*0.5*	72
3	HSPPFRC 1	16.4	128.52	53.76	41.36	10	3	*1*	*1*	75
4	HSPPFRC 1.5	17.23	128.52	53.76	41.36	10	3	*1.5*	*1.5*	80

2.3.Preparation, Casting and Curing of Specimens:

The concrete specimens were then prepared by pouring the mixed concrete into (150 × 150 × 150) mm cubes, (100 × 100 × 400) mm prisms moulds, and (150 diameter × 60 height discs) mm. Steel moulds were used for casting all the specimens. They were well cleaned and oiled before casting to avoid the adhesion of hardened concrete to the internal surface of the molds. Care was taken to avoid segregation of fiber reinforced concrete samples.

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The standard practice prescribed by B.S. 1:881: part 3:1983 stated that the mould must be filled in three layers for cubes and two layers for prisms (50 mm for each layer). Each layer of concrete is compacted by not less than 35 strokes of 25 mm steel rod for cubes and 100 strokes for prisms, after the top surface of cubes has been finished by means of a trowel the cubes are stored for 24 hours, and covered with nylon sheets for 24 hours to reduce evaporation of water so as to avoid the plastic shrinkage cracks, were then transferred to completely immersed in tap water basin until the time of testing.

2.4.Concrete Testing Programs:

Compressive Strength: The compressive strength test was determined according to B.S. 1881: part 116: 1989. This test was conducted on cubes using an electrical testing machine with a capacity of 2000 kN at loading rate of 4 kN per second. The average of three cubes was adopted for each test. The test was conducted at ages of (7, 28) days.

Flexural Strength: Flexural strength of concrete was measured on (100×100×400) mm prism specimens in conformity with ASTM C78-00. The prisms were subjected to two-point loading the, loading rate was subjected using universal machine (SANS) with capacity of 1000 kN at a rate of 3 MPa/min. The specimens were tested at age of 28 days and the average of three specimens in each mix was taken.

Impact Resistance (ACI Method): The drop weight test conducted followed the test technique suggested by the ACI committee 544 **(Niyogi and Chawla 1982)** on fiber reinforced concrete. The disc dimensions are (150 ×63.5) mm. This test rests a disc on the base plate within four positioning lugs. The disc bottom has received a thin layer of a heavy grease to reduce the friction between the disc and the base plate. Then, a 4.54 kg hammer consecutively fields from a 457mm height onto a 50.8mm diameter steel ball standing at the center of the disc, subjecting the disc to repeated impact blows. The equipment for impact test is shown in Figure.(2). The test continued until failure of the specimen. For each specimen, two values were identified corresponding to initial (first crack) and ultimate failure. The former value measures the number of blows required to initiate a visible crack, whereas the latter measures the number of blows required to initiate and propagate cracks until ultimate failure. According to the ACI committee, the ultimate failure occurs when sufficient impact energy has been supplied to spread the cracks enough so that the test specimen touches the steel lugs. However, in this study, if the speclugs, then this was declared the point of ultimate failure. The test was conducted at ages of (28) days. Three specimens were tested for each mix.

Flexural Toughness: Flexural toughness test was carried out on (150×150×1000) mm simply supported beams with a clear span of 900 mm under the third points loading according to ASTM C1018-97. The specimens were tested using universal machine (SANS) with capacity of 5000 kN at a rate of 3 MPa/min. The deflection reading were conducted by using digital dial gage fixed under the beam The load was applied by using Universal machine (SANS) with capacity of 5000 kN. The load deflection has been drawn according to ASTM C1018-97. The test were conducted at ages of (28) days and three specimens was tested for every case.

Dynamic response tests for FRC beams: This test had been carried out for (150×150×1000) mm, RC and FRC beams specimens, the reinforcement of beams shown in Figure.(3).The device used in the examination was synthesized manually and it's consists of several parts:

Impact machine: Steel frame (impact loading applied) manufactured from I-beam and channel sections welded together to carrying the R.C and FRC beams and applied dynamic loads (drop weight load). An instrument of drop-weight with an impact hammer weighing (10kg) was used. For these tests, the drop height was held at 600 mm throughout. Two load cells installed in the hammer and under support was used to record the impact loads and support reactions. A 50 mm LVDT was fastened to the bottom of the beam at mid-span. The data from the load cell and the LVDT were collected at ***10 us*** intervals using a PC based data acquisition system. A schematic sketch of the test setup is shown in Figure.(4).

-Load cells system: Two dynamic load cells (Capacity 45 kN, Omega USA DLC101-1K) had been used as shown in Figure.(5) , by putting one of them under beam support, and the other installed under the hammer to record the impact loads.

-Displacement measurement system (LVDT): 50mm LVDT measurement transducer as shown in Figure.(6) , were installed under the mid-point of the beams to measuring the linear displacement and response of the beams under and over the neutral axis of beams during and after applying the impact load.

-Data Acquisition system: Eight channels differential analog inputs module system with all accessories had been used in this test. This system is responsible for receiving the data from all sensors, and the final output of this device is load under the support vs. time curve and displacement in the midpoint of beam vs. time curve. The system is complete with WINDAQ software for DATAQ WINDAQ/Lite recording and playback software is included DI-710

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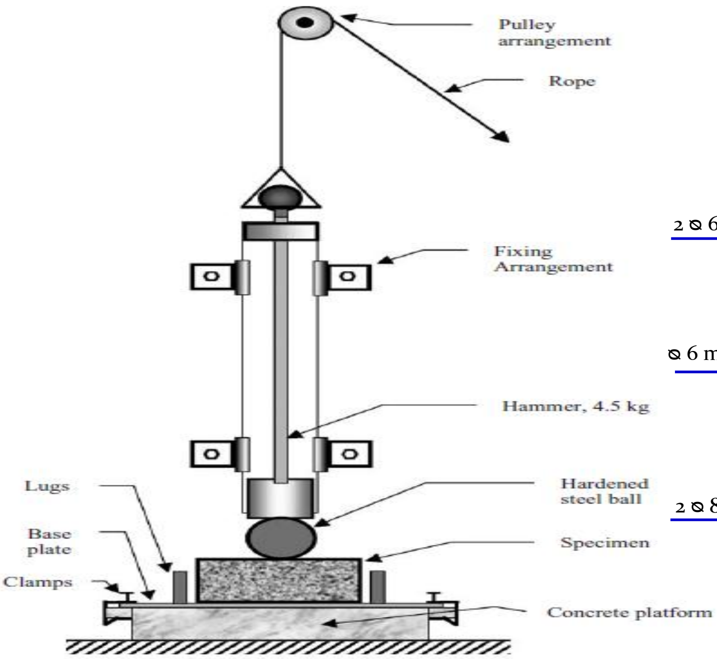
instrument. Record at rate up to 1000 Hz using WINDAQ/Lite software that allow the result to be shown in time domain plots.



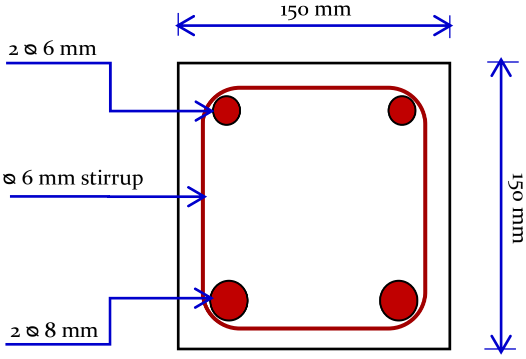


Figure (3): *cross section of R.C. beam.*

Figure.(2): Drop weight equipment used for Impact resistance test

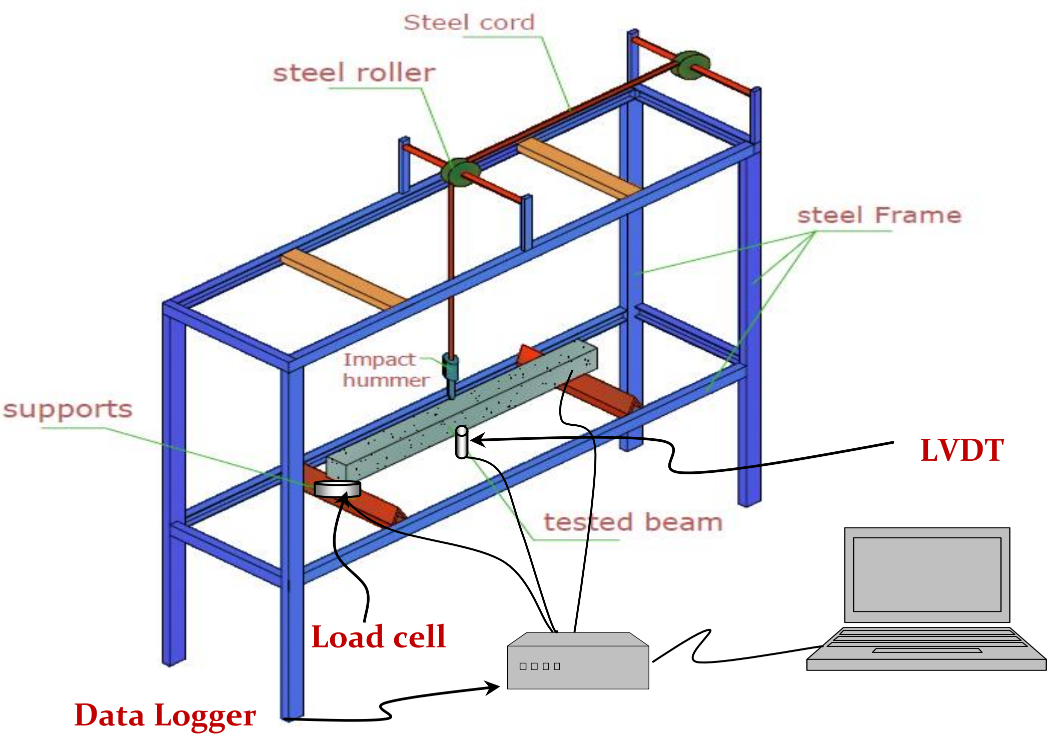


Figure.(4): Impact loading applied frame with all accessories

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Figure.(5): Load cell

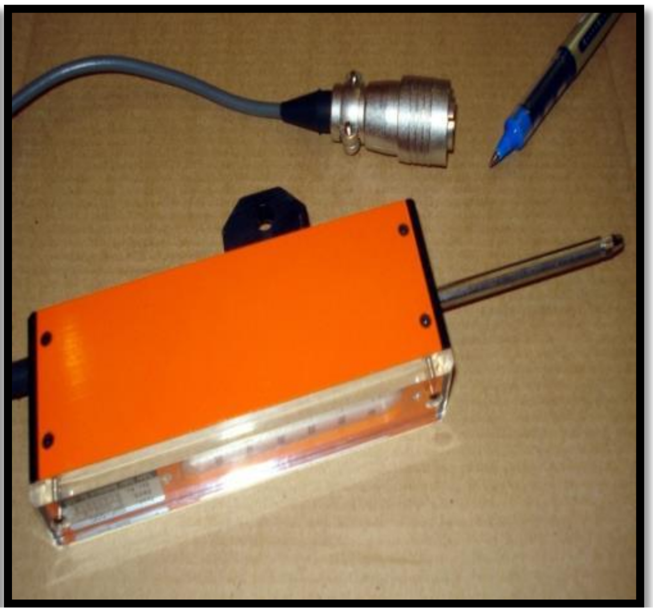

Figure.(6): 50mm LVDT measurement

3.RESULTS AND DISCUSSION

Compressive and tensile strength: Experimentally, the high values of compressive strength had been obtained for mix containing (10 % SF) after fixing the dosage of (HRWRA) to (3%) at early and at (28 days) age. For hybrid steel – polypropylene fiber reinforced concrete, the results of the compressive strength had a slight decreasing firstly and then increasing with increasing of fibers up to 3.84% for 1.5 Steel fiber and 1.5 PPF as shown in Table.(12).

Flexural Strength: The improvement in flexural strength is attributed to the reduced capillary porosity of cement matrix caused by the high reduction in water content of the mix, as well as, to the good dispersion of the cement grains throughout the mix. The flexural strength trend for polypropylene and steel fiber varies when fiber increased. Table.(13), and shows the average flexural strength recorded during the test for all FRC mixes. It can be seen that the increasing in fibers lead to significantly increasing in MOR (modulus of rupture) up to 59.5%.

Flexural Toughness: For fiber-reinforced concrete (FRC), the concept of flexural toughness (which is a measure of the energy absorption) is often used to characterize these important improvements. ASTM C1018 provides a means for evaluating serviceability- based toughness indexes and the first-crack strength of fiber reinforced concretes. The procedure involves determining the amount of energy required to deflect the FRC beam a selected multiple of the first crack deflection based on serviceability considerations. This amount of energy is represented by the area under the load-deflection curve up to the specified multiple of the first-crack deflection

The toughness index is calculated as the area under the *P-d* diagram up to the prescribed deflection, divided by the area under the *P-d* diagram up to the first-crack deflection (first-crack toughness). Table.(14), show ultimate toughness index which mean the value of ultimate toughness divided by first crack toughness. Figure.(7) shows the p-d diagram for all beams groups. It can clearly shows that the occurring of fibers increase toughness of RC beams and give a significantly increasing with high volume fraction.

Table.(12): Average Compressive strength of Fiber Reinforced concrete mixes

Group name	S.F ratio %	S.P ratio%	Vf %	Vf %	w/c	slump (mm)	Comp. strength (7) days	Comp. strength (28) days
Reference	10	3	*0*	*0*	0.29	76	19	52
HSPPFRC 0.5	10	3	*0.5*	*0.5*	0.31	72	18	50
HSPPFRC 1	10	3	*1*	*1*	0.35	75	24	53
HSPPFRC 1.5	10	3	*1.5*	*1.5*	0.36	80	26	54

Table.(13): Flexural strength results of different FRC mixes prisms

Group Name	SF ratio %	SP ratio %	(Vf) %	(Vf) %	MOR (28 days) (MPa)
Reference	10	3	0	0	6.52
HSPPFRC 0.5	10	3	0.5	0.5	8.93
HSPPFRC 1	10	3	1	1	9.76
HSPPFRC 1.5	10	3	1.5	1.5	10.4

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Table.(14): Flexural Toughness results of FRC beams

Group Name	SF %	SP %	PPF (Vf)%	SFRC (Vf)%	w/c	Ultimate Toughness Index ASTM C 1018
Reference	10	3	0	0	0.29	2.66
HSPPFRC	10	3	0.5	0.5	0.34	5.56
HSPPFRC	10	3	1	1	0.40	4.53
HSPPFRC	10	3	1.5	1.5	0.42	7.92

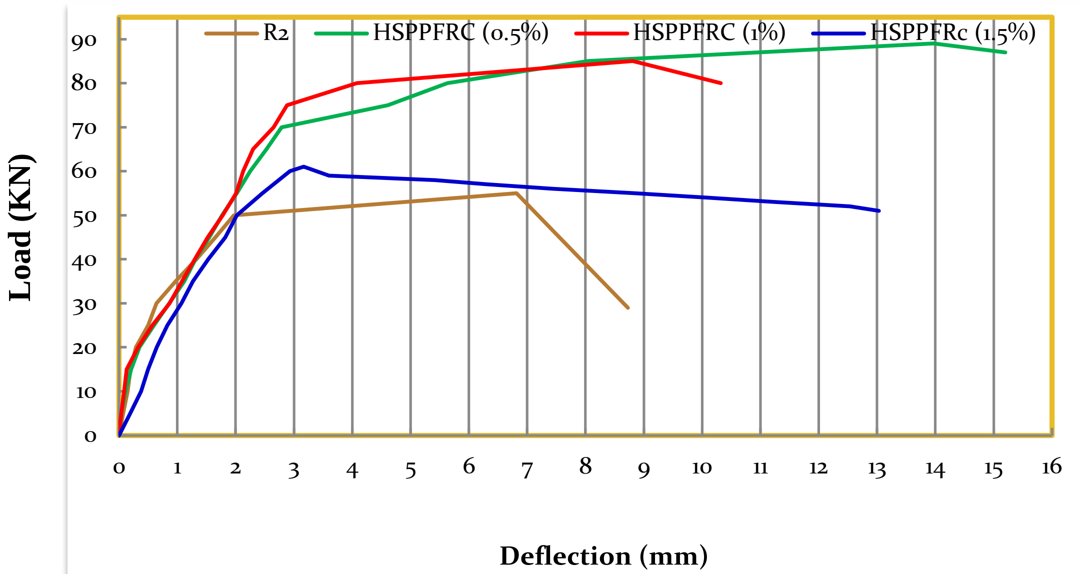

Figure.(7): Load-Deflection curves of fibers RC beams at 28 days

Impact Resistance: This test yields the number of blows necessary to cause prescribed levels of distress in the test specimen. This number serves as a qualitative estimate of the energy absorbed by the specimen at the levels of distress specified **(Schrader 1981)**. The impact resistance results in terms of number of blows for various types of fiber reinforced concrete impact rings specimens (at 28 days age) under the drop-weight test (The test technique suggested by ACI committee 544 on fiber reinforced concrete) , are demonstrated in Table.(15), and plotted in Figure.(8&9). The addition of HRWRA and SF to control mix increases the impact resistance strength at first crack, and ultimate impact resistance strength. This mixes improvement is attributed to the pozzolanic reactivity which chemically reacts with the calcium hydroxide liberated during the hydration of cement and contributes to the densification of the concrete matrix, there by strengthening the transition zone and reducing the micro cracking leading to a significant increase in the energy absorption.

Demonstrate considerably the impact strength resistance at first crack and ultimate failure for fiber reinforced concrete specimens. It had been seen that the impact resistance increases with increasing the fiber volume fraction for both types of hybrid polypropylene and steel together. This is mainly due to the high capacity of polypropylene and steel fiber to absorb large amounts of energy prior to failure. The concrete specimens containing no fibers were cracked and failed in brittle condition when they reached the ultimate resistance. Cracks started at the center of the top face of impact rings specimens and then propagated outwards and toward the outside circumference as the number of blows increased. The number of blows was so closed between the first crack and ultimate stages for the concrete mix without fiber.

However, fiber reinforced concrete impact rings specimens also cracked at ultimate resistance, but it is capable of carrying the repeated impact load well after the crack developed on the concrete, This indicates that the fiber reinforced concrete has the ability to hold on the crack of the concrete and preventing the concrete specimens to fall apart.

Hybrid RC Beams under impact load: In adopted oscillatory system, which has 1 degree of freedom (1-DOF) (the number of independent coordinates required to describe the motion), all the impact test results are demonstrated in Table.(16) and (17), and Figure.(8&9).

In order to evaluate the natural frequency of damped oscillatory (ω_d) (which are properties of the dynamical system established by its mass (m) and stiffness (k) distribution), natural damped period of the oscillation (T_d), natural frequency (f) and damping ratio (ζ) depending on the concept of logarithmic decrement (δ) (which is defined as the natural logarithm of the

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ratio of any two successive amplitudes) **(Thomson 1996) (Clough and Penzien 1975)**, it has been used as following equations:

$$T_d = \frac{\text{Time of last peak (t2)} - \text{Time of first peak(t1)}}{\text{No.of last peak (n)} - \text{No.of first peak (m)}} \quad \text{---------- (1)}$$

$$T_d \cong T_n \cong T$$

$$f = \frac{1}{T} \quad \text{---------- (2)}$$

$$\omega = \frac{2\pi}{T} = 2\pi f \quad \text{---------- (3}$$

$$\delta = \frac{1}{(n-m)} \ln\left(\frac{x_m}{x_n}\right) \quad \text{---------- (4)}$$

Where, x_m and x_n are the first and last amplitude (displacement) respectively.

By substituting for the damped period,

$$T_d = \frac{2\pi}{\omega\sqrt{1-\zeta^2}} \quad \text{---------- (5)}$$

The expression for the logarithmic decrement becomes:

$$\delta = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}} \quad \text{---------- (6)}$$

$$\zeta = \sqrt{\frac{\delta^2}{4\pi^2+\delta^2}} \quad \text{---------- (7)}$$

$$c = \zeta\, c_c = \zeta 2m\omega \quad \text{---------- (8)}$$

Where, c and c_c are the damping and critical damping coefficients respectively.

$$\omega_d = \omega\sqrt{1-\zeta^2} \cong \omega \quad \text{---------- (9)}$$

The whole calculations that had been made for all tested beams with and without fiber are stated in Table.(17). It can be seen from the Table.(16,17), and Figure.(8) and (9) that the addition of fiber improves impact resistance of the tested beams. The type of fiber that had been used in this research has remarkable effect on the results of the impact strength test. This effect was belonging to the different properties of the casted beams that had been obtained, and the mass increasing or decreasing for each tested specimen. Mass and homogenous of fiber distribution play the whole role in the dynamic response and vibration damping effect.

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Table.(15): Impact resistance of cylindrical concrete specimens

Group name	S.F%	S.P%	Vf %	Vf %	No. of blows	
					First crack	Ultimate
Reference	10	3	0	0	653	664
HSPPFRC 0.5	10	3	0.5	0.5	705	1302
HSPPFRC 1	10	3	1	1	871	1550
HSPPFRC 1.5	10	3	1.5	1.5	942	1822

Table.(16): Impact Load test records for references and FRC beams

Specimen ID	Maximum load under support (kN)	Time (sec)	Maximum deflection (mm)	Time (sec)	Time to reach (90%) damping
Reference	3.13	5.293	*6.913*	5.313	2.104
HSPPFRC 0.5	1.41	11.75	*2.926*	11.797	1.006
HSPPFRC 1	1.82	20.063	*4.329*	20.127	2.056
HSPPFRC 1.5	2.00	13.28	*4.426*	13.347	2.756

Table.(17): Dynamic response of tested references and FRC beams

Group Name	t1 (sec)	t2 (sec)	X_m	X_n	m-n	T_d (sec)	f (Hz)	ω (rad/sec)	(δ)	(ζ)	ω_d (rad/sec)
Reference	5.313	*7.41*	*6.913*	0.691	5	0.421	2.376	14.932	0.461	0.073	14.892
HSPPFRC 0.5	11.79	*12.80*	*2.926*	0.31	6	0.167	5.982	37.586	0.376	0.059	37.52
HSPPFRC 1	20.12	*22.18*	*4.329*	0.425	6	0.343	2.918	18.336	0.387	0.061	18.301
HSPPFRC 1.5	13.34	*16.10*	*4.426*	0.42	6	0.459	2.177	13.679	0.392	0.062	13.652

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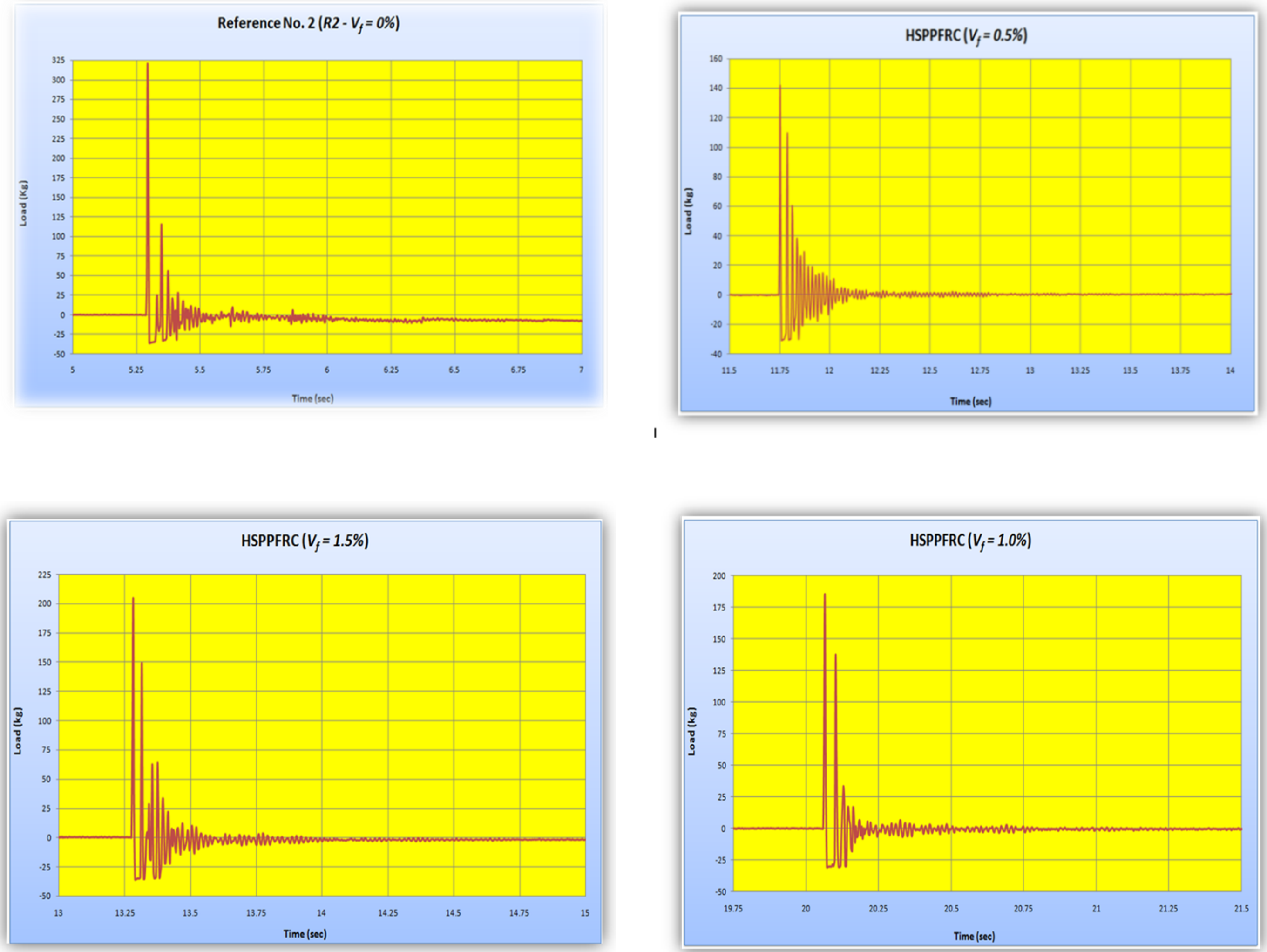

Figure.(8): Time-load for RC beams under impact load

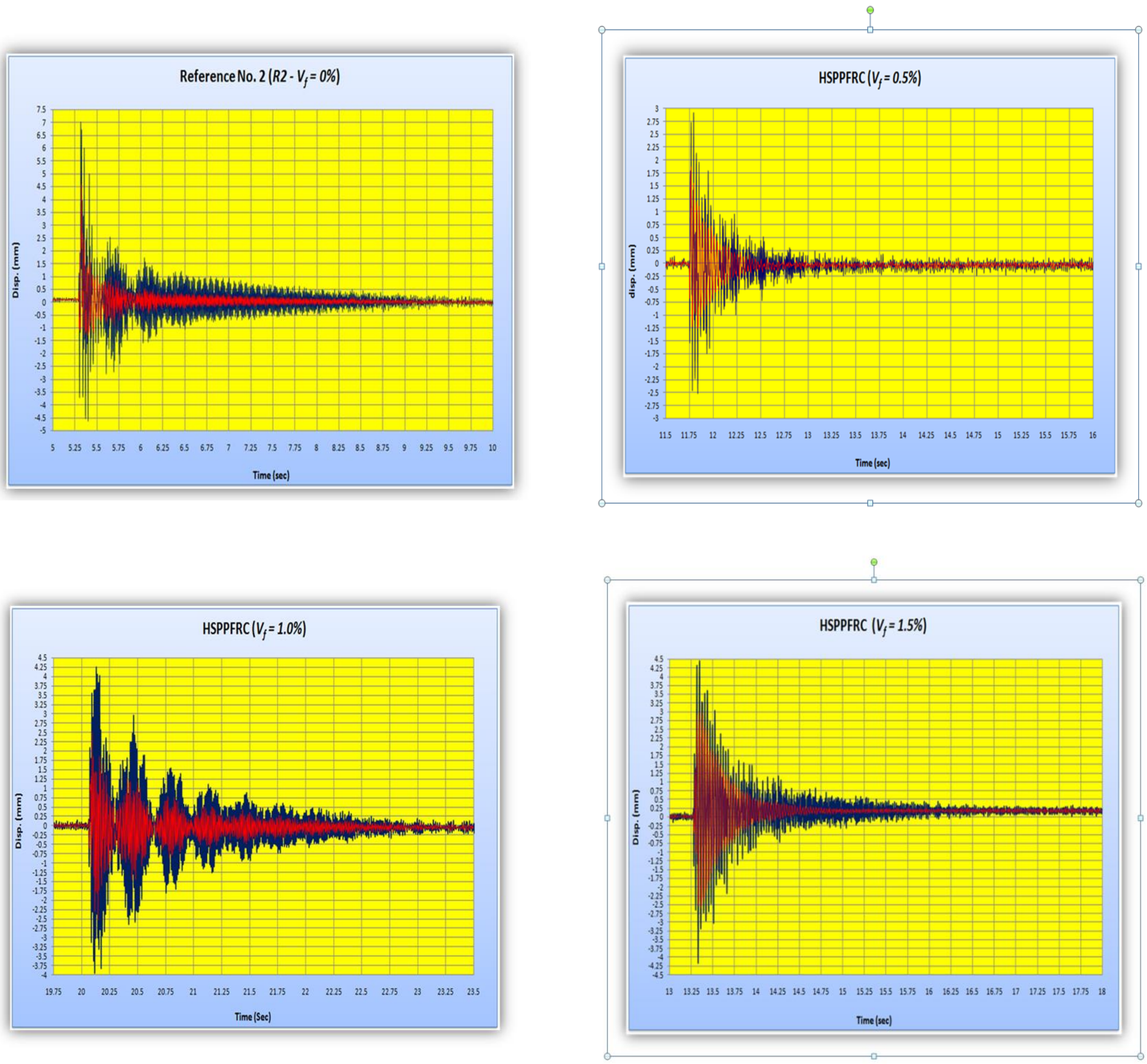

Figure.(9): Time-Displacement curve for RC beams under impact load

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4.CONCLUSIONS

1. In order to mention the same range of workability for all mixes, it's found that the use of (10% by weight of cement) silica fume tended to require more dosages of super plasticizer (3% by weight of cement) which was the optimum dosage.

2. All concrete mixes shows improvement in the compressive strength test results for (7 days), and this due to the effect of (HRWRA) and (SF) on early strength properties.

3.Modulus of rupture increases as the fiber's volume fraction was increased up to 1.5%.

4.Results showed that reference concrete (without fiber) could not sustain any load and failed quickly when the first crack was developed and hence the toughness for these specimens was very low compared to other of FRC. For hybrid fibers reinforced concrete beams, the ratio of (1.5% Vf) has high toughness index result, this may due to the large contribution (by volume fraction) belong to steel as well as polypropylene fibers.

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