Al-Nahrain Journal for Engineering Sciences (NJES) Vol.20 No.2, 2017 pp.462-476
Special Issue - Proceedings of the 4th Eng. Conf. (21April 2016, Al-Nahrain Univ., Baghdad, IRAQ)

Effect of Adding Nano-Materials and Carbon Fiber on Impact Strength of Cementitious Composite (CC)

Zain El-Abdin Raouf
College of Engineering
University of Baghdad

Rafia H. Al-Suhaili
College of Engineering
University of Baghdad

Zainab H. Mahdi
Technical Eng. Coll.
Baghdad-Middle Technical Univ:
zainabhashim@itbaghdad.net

Abstract

This study involves the addition of nano silica (NS) with average particle size 12nm, micro high reactivity mitakaaolin (MHRM) particle size ≥ 0.554 ≤ 1.271 µm, micro ground granulated blast-furnace slag (MGGBFS) particle size ≥ 0.365 <2.932 µm and micro carbon fibers, the length of the fiber 8.5 mm and a diameter of 0.001 mm to cementations mixtures to investigate their effect on the impact strength with used magnetic water or normal water in mixing blends.

The results have shown that cementitious mixtures used in the mixing magnetic water containing 10% MGGBFS, 10% MHRM or 2.5% NS and reinforced with 2% micro carbon fiber have improved greatly in impact strength as the absorbed energy to the emergence of the first crack at age 28 days reaches to (231.55, 209.49 and 199.49) kN.m respectively, whereas for the reference cementitious mixtures it has been 1.574 kN.m

Keywords: Impact Strength, Nano-Silica, Micro Metakaaolin, Magnetized Water, Micro Carbon Fibers, Micro Slag Powder.

1- Introduction

1-1 General

Recently, nano technology has attracted considerable scientific interest due to the new potential uses of particles in nano (10-9 m) scale. The use of nano-scale size of particles can result in dramatically improved properties from conventional grain-size materials of the same chemical composition. Thus, industries may enable to reengineer many existing products and design new and novel ones that function at unprecedented levels. There are few reports about mixing nano particles in cement- based building materials [1, 2]

Infrastructure in buildings can be exposed to different combination of dynamic loads caused hazardous structural damage to result in catastrophic failure. From here appeared need to design infrastructure resist earthquakes, impact, machine vibrations and load devastating to secure the public safety.

Soutsos et al [3] investigated impact resistance of reactive powder concrete. The aggregate used was silica sand of particles size less than 400 µm. The types of superplasticizers used were naphthalene based and two polycarboxylate polymers in powder and liquid form. The fibers were 12 mm in length and 0.16 mm in diameter. The results from simple impact load test on 1000mm square ∗ 100mm thick unreinforced slab supported on all sides, were very encouraging. The slab was tested using a seven-pound sledgehammer. It took about 70 blows for a hole to appear through the slab. The concrete at the top was powdering under the blows but there was no indication of tensile cracking.

1-2 Research Significance

Significance of this research the possibility of production concrete has been high impact resistance through the use of nano silica, micro ground granulated blast-furnace slag and micro high reactivity metakaolin whereas reacts rapidly with the calcium hydroxide in the cement paste converting it into stable cementitious compounds. These refinement processes will strengthen the microstructure and reduce micro cracking. On the other hand, the use of micro carbon fiber with nano-micro materials is produce greater impact, abrasion and shatter resistance in concrete.

1-3 Objectives

The Primary objectives of this search are:
To improve properties of local materials to achieve similar properties of nano-silica by cheaper means that lead to improvement of cementitious composite properties like impact strength

To evaluate the effect of water dosage, nano-silica (NS), micro high reactivity metakaolin (MHRM), micro ground granulated blast-furnace slag (MGGBFS), curing methods, micro carbon fiber addition and magnetic water on the impact strength of cementitious composite (CC)

To develop a drop hammer rig apparatus according to ACI Committee 544 method to understanding impact strength of cementitious composite containing nano-materials reinforced with and without micro carbon fibers.

2- Materials

2-1 Cement

Ordinary Portland cement (type I) was used throughout this research. It was stored in a suitable way to avoid any exposure to hazard conditions. The chemical and physical properties of cement used throughout this research are shown in Table 1 and 2 respectively. Test results were indicated that the adopted cement was conformed to the Iraqi specification No.5 [4]. A particle size distribution was acquired by a SHIMADZU SALD-2101 LASER is shown in Figure (1).

Table 1: Chemical composition and main compounds of cement*

Oxides composition	Content %	Limits of Iraqi specification No.5/1984
CaO	62.2	---
SiO_2	20.1	---
Al_2O_3	5.89	---
Fe_2O_3	3.08	---
MgO	2.31	<5.00
SO_3	2.01	<2.80
L.O.I.	2.53	<4.00
Insoluble residue	1.03	<1.5
Lime Saturation Factor, L.S.F.	0.87	0.66-1.02
Main compounds (Bogue's equations)		
C_3S	50.68	-
C_2S	19.474	-
C_3A	10.3	-
C_4AF	9.55	-

* Chemical analysis has been conducted by National Center for Geological Survey and Mining.

Table 2: Physical properties of cement*

Physical Properties	Test results	Limits of Iraqi specification No.5/1984
Specific surface area (Blaine method), m^2/kg	322	≥230
Setting time (Vicate apparatus), Initial setting, hr:min Final setting, hr:min	 2:10 6:35	 ≥00:45 ≤10:00
Compressive strength, MPa 3 days 7 days	 22.1 33.46	 ≥15.00 ≥23.00
Soundness (Autoclave method), %	0.24	≤0.8

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

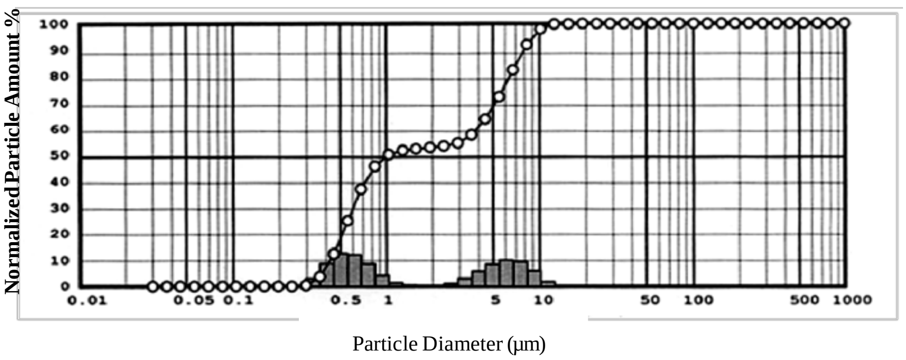


Figure 1: Particle size distributions of cement

2-2 Natural Sand

Al-Ekhaider natural sand was used throughout this research as the fine aggregate with particle size distribution smaller than 600 μm and greater than 150 μm.

2-3 Nano Silica (NS)

The nano silica used in this research named as CAB-O-SIL is made in Germany. It has a specific surface area $200m^2/g$. The chemical composition of this material is shown in Table 3. The NS used in this work conforms to the chemical and physical requirements of ASTM C1240-03 [5]. Tables 4 and 5 show the chemical and physical requirements, respectively. According to the manufacture company average primary particle size is 12 nanometers. X-ray diffraction diagram NS is shown in Figure (2).

Table 3: Chemical analysis of nano silica *

Oxide composition	Oxide content %
SiO_2	99.8
Al_2O_3	0.05
Fe_2O_3	0.003
Na_2O	0.05
K_2O	0.03
MgO	0.01
TiO_2	0.03
HCl	0.025

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

Table 4: Chemical requirements of nano silica ASTM C 1240-03*

Oxide composition	NS	Limit of specification requirement ASTM C 1240
SiO_2, min. percent	99.8	85.0
Moisture content, max. percent	1.5	3.0
Loss on ignition, max	1	6.0

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

Table 5: Physical requirements of nano silica ASTM C 1240- 03

Physical properties	**NS**	**Limit of specification requirement ASTM C 1240**
Percent retained on 45-µm (No.325) sieve, max.	-	10
Accelerated pozzolanic Strength Activity Index with Portland cement at 7 days, min. percent of control	210.58	105
Specific surface, min., m^2/g	200	15

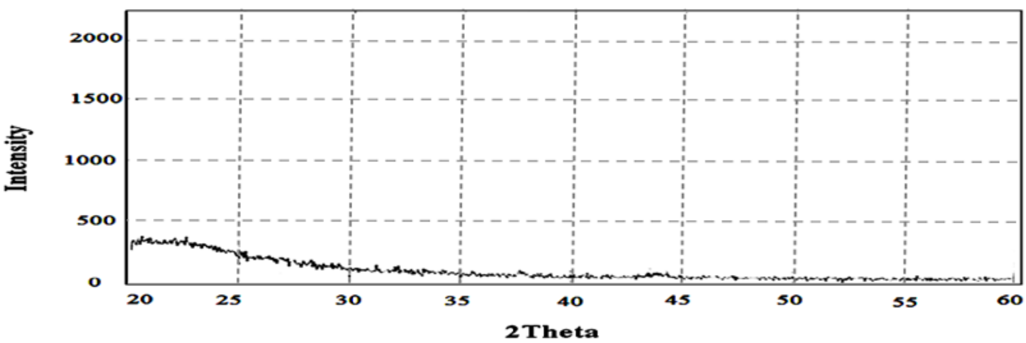


Figure 2: X-Ray diffraction patterns of NS

2-4 Ground Granulated Blast-Furnace Slag (GGBFS)

The Iraqi slag used in this investigation has been brought from Al-Sumood General Company in Al-Taji region as a large block. The grinding of GGBFS has been carried out in a grinding ball mill for a period of 25 hours for each 0.5kg of the GGBFS converted to micro micro ground granulated blast-furnace slag (MGGBFS). Particles size distribution has been acquired by a SHIMADZU SALD-2101 LASER DIFFRACTION PARTICLE SIZE ANALYSIS instrument in The Ministry of Technology and sciences, materials department .The instrument used has been attached to a computer that gives a plot and data about the amount of particles according to the diameter as shown in Figure (3). The chemical composition of MGGBFS has been shown in Table 6. The MGGBFS used in this work conforms to the physical and chemical requirements of ASTM C618 [6] Class N pozzolan as shown in Table 7 and Table 8.

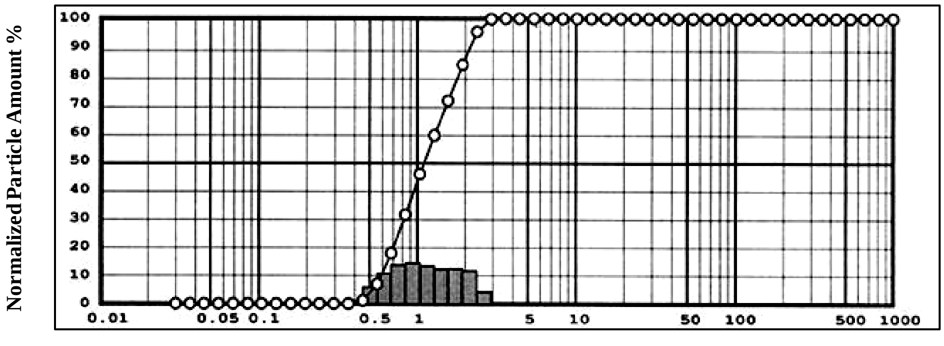


Figure 3: Particle size distributions of Micro Ground Granulated Blast-Furnace Slag MGGBFS)

Table 7: Physical requirements of pozzolan ASTM C618 (2006)

Physical properties	Pozzolan class N	MGGBFS
Strength activity index with Portland cement at 28 days ,min. % of control	75	213.36
Flow, max. %	115	110
Specific gravity		3.38

Table 8: Chemical requirements of pozzolan ASTM C618 (2006)

Oxide composition	Pozzolan class N	MGGBFS
SiO_2+AlO_3+Fe_2O_3, min.%	70	81.92
SO_3, max. %	4	0.0 7
Loss on ignition	Max.10	0.0

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

2-5 High Range Water Reducing Admixture (HRWRA)

The superplasticizer used was a modified polycarboxylates based polymer manufactured and supplied by SIKA® under the commercial name Sika® Viscocrete® Hi-Tech 36 [7].

2-6 Micro High Reactivity Metakaolin (MHRM)

The raw kaolinite clay used in this investigation have been brought from Al-Dwakhla region in Anbar city, and provided by Al- takamoul Company as a powder. Kaolinite clay has been calcinated at 700°C for one hour and the rapidly quenched in water. This material has been dried by oven at 110°C and then converted into very fine particle by grinding resulting in a highly active pozzolana. X—ray diffractomete has been used to determine the types of clay (metakaolin) minerals present in the clay as shown in Figure (4). Particles size distribution has been acquired by a SHIMADZU SALD-2101 instrument. The instrument used is attached to a computer that gives plot and data about the amount of particles According to the diameter as shown in Figure (5). The chemical composition of the micro high reactivity metakaolin has been shown in Table 9. The MHRM used in this work conforms to the chemical and physical requirements of ASTM C618 [6] Class N pozzolan. Table 10 and Table 11 show the chemical and physical requirements, respectively

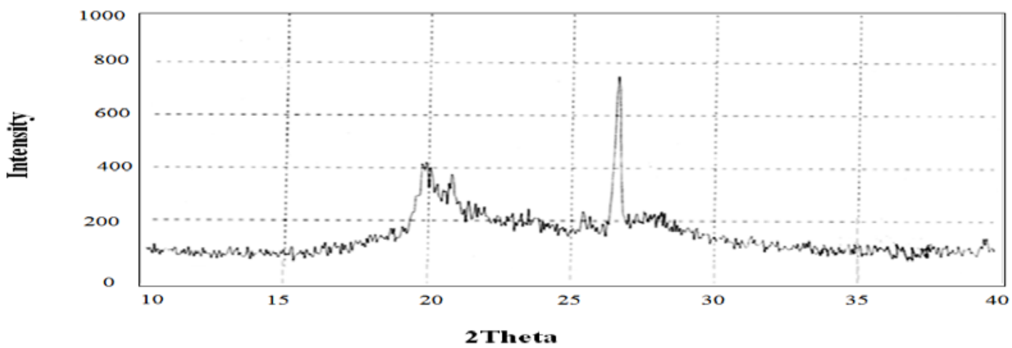


Figure 4: X-Ray diffraction patterns of Kaolinite clay calcined at 700^{O} C for one hour then rapidly quenching in water

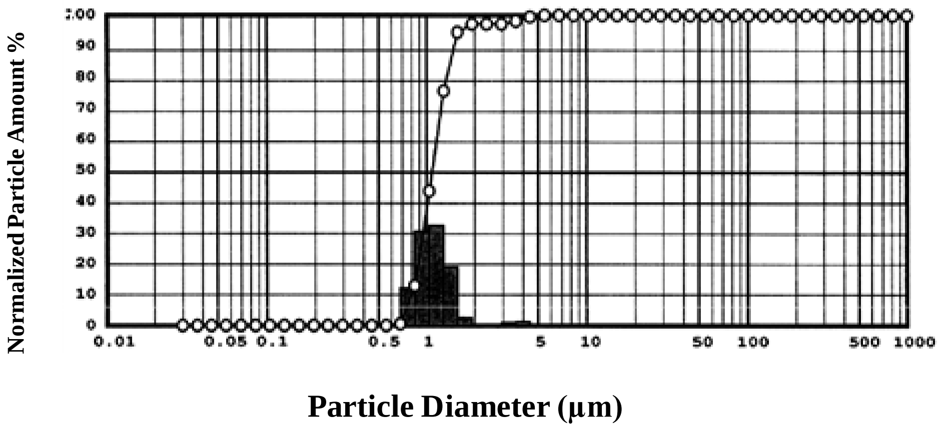


Figure 5: Particle size distributions of metakaolin

Table 9: Chemical analysis of micro high reactivity metakaolin*

Oxide composition	Oxide content %
SiO_2	55.22
Al_2O_3	32.38
Fe_2O_3	1.54
CaO	2.24
MgO	0.41
SO_3	2.55
Na_2O	0.96
K_2O	0.3
L.O.I	2.39
Other materials	2.01

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

Table 10: Chemical requirements of pozzolan ASTM C618 (2006)

Oxide composition	Pozzolan class N	MHRM
SiO_2+AlO_3+Fe_2O_3, min.%	70	89.14
SO_3, max. %	4	2.95
Loss on ignition max.%	10	4.4

*Chemical analysis has been conducted by National Center for Geological Survey and Mining.

Table 11: Physical requirements of pozzolan ASTM C618 (2006)

Physical properties	Pozzolan class N	MHRM
Strength activity index with Portland cement at 28 days ,min. % of control	75	197.41
Flow, max. %	115	110
Specific gravity	-	2.6 1

2-7 Mixing water

Two types of water were used in this research, the first one is tap water and the second is magnetized water. The magnetized water was produced by passing the tap water in a magnetic funnel

2-8 Carbon Fibers (CF)

The micro carbon fibers used in this research was brought from Alibaba Company [8]. It has small diameter 0.001mm and a length 8.5mm. Table 12 shows the properties of these carbon fibers.

Table 12: Physical properties of carbon fibers used in this investigation (Alibaba Company)

Description	Chopped carbon fiber
Length mm	8.5mm
Diameter mm	0.001mm
Weight (g/m^2)	300
Tensile strength (kgf/cm^2)	590
Tensile strength design (kg/cm^2)	35.500
Tensile modulus design (kg/cm2)	$2.35 * 10^6$
Carbon content (%)	98 wt
Specific gravity	1.9
Elongation at break (%)	1.4

2-9 Materials Proportion:-

This research included the sixteen mixtures in the cementitious composite reinforced or unreinforced with micro carbon fiber 2% by weight of cement. Tap water has been used in mixing eight of these mixtures, while the other eight have been mixed using magnetic water as follows:

1. Used sand with Portland cement at a ratio of 1:1 and water/cement ratio 0.44 (Reference) (CC)
2. Used sand with Portland cement at a ratio of 1:1 with the addition of 5% of Sika ViscoCrete-36 by weight of cement and water/ cement ratio 0.17.(HRWRA-CC)
3. Used sand with Portland cement at a ratio of 1:1 with the addition of 7% of Sika ViscoCrete-36 by weight of cement and water/ cement ratio 0.17, nano silica 2.5 % by weight of cement. (2.5 % NS-HRWRA-CC)
4. Used sand with Portland cement at a ratio of 1:1 with the addition of 6% of Sika ViscoCrete-36 by weight of cement and water/cement ratio 0.17, micro high reactivity metakaolin10% by weight of cement. (10%MHRM-HRWRA-CC).
5. Used sand with Portland cement at a ratio of 1:1 with the addition of 5.8% of Sika ViscoCrete-36 by weight of cement and water/ cement ratio 0.17, micro ground granulated blast-furnace slag 10% by weight of cement. (10%MGGBFS- HRWRA-CC).
6. Used sand with Portland cement at a ratio of 1:1 with the addition of 7.3% of Sika ViscoCrete-36 by weight of cement and water/cement ratio 0.17, nano silica 2.5% by weight of cement, incorporated 2% micro-carbon fibers (2.5 % NS- HRWRA-2% CF-CC).
7. Used sand with Portland cement at a ratio of 1:1 with the addition of 6.3% of Sika ViscoCrete-36 by weight of cement and water/cement ratio 0.17 micro high reactivity metakaolin 10% by weight of cement, incorporated 2.5% micro-carbon fibers (10%MHRM-HRWRA-2% CF-CC)
8. Used sand with Portland cement at a ratio of 1:1 with the addition of 6.1% of Sika ViscoCrete-36 by weight of cement and water/cement ratio 0.17, micro ground granulated blast-furnace slag 10% by weight of cement, incorporated 2.5% micro-carbon fibers (10%MGGBFS-HRWRA-2% CF-CC).

2-10 Casting and Curing of Test Specimens

The moulds have been filled with concrete and compaction has been performed by vibrating table for a sufficient period to remove any entrapped air as much as possible for all specimens. This has been attained within (20 seconds). Then the concrete surfaces are leveled and smoothed by means of trowel. The specimens have been covered with Polyethylene sheet to assure a humid air for about 24 hours. After that, the specimens have been demolded and cured in tap water saturated with $Ca(OH)_2$ at laboratory temperature (20-23)^{o}C up to test.

2-11 Impact Strength Test

The conducted impact test has been the drop-weight test, following the procedure recommended by ACI committee 544 [9]. Test specimens have been 150mm in diameter and 60mm thick. This test measures the amount of impact energy necessary to start visible crack in the specimen and then continue to open that cracks until failure.

The electrical drop-weight equipment has been manufactured by welding workshop of the Training and Workshops of Center in University of technology consists of:

1-Standard, manually operated 4.54 kg compaction hammers with 457 mm drop.

2- A 63.5 mm diameter hardened steel ball.

3- A flat base-plate with positioning bracket the average of three specimens has been taken for test at 7, 28, 90,180 and 360 days. It has been tested as follows:

The sample has been placed on the base-plate within the positioning lugs with the finished face up. The positioning bracket is then bolted in place, and the hardened steel ball is placed on top of the specimen within the bracket. Foamed elastic pieces have been placed between the specimen and positioning lugs to restrict movement of the specimen during testing to the first visible crack as shown in Figure **(**6-a). The drop hammer has been placed with its base upon the steel ball as shown in Figure (6-b). The base-plate has been bolted to rigid steel base. The hammer has been dropped repeatedly, and the number of blows required to cause the first visible crack on the top and to cause ultimate failure are both recorded. Test results have been put into more scientific terminology by converting them to units of energy. Each blow represents 20.2 N.m of energy. The foamed elastic is removed after the first visible crack is observed. Ultimate failure is defined as the opening of cracks in the specimen sufficiently so that the pieces of concrete can touch three of the four positioning lugs on the base-plate.

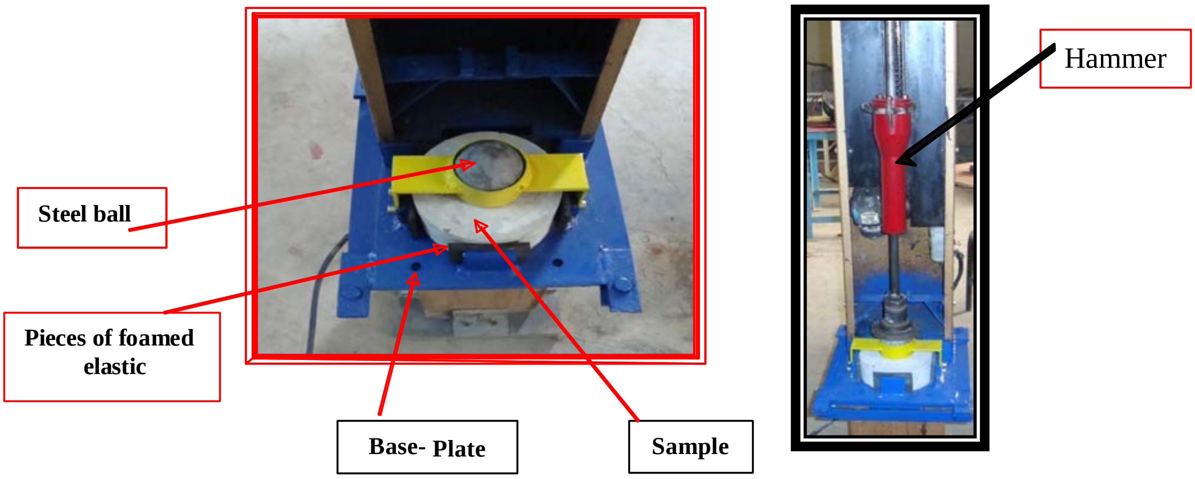


Figure 6: The arrangement of the impact equipment for measurement impact strength

3- Result and Discussion

Cementitious composite (CC) reinforced with micro carbon fibers is particular by ultra- high strength and high fracture. Because of its distinguished properties, CC may be suitable as an advanced material for reinforced concrete structure subjected to impact load resulting from crashing vehicles, ships or airplanes, avalanches or explosions. However, since CC containing nano silica, micro high reactivity metakaolin and micro ground granulated blast-furnace sag are a new materials; little information on the impact response of CC reinforced with micro carbon fibers is available.

The impact strength results in terms of energy (kN.m) for various types of CC using tap or magnetic water at all ages are illustrated in Table 13, Table 14 and plotted in Figure (7) through (18).

HRWRA-CC exhibits considerable increases in impact resistance at first crack and at ultimate failure at all ages with respect to reference CC, as shown in Figure (7).

At 28 and 360 days the percentages of increase in energy required to cause first crack and ultimate failure in HRWRA-CC with respect to reference CC have been (105.2, 113.2 and 107.76, 114.65)% respectively. Al-

Kadhi [10] and Mahdi [11] explained that this behavior may be ascribed to the reduced capillary porosity caused by the reduction of the water content of the mixtures, in addition to deflocculating or dispersion of the cement agglomerates into primary particles.

Figure (8) shows that the impact strength of 2.5%NS-HRWRA, 10%MHRM-HRWRA and 10%MGGBFS-HRWRA nonmagnetic CC at all age are higher than that of HRWRA-CC. The percentages of increase in energy required to cause first crack and ultimate failure with respect to HRWRA-CC have been (69.4, 62.7 and 73.1, 64.4)%, (74.4, 67.9 and 76.4, 68.4)% and (84.1, 76.96 and 88.4, 77.5)% at 28 and 360 days respectively. From these percentages, it is clear that 10%MGGBFS-HRWRA is higher than 10% MHRM-HRWRA and the later higher than 2.5%NS-HRWRA. This may be attributed to total w/c ratio (0.17 + 0.75 from 5.8 % (SV-Hi-Tech- 36) by weight of cement) which is less than total w/c ratio used in10%MHRM-shown in Figure (7) and (8). This behavior confirms the results that achieved by Mahdi [11] when he used 10% densified silica fume in his study about properties of self-compacted reactive powder concrete exposed to saline solution.

Figure **(**9) through 11 demonstrates considerably very high impact strength at first crack and at ultimate failure for 2.5% NS-HRWRA, 10%MHRM-HRWRA and 10%MGGBFS- HRWRA nonmagnetic cementitious composite reinforced with micro carbon fibers compared with unreinforced the same mixtures. The percentages of increase in energy required to cause first crack and produce ultimate failure at 28 and 360 days for 2.5%NS-HRWRA, 10%MHRM-HRWRA and 10%MGGBFS-HRWR nonmagnetic cementitious composite reinforced with carbon fibers with respect to the same unreinforced mixtures have been (3281.26, 3175.09 and 3108.4, 3079.48)%, (3299.18, 3179.28 and 3144.72, 3093.57)% and (3363.194, 3239.939 and 3170.922, 3245.611)% respectively. This is mainly imputed to the high capacity of micro carbon fibers CC to absorb large amounts of energy prior to failure. Therefore, the energy input required to initiate first crack and produce failure in fiber reinforced CC is very much greater than that for unreinforced CC. In addition to that, the uniform distribution of micro carbon fibers can significantly enhance its impact strength and ductility, Ynsheng et al [13] who found the compressive wave that is transmitted into the specimen is reflected by the specimen fixed end as a tensile wave. The superposition of the incident compressive wave and the reflected tensile one generates a tensile stress that grows HRWRA and 2.5%NS-HRWRA that have been(0.17 + 0.75 from 6 % (SV-Hi-Tech-36) by weight of cement) and (0.17 + 0.75 from 7% (SV-Hi-Tech-36) by weight of cement) respectively. This result corresponds to the result achieved by Al Attar [12] when she studied the microstructure and mechanical properties of lightweight aggregate concrete containing fibers where she found that the mixtures containing 8% high reactivity metakaolin had impact strength higher than the mixtures containing 8% silica fume. This can be attributed to the activity of pozzolanic materials which chemically reacts with the calcium hydroxide liberated during the hydration of cement and contributes to the densification of the concrete matrix, thereby strengthening the transition zone and reducing the microcracking leading to a significant increase in the energy absorption. In addition to that, the results have revealed that mode of failure in all specimens mentioned above were brittle where the specimens have divided into two parts as rapidly in time along the concrete specimen. Due to the wave superposition, the net tensile wave leads to spilling (tensile fracture) of the concrete specimen at a certain distance from the free end, where the tensile stress reaches the critical value.

The pictures in Figure **(**9) through (11) explain mode of failure where the specimens have been divided into three parts with roughness of the failure plan after creating a very deeper local damage due to the number of blows before failure while Mahdi [11] found that when using steel fibers 2% by volume, the specimen divided into two parts.

Test results when used magnetic water have shown an obvious increase in impact strength at first crack and ultimate failure at all ages for all various types of CC with and without micro carbon fibers as illustrated in Table 14 and Figure (12) through 18 and the mode failure of magnetic specimen corresponding to the nonmagnetic specimen while, the mode failure of reinforced magnetic specimen with 2% micro carbon fibers are divided into more than three parts as shown in pictures in Figure **(**16**)** through18. However, the percentages of increase in energy required to cause first crack and produce ultimate failure at 28 and 360 days for all various types of magnetic CC with and without micro carbon fibers with respect to the same nonmagnetic mixtures have explained in Table 15, and it can be seen that 10%MGGBFS-HRWRA has percentage of increase in impact strength is higher than 10% MHRM-HRWRA and the later higher than 2.5% NS-HRWRA. That means that MGGBFS reactive with magnetic water more than MHRM and NS.

Table 13: Impact strength of various type of nonmagnetic CC.

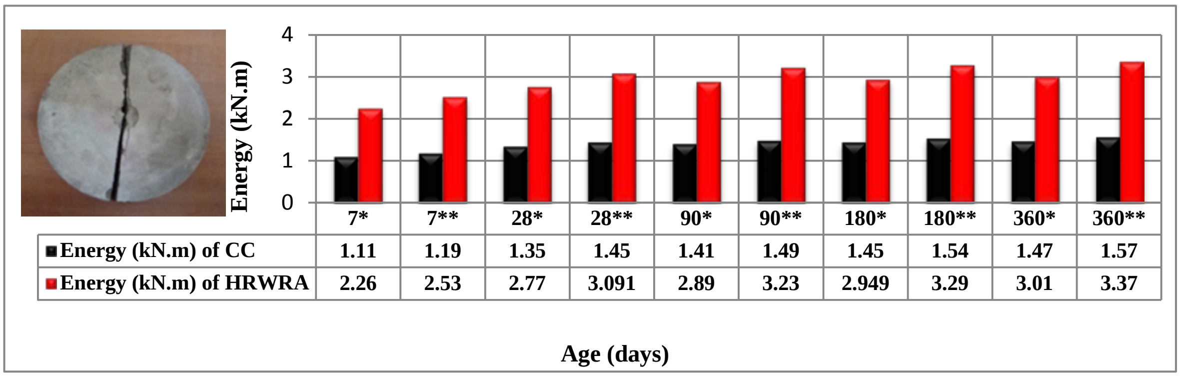
Mixtures	Energy(kN.m)									
	Age (days)									
	7		28		90		180		360	
	*	**	*	**	*	**	*	**	*	**
CC Tap Water (TW)	1.11	1.19	1.35	1.45	1.41	1.49	1.45	1.54	1.47	1.57
HRWRA- CC-TW	2.26	2.53	2.77	3.091	2.89	3.23	2.949	3.29	3.054	3.37
2.5% NS–HRWRA– CC-TW	3.78	4.06	4.69	5.03	5.05	5.25	5.16	5.39	5.286	5.54
10% MHRM–HRWRA– CC-TW	3.94	4.24	4.83	5.19	5.11	5.43	5.23	5.55	5.387	5.675
10% MGGBFS-HRWRA-CC-TW	4.18	4.53	5.1	5.47	5.17	5.58	5.25	5.7	5.754	5.78
2.5% NS–HRWRA–2% CF–CC-TW	130.74	136.05	158.58	164.74	166.23	172.49	167.85	174.19	169.59	176.14
10% MHRM–HRWRA–2% CF- CC-TW	135.86	141.35	164.18	170.19	171.61	177.77	172.92	179.46	174.79	181.24
10% MGGBFS-HRWRA-2% CF- CC-TW	149.63	155.73	176.62	182.69	184.13	190.16	185.35	191.85	188.21	193.38

*Up To first crack, ** Up to ultimate failure

Table 14: Impact strength of various type of magnetic CC.

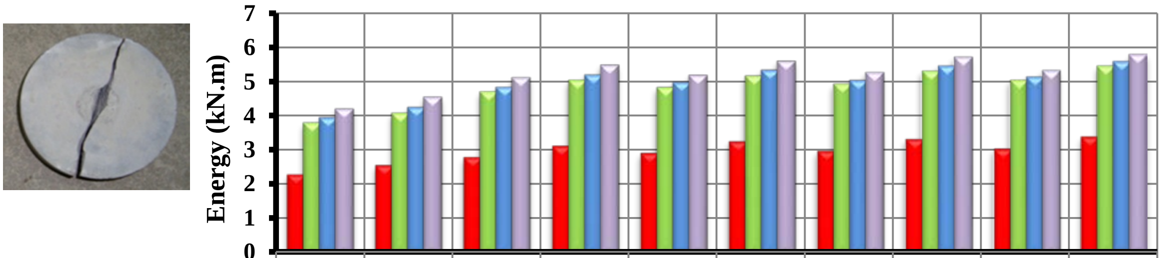
Mixtures	Energy(kN.m)									
	Age (days)									
	7		28		90		180		360	
	*	**	*	**	*	**	*	**	*	**
CC Magnetic Water (MW)	1.334	1.414	1.574	1.674	1.634	1.714	1.674	1.764	1.694	1.794
HRWRA-CC-MW	2.813	3.083	3.323	3.644	3.443	3.783	3.502	3.843	3.607	3.923
2.5% NS -HRWRA -CC-MW	5.037	5.317	5.947	6.287	6.307	6.507	6.417	6.647	6.643	6.797
10% MHRM-HRWRA-CC-MW	5.23	5.53	6.12	6.48	6.4	6.72	6.52	6.84	6.677	6.965
10% MGGBFS-HRWRA -CC- MW	5.83	6.18	6.75	7.12	6.82	7.23	6.9	7.35	7.404	7.43
2.5% NS-HRWRA–2% CF- CC-MW	163.82	166.47	199.49	202.18	209.45	212.16	211.66	214.42	214.20	217.01
10% MHRM - HRWRA – 2% CF-CC-MW	172.81	175.84	209.49	212.40	219.31	222.04	221.17	224.32	223.74	226.91
10% MGGBFS-HRWRA-2% CF- CC-MW	195.84	199.25	231.55	235.13	241.59	245.21	243.83	247.45	248.38	250.04

*Up To first crack, ** Up to ultimate failure



***Up To first crack, ** Up to ultimate failure**

Figure 7: Effect of nonmagnetic mixture containing HRWRA on the impact strength with age.

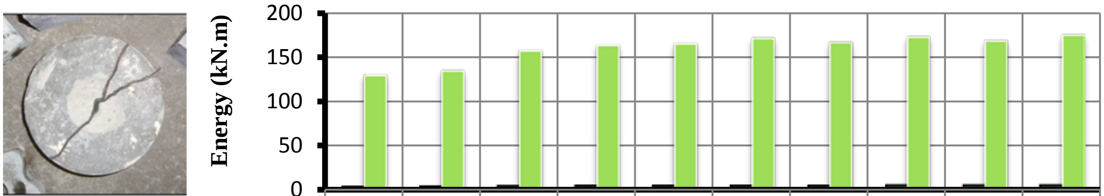


	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
Energy (kN.m) of HRWRA	2.26	2.53	2.77	3.091	2.89	3.23	2.949	3.29	3.01	3.37
Energy (kN.m) of 2.5% NS–HRWRA	3.78	4.06	4.69	5.03	4.81	5.15	4.91	5.29	5.03	5.44
Energy (kN.m) of 10% MHRM–HRWRA	3.94	4.24	4.83	5.19	4.97	5.33	5.03	5.45	5.13	5.575
Energy (kN.m) of 10% MGGBFS-HRWRA	4.18	4.53	5.1	5.47	5.17	5.58	5.25	5.7	5.31	5.78

Age days

***Up To first crack, ** Up to ultimate failure**

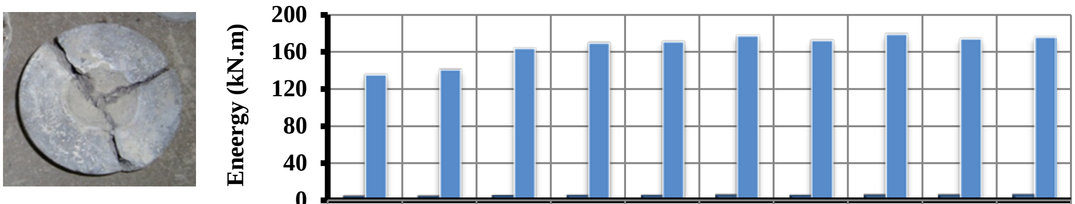
Figure 8: Effect of nonmagnetic mixtures containing 2.5% NS-HRWRA, 10%MHRM-HRWRA and 10% MGGBFS-HRWRA on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
Energy (kN.m) of 2.5% NS–HRWRA	3.78	4.06	4.69	5.03	5.05	5.25	5.16	5.39	5.286	5.54
Energy (kN.m) of 2.5% NS–HRWRA–2% CF	130.74	136.05	158.58	164.74	166.23	172.49	167.85	174.19	169.59	176.14

Age (days)

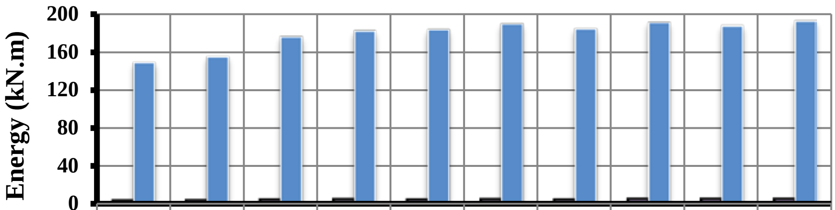
Figure 9: Effect of nonmagnetic mixtures containing 2.5% NS-HRWRA reinforced with micro carbon fibers on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
Energy (kN.m) of 10% MHRM–HRWRA	3.94	4.24	4.83	5.19	5.11	5.43	5.23	5.55	5.387	5.675
Energy (kN.m) of 10% MHRM-HRWRA-2% CF	135.87	141.35	164.18	170.19	171.61	177.77	172.92	179.46	174.79	176.39

Age (days)

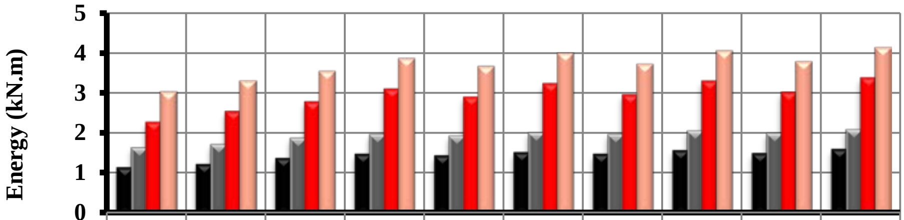
Figure 10: Effect of nonmagnetic mixtures containing 10%MHRM-HRWRA reinforced with micro carbon fibers on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
Energy (kN.m) of 10% MGGBFS-HRWRA	4.18	4.53	5.1	5.47	5.17	5.58	5.25	5.7	5.754	5.78
Energy (kN.m) of 10% MGGBFS-HRWRA-2% CF	149.63	155.73	176.62	182.69	184.13	190.16	185.35	191.85	188.21	193.37

Age (days)

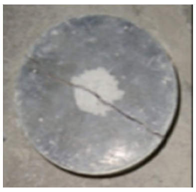
Figure 11: Effect of nonmagnetic mixtures containing 10% MGGBFS-HRWRA reinforced with micro carbon fibers on the impact strength with age

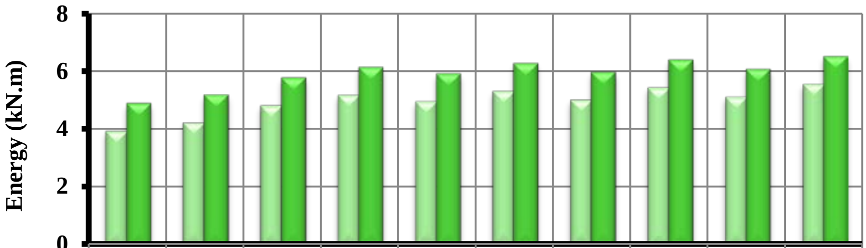


	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
CC-TW	1.11	1.19	1.35	1.45	1.41	1.49	1.45	1.54	1.47	1.57
CC-MW	1.61	1.69	1.85	1.95	1.91	1.99	1.95	2.04	1.97	2.07
HRWRA-TW	2.26	2.53	2.77	3.091	2.89	3.23	2.949	3.29	3.01	3.37
HRWRA-MW	3.02	3.29	3.53	3.851	3.65	3.99	3.709	4.05	3.77	4.13

Age (days)

Figure12: Effect of magnetic mixture of CC containing HRWRA on the impact strength with age.

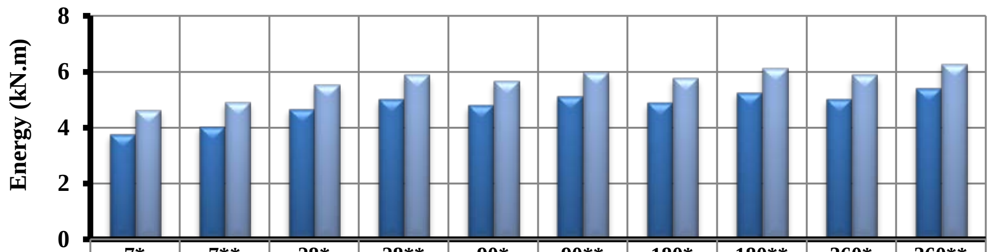




	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
2.5% NS-HRWRA-TW	3.94	4.24	4.83	5.19	4.97	5.33	5.03	5.45	5.13	5.575
2.5% NS-HRWRA-MW	4.86	5.16	5.75	6.11	5.89	6.25	5.95	6.37	6.05	6.495

Age (days)

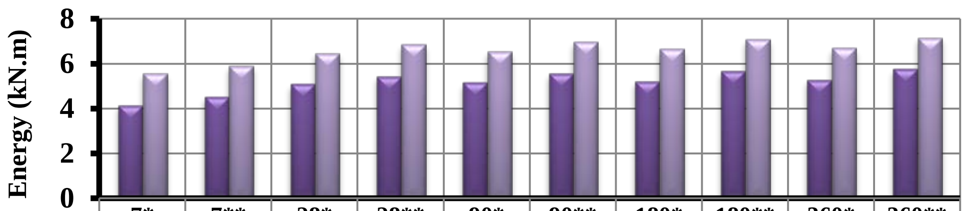
Figure 13: Effect of magnetic mixtures containing 2.5% NS-HRWRA on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
10% MHRM-HRWRA-TW	3.78	4.06	4.69	5.03	4.81	5.15	4.91	5.29	5.03	5.44
10% MHRM-HRWRA-MW	4.65	4.93	5.56	5.9	5.68	6.02	5.78	6.16	5.9	6.31

Age (days)

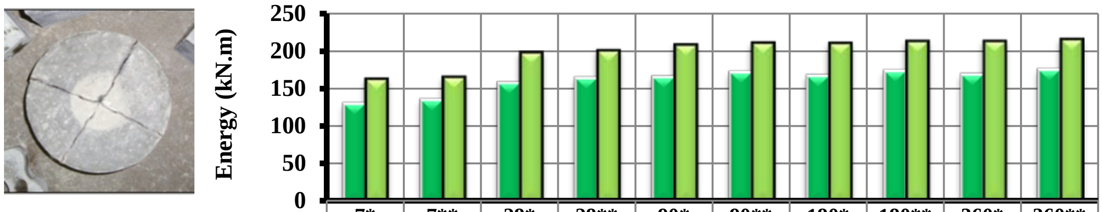
Figure 14: Effect of magnetic mixtures containing 10%MHRM-HRWRA on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
10% MGGBFS-HRWRA-TW	4.18	4.53	5.1	5.47	5.17	5.58	5.25	5.7	5.31	5.78
10% MGGBFS-HRWRA-MW	5.58	5.93	6.5	6.87	6.57	6.98	6.65	7.1	6.71	7.18

Age (days)

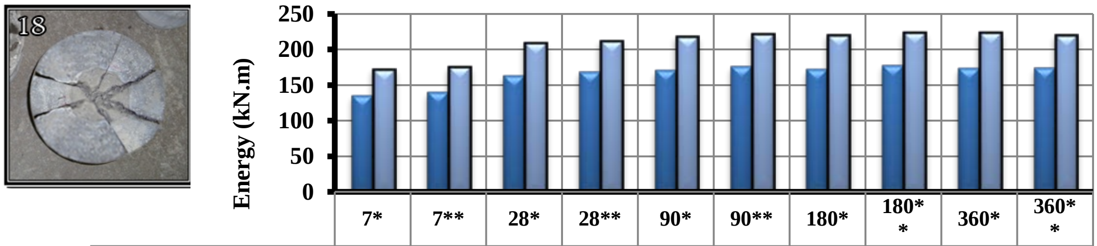
Figure 15: Effect of magnetic mixtures containing 10% MGGBFS-HRWRA on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
2.5% NS–HRWRA –2% CF-TW	130.74	136.05	158.58	164.74	166.23	172.49	167.85	174.19	169.59	176.14
2.5% NS–HRWRA –2% CF-MW	163.82	166.47	199.49	202.18	209.45	212.16	211.66	214.42	214.2	217.01

Age (days)

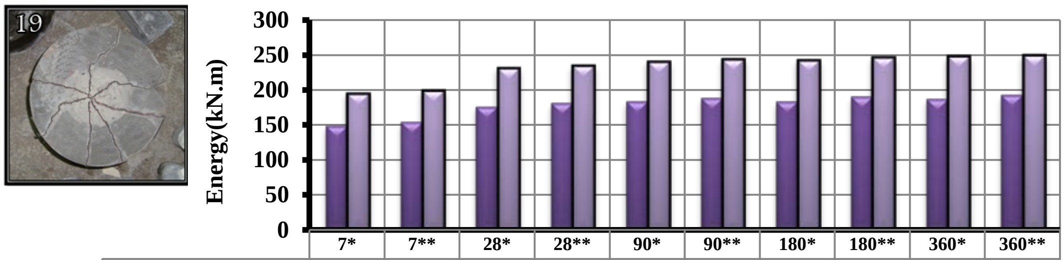
Figure 16: Effect of magnetic mixtures containing 2.5% NS-HRWRA reinforced with micro carbon fibers on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
10% MHRM–HRWRA –2% CF-TW	135.87	141.35	164.18	170.19	171.61	177.77	172.92	179.46	174.79	176.39
10% MHRM–HRWRA –2% CF-MW	172.81	175.84	209.49	212.4	219.31	222.04	221.17	224.32	223.74	220.85

Age (days)

Figure 17: Effect of magnetic mixtures containing 10%MHRM-HRWRA reinforced with micro carbon fibers on the impact strength with age.



	7*	7**	28*	28**	90*	90**	180*	180**	360*	360**
10% MGGBFS -HRWRA-2% CF-TW	149.63	155.73	176.62	182.69	184.13	190.16	185.35	191.85	188.21	193.37
10% MGGBFS-HRWRA-2% CF-MW	195.89	199.25	231.55	235.13	241.59	245.21	243.83	247.45	248.38	250.04

Aage (days)

Figure 18: Effect of magnetic mixtures containing 10% MGGBFS- HRWRA reinforced with micro carbon fibers on the impact strength with age.

Table 15: The percentages of increasing in energy for all various type of magnetic CC with respect to the same nonmagnetic mixtures.

Mixtures	Energy(kN.m)			
	Age (days)			
	28		360	
	Up To first crack	Up to ultimate failure	Up To first crack	Up to ultimate failure
CC	16.6	15.44	15.2	14.26
HRWRA - CC	19.98	17.89	18.4	16.4
2.5% NS - HRWRA - CC	26.86	24.99	23.19	22.68
10% MHRM -HRWRA -CC	26.44	24.855	23.94	22.73
10% MGGBFS-HRWRA - CC	32.45	30.16	28.67	28.55
2.5% NS–HRWRA–2% CF–CC	25.8	22.73	26.3	23.2
10% MHRM - HRWRA – 2% CF- CC	27.6	24.8	28.0	25.2
10% MGGBFS-HRWRA-2% CF- CC	31.1	28.7	31.97	29.3

4-Conclusions

1- Nonmagnetic HRWRA-CC exhibits considerable increases in energy at first crack and at ultimate failure at all ages with respect to reference CC the percentages of increase (105.2, 113.2 and 107.76, 114.65)% at 28 and 360 days respectively

2- The results show that the impact strength of nonmagnetic CC incorporation 2.5%NS-HRWRA, 10%MHRM-HRWRA and 10%MGGBFS-HRWRA at all age is higher than that of HRWRA-CC. The percentages of increase in energy required to cause first crack and ultimate failure with respect to HRWRA-CC have been (69.4, 62.7 and 73.1, 64.4) %, (74.4, 67.9 and 76.4, 68.4) % and (84.1, 76.96 and 88.4, 77.5) % at 28 and 360 days respectively.

3-Nonmagnetic CC incorporation of 2.5%NS-HRWRA, 10%MHRM-HRWRA and 10%MGGBFS-HRWRA reinforced with 2% micro carbon fibers demonstrates considerably very high impact strength at first crack and at ultimate failure. The percentages of increase in energy with respect to the same unreinforced mixtures have been (3281.26, 3175.09 and 3108.4, 3079.48)%, (3299.18, 3179.28 and 3144.72, 3093.57)% and (3363.194, 3239.939 and 3170.922, 3245.611)% at 28 and 360 days respectively.

4-Effect of magnetic water has been revealed an increase in impact strength at first crack and ultimate failure at all ages for all various types of CC with and without Carbon fibers and the higher percentage of impact strength has been 10%MGGBFS-HRWRA–CC. The percentage of increase in energy for all various types of magnetic CC with respect to the same nonmagnetic mixtures was range between 16.6 to 30.92% at first crack and 15.44 to 30.16 % at ultimate failure at 28 day.

5-References

[1] Lau, A. and Hui, D., "The Revolutionary Reaction of New Advanced Materials-Carbon Nano tube Composites", Composites Part B: Engineering. Vol. 33, No. 4, pp. 263-277, 2002.

[2] Li, H., Xiao, H., Yuan, J. and Ou, J., "Microstructure of cement mortar with nano-particles Composites", Part B, Vol. 35, No. 2, pp.185-189, 2004.

[3] Soutsos, M., Millard, S., Karaiskos, K., "Mix design, mechanical properties, and impact resistance of reactive powder concrete", Cement and Concrete Research, V. 39, No. 4, pp. 31-38, 1996.

[4] Iraqi specification, No.5/1984.,"Portland cement". Ministry of Planning Central Organization for Standardization and Quality control.

[5] ASTM C 1240–2003, "Standard Specification for Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout", Vol. 04.02, pp.1-6, 2003.

[6] ASTM C 618- 2006,"Standard Specification for Coal Fly Ash and Raw or calcined Natural pozzolan for use in concrete" (Section 4, volume 04.02 October 2006)

[7] Sika®ViscoCrete® Hi-Tech 36, Product Data Sheet, Turkey, pp. 1-3, www.sika.com.tr.

[8] Alibaba Company, Hong Kong Limited and licensors. www.alibaba.com/country

[9] ACI Committee 544, Measurement of properties of fiber reinforced concrete. American Concrete Institute, Material Journal, PP. 583–593, 1988 .

[10] Al–Kadhi, A. Gh., "Durability And Dynamic Properties Of Reactive Powder Concrete Exposed To Aggressive Ions" PhD, University of Technology, Building and Construction Engineering Department, 2007.

[11] Mahdi, B. S., "Properties of Self- Compacted Reactive Powder Concrete Exposed to Saline Solution" Ph. D. Dissertation, University of Technology, Building and Construction Engineering Department, 2009.

[12] Al-Attar, A. A., "Microstructure and Mechanical Properties of Lightweight Aggregate Concrete Containing Fibers", PhD, University of Technology, Building and Construction Engineering Department, (2006), .

[13] Yunsheng, Z., Wei, S, Sifeng, L, Chujie, J, Jianzhong, L, "Preparation of C200 Green Reactive powder Concrete and Its Static-Dynamic Behaviors", Cement & Concrete Composites, 2008.

[14] Abbas, R., "Influence of Nano-Silica addition on properties of conventional and ultra- high performance concretes", HBRC Journal, vol.20, No. 20, pp. 1-13, 2009.

[15] ACI 226.IR-87, "Ground granulated blast-furnace Slag as a cementitious constituent in concrete", ACI Manual of concrete practice, part 1: materials and general properties of concrete, Detrooit, Michigan, pp16, 1994.

[16] Advanced Cement Technology, LLC, "High reactivity metakaolin (HRM) engineeredmineral admixture for use with Portland cement", http://www.sales@metakaolin.com Vol.10, No.102, pp.10, 2002.

[17] Afshin, H., Gholizadeh, M. and Khorshidi, N., "Improving Mechanical Properties of High Strength Concrete by Magnetic Water Technology", Sharif University of Technology, Vol. 17, No. 1, pp. 74-79, 2010

[18] Arabshahi, H., "The Effect of Magnetic Water on Strength Parameters of Concrete", Alfa Universal, An International Journal of Chemistry, Vol. 1, No.,1, pp. 30-35, 2010.

[19] ASTM C 494/C 494M–1999a, "Standard Specification for Chemical Admixtures for Concrete", Vol. 04.02, pp.1-9, 1999.

[20] Balaguru, P. and Chong, K., "Nanotechnology of concrete: Recent Developments and Future Perspectives", Denver, USA, November 7, pp. 15-28, 2006.

[21] Cao, J. and Chung, D. D. L., "Carbon fiber reinforced cement mortar improved by using acrylic dispersion as an admixture", Cem Concr Res, Vol.31, No.11, pp.1633-1637, 2001.

[22] Cargile, J.D., O'Neil, F. and Neeley, B.D., "very –hig–strength concrete for use in blast– and penetration-resistant structures", The

AMPTIAC Quarterly, Vol. 6, No. 4, pp.61-67, 2006.
[23] Chacko, R., M., "Carbon-fiber reinforced cement based sensors" M.Sc. Thesis, The University of British Columbia, Civil engineering, pp.23-29, 2005.
[24] Chung, D.D.L., "Improving cement- based materials by using silica fume", J Mater Sci, Vol. 37, No.4, pp.673-682, 2002.
[25] Collepardi, S., Coppola, L., Troli, R. and Collepardi, M., "Mechanical Properties of Modified Reactive Powder Concrete" In: V-M. Malhotra Ed. Proceedings Fifth CANMET / ACI International Conference on Superplasticizers and the Chemical Admixtures in Concrete, Rome, Italy, and Farmington Hills, MI: ACI Publication SP-173,pp.1-21, 1997.
[26] Collepardi, S., Coppola, L., Troli, R. and Collepardi, M., "Mechanical properties of modified reactive powder concrete" In: V-M. Malhotra Ed. proceedings fifth CANMET/ACI International Conference on Superplasticizers and the Chemical Admixtures in Concrete, Rome, Italy. Farmington Hills, MI: ACI Publication SP- 173, pp.1-21, 1999.
[27] Collepardi, M ., Collepardi, S., Troli, R. and Skarp, U., "Combination of Silica Fume, Fly Ash and Amorphous Nano-Silica in Superplasticized High-performance Concretes", Proceeding of First International Conference on Innovative Materials and Technologies for construction and Rehabilitation, Lecce, Italy, pp. 459-468, 2004.
[28] Estevez, M., Vargas, S., Castaño, V. M. and Rodríguez, R., "Silica nano-particles produced by worms through a bio-digestion process of rice husk", Journal of Non-Crystalline Solids Vol. 355, pp 844–850, 2009.
[29] Flores, I., Garza-Tovar, L.L., Torres-Martínez, L.M., and Sobolev, K, "Effect of Nano-SIO_2 on Properties of Cement Based Materials"1st International Conference on Advanced ConstructionMaterials, pp.17-18., 2006, E- mail: ismaelfv1975@yahoo.com.mx.
[30] Fujikake , k., Senga, T.,Ueda, N.,Ohno, T., and Katagiri, M., "Study on Impact Response of Reactive Powder Concrete Beam and its Analytical Model ", journal of Advanced Concrete Technology Vol. 4, No.1, pp. 99-108, (2006).

تأثير اضافة مواد نانوية والياف الكاربون على مقاومة الصدمة للمتراكبات السمنتية

د. زين العابدين رؤوف
قسم الهندسة المدنية
جامعة بغداد

د. رافع هاشم
قسم الهندسة المدنية
جامعة بغداد

د. زينب هاشم مهدي
قسم البناء والانشاءات
الجامعة التقنية الوسطى
Zainabengineeringcollege@yahoo.com

المستخلص

تضمنت هذه الدراسة إضافة نانو سيليكا معدل المقاس الحبيبي 12 نانو، مايكرو ميتاكاؤولين مقاسه الحبيبي ≤ 0.554 ≥ 1.271، مايكرو مسحوق خبث الفرن العالي مقاسه الحبيبي ≤ 0.365 > 2.932 ومايكرو الياف الكاربون، طول الليف 8.5 ملم وقطره 0.001 ملم إلى الخلطات السمنتية لمعرفة تأثيرها على مقاومة الصدمة واستخدم الماء الممغنط أو الماء الاعتيادي في خلط الخلطات.

أظهرت النتائج إن الخلطات السمنتية المستخدم في خلطها الماء الممغنط التي تحتوي على 10 % مايكرو مسحوق الخبث, 10 % مايكرو ميتاكاؤولين أو 2.5 % نانو سيليكا المسلحة بـ 2% ألياف الكاربون تحسن وبدرجة كبيرة جدا في مقاومة الصدمة حيث تصل الطاقة الممتصة إلى ظهور الشق الأول عند العمر 28 يوم (231.55, 209.49 و 199.49) كلونيوتن .مترعلى التتابع, أما الخرسانة المرجعية فكانت 1.574 كيلونيوتن .متر

الكلمات الدالة: مقاومة الصدمة، نانو سليكا، مايكرو ميتاكاؤولين، الماء الممغنط، الياف الكاربون، مايكرو مسحوق الخبث