BEHAVIOR OF FERROCEMENT SLABS CONTAINING WASTE PLASTIC FIBERS UNDER IMPACT LOADINGS

Dr. Abdulkader Ismail Abdulwahab Al-Hadithi*+ and Zayd Abdul-Jabbar Al-Obaidi*

*Dams & Water Resources Engineering Department, College of Engineering, University of Anbar. Ramadi, Anbar, Iraq.

+Corresponding author: al_hadithi2000@yahoo.com , Mobile Phone: +964 7710007876

ABSTRACT

Ferrocement is one of the structural materials, widely used due to its advantage from its particular behavior such as mechanical properties, and impact strength. The main aim of this work was to investigate the behavior of ferrocement reinforced with waste plastic fibers WPF panels under impact loadings.

A total of 36 ferrocement panels with dimensions of (500×500×50 mm) were constructed and tested under low velocity impact. The main parameter considered in the present investigation was the number of wire mesh layers, content of waste plastic fibers and height of falling mass. The results of low velocity impact test at age of (56) days, showed that the addition of waste plastic fibers increased the number of blows which were required to make the first crack and ultimate failure, with the increase of number of wire mesh layers.

Keywords: Ferrocement, Impact, fiber reinforced concrete, waste plastic fibers, wire mesh

INTRODUCTION

Ferrocement is a form of reinforced concrete that differs from conventional reinforced or pre stressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar [1]. Raw materials for ferrocement construction in developing countries are easily available, and it could be constructed in any complicated shape, whereas it needs low level of skill which is required. This kind of material has superior strength properties as compared to conventional reinforced concrete [2–7]. Many researches deal with the developing of ferrocement properties by adding different materials like polymers. Mechanical properties of ferrocement improved by adding styrene butadiene rubber SBR[8]. Kadhum [9] produced a new type of ferrocement of polystyrene concrete, which has several advantages compared to ordinary reinforced concrete plates, such as lower density, abrasion resistance, compressive strength and flexural strength. Gaylan [10] enhanced mechanical properties and impact resistance of ferrocement by adding different types of fibers .

FIBER REINFORCED CONCRETE

Normal unreinforced concrete is brittle with a low tensile strength and strain capacity [11]. Ordinary concrete includes numerous micro cracks which are rapidly increased under the applied stresses. These cracks are responsible of the low tensile, flexural strength, and impact resistance of concrete [12]. The fibrous reinforced concrete is a composite materials essentially consisting of concrete reinforced by random placement of short discontinuous, and discrete fine fibers of specific geometry [13-16]. It is now well established that the addition of short, discontinuous fibers plays an important role in the improvement of the mechanical properties of concrete. It increases elastic modulus, decreases brittleness; controls crack initiation, and its subsequent growth and propagation. Debonding and pull out of the fibers require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the material to cyclic and dynamic loads [17]. Concrete, the dominant construction material in our time, suffers from a major shortcoming; it cracks and fails in a brittle manner under tensile stresses caused by external loading or restrained shrinkage movements. Concrete failure initiates with the formation of micro cracks which eventually grow and coalesce together to form macro cracks. The macro cracks propagate till they reach an unstable condition and finally result in fracture. Thus, it is clear that cracks initiate at a micro level and lead to fracture through macro cracking. Fibers, used as reinforcement, can be effective in arresting cracks at both micro cracks and macro cracks from forming and propagating [18].

WASTE

Waste is defined as unused discharge products generated from human life, social and industrial activity. The industrial wastes are roughly classified into residential wastes and business wastes. Residential wastes are wastes discharged from human activities and consist of refuse and human waste, and are referred to as general waste. It also includes refuse and human waste generated from institutional facilities [19].In developing countries, Increasing population levels, booming economy, rapid urbanization and the rise in community living standards have greatly accelerated the municipal solid waste generation rate [20].There was an incredible growth in the consumption of plastics due to their good safety, low cost, durability, lighter weight than competing materials, and extreme versatility and ability to be tailored to meet specific technical needs [21].Waste Plastic:The potential of using recycled plastic waste as reinforcing fibers in concrete studied by Alhozaimy [22]. Different volume fractions varied between 1% to 4% of recycled plastic, low density polyethylene fibers (RP fibers) and control with no RP fibers were considered. The results showed that at volume fraction of 1 to 2% of RP fibers, plastic shrinkage cracking was almost similar to plain concrete without RP fibers (i.e., 0%) while at a volume fraction of 3 to 4 %, no plastic shrinkage cracks were observed. Also, it was found that RP fibers have no significant effect on the compressive and flexural strengths of plain concrete at volume fractions used in this study. However, the RP fibers increased flexural toughness up to 270%.Al-hadithi [23], studied the effect of adding plastic chips resulting from cutting the plastic beverage bottles (which is used in

Iraqi markets now) as fiber added to the polymer concrete and study there effects on some properties of polymer modified concrete like compressive strength and flexural strength. Results proved that, an improvement in mechanical properties with an increasing of waste plastic fibers percentage by volume. The increasing in flexural strength (modulus of rupture) appeared more clearly than that of compressive strength. The maximum increasing in the value of 28 day modulus of rupture equal to 24.4% for PMC mix with fiber percentage by volume equal to 0.1%, whereas the maximum increasing in compressive strength was equal to 4.1% for the same mix. Thirty kilograms of waste plastic of fabriform shapes was used as a partial replacement for sand by 0%, 10%, 15%, and 20% with 800 kg of concrete mixtures by Ismail [24]. Many tests were done include performing slump, fresh density, dry density, compressive strength, flexural strength, and toughness indices. Curing ages of 3, 7, 14, and 28 days for the concrete mixtures were applied in this work. The results proved the arrest of the propagation of micro cracks by introducing waste plastic of fabriform shapes to concrete mixtures and also proved that reusing of waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics. There were some researches deals with investigating the effects of adding waste plastic fibers WPF resulting from cutting PET bottles on the concrete mechanical, physical and some other properties were done [25-29]. The results of these studies proved that there were decreasing in concrete density, developing in flexural strength and enhancing in the ability of concrete to arresting cracks.

EXPERIMENTAL PROGRAM

The experimental program was planned to investigate the effect of using waste plastic fibers on the mechanical properties and impact resistance of Ferrocement. The test variables include compressive strength, flexural strength. Number of wire mesh Ferro-cement slabs for low and high impact tests.

MATERIALS

Ordinary Portland cement (Type I) is used in this research. The chemical analysis was conformed to Iraqi standard specifications no. (5/1984) [30] and physical test was conformed to (B.S.12:part2 :1971) [31].The fine aggregate used is natural sand brought from Ramadi region. It was clean, free of organic impurities and deleterious substances and relatively free of clay. The grading of sand is conformed to the requirements of the (B.S.882/1992) specification[32].Ordinary drinking water was used for mixing and curing for all specimens. It was tested at Laboratories of Civil Department/College of Engineering/University of Anbar. The water was conform to Iraqi standard specifications no.(1703/ 1992) [33].Rectangular shape of waste plastic fiber with dimension 20 × 4 mm and thickness of 0.3 mm was used to this research .The waste fibers made by shredded beverage bottles made of (PET) into a regular shapes and dimensions using shredder machine . The aspect ratio (l/d) was (17). Fibers were added to the mixes as a ratio by volume of mixture of 0.5% ,1.0% and 1.5% respectively. figure 1. Showing the waste plastic fibers which used in this study. Square meshes of reinforcement, fabricated from 1.8 mm-nominal diameter steel bars, are used in the panels. The spacing of bars in both directions was 16 mm which does not exceed three times the panel thickness, with a clear cover of 10 mm (0.39 in.) over the bars. The wire mesh provides support to the thinner section 50 mm thick of the panel. Table 1 gives the average value of the obtained results.

MOULDS OF FERRCEMENT SLABS

For low velocity impact strength, square slabs of 500 × 500 × 50 mm were used respectively. Experimental program was planned to investigate the effect of using waste plastic fibers on the impact resistance of Ferrocement. The test variables include Ferrocement slabs for low and high impact tests. Table 2 shows the details of reference concrete mix and concrete with fibers mixes.

MIXES

The proportion of the constituents for the prepared concrete mix is 1 : 2 (by weight) of ordinary Portland cement: fine aggregate of maximum size 4.75 mm with a water/ cement ratio of 0.45 and waste plastic fiber is used as a ratio by volume of mixture of 0.5%, 1.0%, and 1.5% as percentage . The water/cement ratio used is 0.45 for all mixes. Molds were prepared according to ASTM C192-88 [34].

TESTS

TESTING OF HARDENED CONCRETE

This test was done on cubes according B.S. 1881 part 116[35].A 2000 kN capacity ELE testing machine was used for the compressive test .The average compressive strength of three cubes was recorded for each testing age (14,28 and 56 days). Concrete prisms were prepared according to ASTM C192-88 [34].The test was carried out using two points load according to ASTM C78-94 [36] using ELE 50 KN capacity machine. Average modulus of rupture of three prisms was obtained for each testing age (14, 28 and 56) days.

IMPACT TEST

The resistance of concrete under dynamic loadings can be assess through different types of test procedures, such as the explosive test, drop-weight test, projectile impact test, and constant strain rate test [37], the drop-weight test, as reported by the ACI Committee 544 [38] is the rig which is used in this research. The low velocity impact test was conducted using 1400 gm steel ball dropping freely from heights 2.4 m and 1.2 m . Thirty two, 56-day age 500 × 500 × 50 mm slab specimens were tested under low velocity impact consists of three main components as shown in Figure 2. A steel frame ; strong and heavy enough to hold rigidly during impact loading. The dimensions of the testing frame were designed to allow observing the specimens (square slab) from the bottom surface to show developing failure, during testing. The specimen was placed accurately on mold which were welded to the support ensure the simply supported boundary condition. The vertical guide for the falling mass used to ensure mid-span impact. This was a tube of a round section. Steel ball with a mass of 1400 gm . Specimens were placed in their position in the testing frame with the finished face up. The falling mass was then dropped repeatedly and the number of blows required to cause first crack was recorded. The number of blows required for failure (no rebound) was also recorded. The number and details of specimens which were used in this test are shown in Table 2.

RESULTS AND DISCUSSION

Compressive Strength Test: The average compressive strength of three cubes was recorded for each testing age 14, 28 and 56 days. The relationship between the compressive strength at different ages and volume of fiber is shown in Figure 4. From this figure, it can be seen that the compressive strength of all specimens' increases with time, but the percentage of the increase in compressive strength differs between the reference mix and the fiber-reinforced mortar. The lowest magnitude of the compressive strength at 14 days curing is 37.1 MPa for specimens with (1.5%) V_f ratio and the lowest magnitude of the compressive strength at 28 days curing is 40.2 MPa for specimens with (1.5%) V_f ratio, while at 56 days curing, the respective lowest magnitude is 43.5 MPa for specimens with (1.5%) V_f ratio. That decrease in the compressive strength might be due to the forming of segregate on mix. This led to form stiff bond around these bulks. Therefore, the existence of waste plastic fibers allows the absorption of water inside the porous Also, exciting of waste plastic fiber reduces the density of cubes. That led to a decrease in the compressive strength of composite [26]. Use of waste plastic fiber increased the porous inside the mortar structure and that caused reducing the compressive strength.

Flexural strength test : Average modulus of rupture of three prisms was obtained for each testing age 14, 28 and 56 days. This strength was determined at ages of 14, 28 and 56 days for moist cured cement mortar prisms of 100×100×500 mm dimensions. The effect of curing ages on the flexural strength on various types of cement mortar is presented in Figure 5. The results indicated that flexural strength increased with development of curing ages, also the flexural strength increased with the increase in fibers volume of all ages for different types of mortar mixes. At 14 days curing, the highest magnitude of flexural strength is 6.73 MPa for specimens with (1.5%) V_f ratio, at 28 days curing the highest magnitude of flexural strength is 7.90 MPa for specimens with (1.5%) V_f ratio while at 56 days curing, the highest respective magnitude is 8.22 MPa for specimens with (1.5%) V_f ratio. The addition of waste plastic fiber improved flexural strength. This increase in flexural strength can be attributing to the fact that the waste plastic fibers arrest cracks progression Also, the addition of waste plastic fibers contributed to strengthen the interior tensile stresses [39]. In contrast, the increase of flexural strength of specimens reinforced with waste plastic fibers is due to the fiber bridging effect, which prevented cracks from opening widely.

Behavior of ferrocement specimens under low velocity impact: The increase in impact resistance at first crack and ultimate failure for the slabs containing WPF compared with reference mix are plotted in Figures 3 to 6 for all concrete mixes at age of 56 days. From Table 3 and Table 4, it can be see that the specimens reinforced with one layer of wire mesh needed a number of blows to cause a first crack and ultimate failure more unreinforced specimen. The specimens reinforced with two layers of wire mesh needed a number of blows to cause a first crack and ultimate failure more than unreinforced specimen and the specimen that reinforced with one layer. The specimens reinforced with three layers of wire mesh needed a number of blows to cause a first crack and ultimate failure more than the unreinforced specimen and the specimen reinforced with one or two layer. This may be attribute to the fact that ferrocement exhibited continuous increase in impact resistance with increases in volume of reinforcement [40]. This behavior may be ascribe to the significant addition of waste plastic fibers to the ferrocement slabs that caused the bridging of the micro cracks; the internal bond strength of ferrocement is dramatically increased leading to a significant increase in internal energy of concrete (impact resistance). In addition, results showed that the increase in V_f ratio leads to the increase in impact resistance at first crack and ultimate failure especially at V_f ratio (1.0 %) compared with reference concrete. This may be attributed to the fact that the fiber itself has excellent impact resistance. For 2.4 m height falling mass, the maximum value of the number of blows to cause a first crack was (84) blows for the specimen reinforced with three layers of wire mesh while the maximum value for the number of blows to cause ultimate failure was (99) blows for the specimen reinforced with three layers of wire mesh, both values with the addition of V_f of (1.0%). The percentage increase of the number of blows to cause first crack was (300 %), (525 %) and (350%), while the percentage increase in the impact resistance at ultimate failure was (367 %), (476 %) and (266%) for unreinforced ferrocement slabs with wire mesh and modified with V_f ratios (0.5 %), (1.0%) and (1.5 %) respectively when compared with reference concrete , the percentage increase of the number of blows to cause a first crack was (150 %), (340 %) and (240 %), while the percentage increase in the impact resistance at ultimate failure was (146 %), (285 %) and (215%) for reinforced ferrocement slabs with one layer of wire mesh and modified with V_f ratios (0.5%), (1.0 %) and (1.5 %) respectively when compared with reference concrete , the percentage increase of the number of blows to cause a first crack was (62.5 %), (350 %) and (262.5 %), while the percentage increase in the impact resistance at ultimate failure was (76 %), (305 %) and (235 %) for reinforced ferrocement slabs with two layers of wire mesh and modified with V_f ratios (0.5 %), (1.0 %) and (1.5 %) respectively when compared with reference concrete, and the percentage increase of number of blows to cause a first crack was (85 %), (320 %) and (290 %), while the percentage increase in the impact resistance at ultimate failure was (76 %), (296 %) and (260 %) for reinforced Ferrocement slabs with three layers of wire mesh and modified with V_f ratios (0.5 %), (1.0 %) and (1.5 %) respectively when compared with reference concrete ,Table 4. For 1.2 m height falling mass, the maximum value of the number of blows to cause a first crack was (106) blows for the specimen reinforced with three layers of wire mesh while the maximum value for the number of blows to cause ultimate failure was (124) blows for the specimen reinforced with three layers of wire mesh, both values were by adding (1.0 %) V_f. The percentage increase of the number of blows to cause first crack were (420 %), (780 %) and (720 %), while the percentage increase in the impact resistance at ultimate failure was (300 %), (513 %) and (475 %) for unreinforced ferrocement slabs with wire mesh with V_f ratios (0.5 %), (1.0 %) and (1.5 %), respectively when compared with reference concrete , the percentage increase of the number of blows to cause first crack was (165 %), (275 %) and (169 %), while the percentage increase in the impact resistance at ultimate failure was (120 %), (245 %) and (165 %) for reinforced ferrocement slabs with one layer of wire mesh and modified with V_f ratios (0.5 %), (1.0 %) and (1.5 %), respectively when compared with reference concrete, the percentage increase of the number of blows to cause first crack was (256 %), (350 %) and (261 %), while the percentage increase in the impact resistance at ultimate failure was (188 %), (284 %) and (220 %) for reinforced ferrocement slabs with two layers of wire mesh and modified with V_f ratios (0.5 %), (1.0%) and (1.5 %), respectively when compared with reference concrete and the percentage increase of the number of blows to cause first crack was (217 %), (361 %) and (300 %), while the percentage increase in the impact resistance at ultimate failure was (186 %), (328 %) and (276 %) for reinforced ferrocement slabs with three layers of wire mesh and modified with V_f ratios (0.5 %), (1.0%) and (1.5 %), respectively when compared with reference concrete ,Table 4. From the figures mentioned, it can be seen that the impact resistance represented by number of blows until failure decreases with the increase in falling mass height. That might be due to an increase in strike force with an increase in falling mass height, which means an increase in the absorbed energy by ferrocement slab body in each strike, this leads to distribution of the total impact energy on the fewer number of blows until failure.

Mode of failure under low velocity impact: Fig. 7. shows the failure of specimens, tested in this work. From these figures, it can be seen that, for slabs used in low velocity impact tests, the waste plastic fiber reinforced ferrocement slabs failed with number of blows more when compared with reference mix and the crack started from center of top face and propagated on length and width of specimens, and specimens failed (ultimate failure) with number of blows more than that in first crack stage. It is obvious from these figures that, the failure of slabs reinforced with two or three layers of wire meshes happened without cracks, or in other words the ball penetrated the slabs without madding any cracks . For impact test in which the height of falling mass equals 2.4 m , the unreinforced slabs with wire mesh reach the ultimate failure with a number of blows near to the number of blows that caused a first crack. For low velocity impact tests with falling mass, failure of unreinforced concrete was more brittle than the waste plastic fiber reinforced ferrocement slabs. The slabs made of reference mixes reach the first crack and ultimate failure at a number of blows less than that of the slabs made of waste plastic fiber reinforced ferrocement slabs. From tables (3 and 4) it can be noticed that, the energy absorbed of slabs increased with increased the volume of fibers and number of wire meshes. We can calculate the total energy by multiply the total blows for slabs until first crack or until failure with the energy of one blow.

CONCLUSIONS

Based on the extensive research work, the following conclusions can be drawn:-

A- The compressive strength of waste plastic fibers reinforced ferrocement had shown a clear decrease in general due to the inclusion of fiber for the reinforced and unreinforced specimens.

B- The flexural strength of waste plastic fibers reinforced ferrocement had shown an increase due to the inclusion of fiber for the reinforced and unreinforced specimens.

C- Dry density of mortar cubes was 2400 kg/m3 at 28 days. Adding waste plastic fibers caused a decrease in the density and the lowest density was 2255 kg/m3 for (Vf = 1.5%).

D- Low velocity impact resistance of waste plastic fiber reinforced ferrocement panels is greater than that of the reference ferrocement panels. The slabs of waste plastic fiber reinforced ferrocement need more blows to cause first crack and ultimate failure compares with references panels. Also the energy absorbed by waste plastic fiber reinforced ferrocement panels increased with increased the volume of fibers and number of wire meshes.

REFERENCES

1.ACI Committee 549, " State–of–the Art Report on Ferrocement," ACI Manual of Concrete Practice, American Concrete Institute, Farmington Hills, MI, 1997.

2.Rathish Kumar P., Oshima T., Mikami Sh., and Yamazaki T.," Ferrocement confinement of plain and reinforced concrete," International Journal of Progress Structural Engineering Material, 2004, pp. 41–51.

3. ACI Committee 549.1–R88, "Guide for the design, construction and repair of ferrocement,". ACI Structural Journal V.85, No.3, 1988, pp.32–51.

4.Balaguru P. ,"Use of ferrocement for confinement of concrete. In: Proceedings of the third international conference on ferrocement. Roorkee, India; 1988, pp.296–305.
5.Rao C.B.K, Rao A.K.," Stress–strain curve in axial compression and Poisson's ratio of ferrocement," Journal of Ferrocement V.16, No.2,1988,pp. 17–28.
6.Singh K.K., Kaushik S.K.," Ferrocement composite columns," Proceedings of the third International conference on ferrocement," Roorkee, India, 1988, pp. 16–25.
7.Ganesan A., Anil J. ,"Strength and behavior of reinforced concrete columns confined by ferrocement," Journal of Ferrocement ,V.23, No.2, 1993, pp.99–108.
8.Al-Hadithi Abdulkader Ismail , Aziz Khalil I. , Al-Dulaimi Mohammed Tarrad N. ,"Some Mechanical Properties of Ferro-Cement Slabs Modified by Polymer," Proceedings of the international conference on green technology & ecosystems for global sustainable development (ICGTEC2012).University of Tuzla, Busnia and Erzegovina; 28th - 30th May, pp.106-115.
9.Kadhum, M. Mansour," Experimental studies to investigate the properties of polystyrene concrete ferrocement plates," Babylon University Journal-Engineering Sciences, V.20, No.4, 2013,pp.1015-1032.
10.Gaylan , A. A.," Behavior of fiber reinforced ferrocement slabs under static and cyclic loadings. Ph.D. Thesis, Building and Construction Eng. Dept., University. of Technology, Baghdad, Iraq . January, 2008.
11.Colin, D. Johnston, " Fiber reinforced cements and concretes," Advances in concrete technology.2001 , 3 – Gordon and Breach Science publishes.
12.Balaguru , P. , Ramakrishnan V. ,"Properties of fiber reinforced concrete :workability , behavior under long – term loading , and air – void characteristics," ACI Materials Journal. V.85, No.3, 1988, pp.189 – 196.
13.Swamy, R.N., Managat S.P., and Rao CVSK, "The mechanism of fiber reinforcement of cement matrices," Detroit ,1974. SP-44, ACI:1-28.
14.Ramakrishnan V.," Materials and properties of fiber reinforced concrete," Proceedings of International symposium on fire reinforced concrete. Madras, India, SERC; 1987, pp.2.3-2.23.
15.Ramesh, K., Seshu, D.R. , and Prabhakar, M. ,"Constitutive behavior of confined fiber reinforced concrete under axial compression," Cement and Concrete Composites J., 2003, No. 25, pp.343-350.
16.Mahasneh, B.Z. ,"The effect of addition of polymeric fiber reinforcement on fire resistant composite concrete material," Journal of Applied Sciences. V.5, No.2, 2005 , pp. 373-379.
17.Bencardino, F., Rizzuti, L., Spadea, G., and Swamy, R.N. ,"Stress-strain behavior of steel fiber reinforced concrete in compression," Journal of materials in civil engineering ASCE March 2008,pp.255.
18.Yew, M.K. , Othman, I., Yew , M.C., Yeo, S.H., and Mahmud, H.B. ," Strength properties of hybrid nylon-steel and polypropylene-steel fiber-reinforced

high strength concrete at low volume fraction," International Journal of the Physical Sciences, V.9, No.9, December 2011, p p. 7584-7588.
19.Satish ,Chandra," Waste materials used In concrete manufacturing". Division of Concrete Structures Chalmers, University of Technology, Goteborg, Sweden,1997.
20.Minghua, Z., Xiumin, F., Rovetta, A., Qichang, H., Vicentini, F., Bingkai, L., Giusti, A., and Yi, L. ,"Municipal solid waste management in Pudong New Area, China," Waste Management Journal, V.2009. No.29, pp.1227–1233.
21.Siddique, R., Khatib, J., and Kaur, I. , "Use of recycled plastic in concrete: a review. Waste Management Journal,". V.2008, No. 28, pp. 1835–1852.
22.Alhozaimy , A.M.. ,"Fiber reinforced concrete using recycled plastic," King Saud University, College Of Engineering, Research Center, July 2006.
23. Al-Hadithi, Abdulkader I. ,"Some Properties of concrete using waste plastic fiber with a very small percentages". The First International Engineering Sciences Conference of Aleppo University(IESC"2008, Aleppo, Syria.2008.
24.Ismail, Z. , Al-Hashmi, E.A. ,"Use of waste plastic in concrete mixture as aggregate replacement," Waste Management Journal, V.2008 ,No.28, pp. 2041-2047.
25.Al-Hadithi. Abdulkader I. ,"Improving impact and mechanical properties of gap-graded concrete by adding waste plastic fibers," International Journal of Civil Engineering and Technology (IJCIET)," India,. V. 4, No. 2; March – April,2013, pp.118-131.
26.Al-Hadithi. Abdulkader I. , Al-Ejbari A.T. , and Jamil, G.S. ,"Behaviour of waste plastic concrete slabs under low velocity impact," Iraqi Journal of Civil Engineering, V.9, No.1, 2013, pp.135-148.
27.Foti, D. ,"Preliminary analysis of concrete reinforced with waste bottles PET fibers," Construction and Building Materials Journal, V.2011, No.25, pp. 1906-1915.
28.Foti, D. ,"Use of recycled waste pet bottles fibers for the reinforcement of concrete," Composite Structures Journal , V.2012 , No.96, pp. 396-404.
29.Iucolano, F., Liguori, B., Caputo, D., Colangelo, F., Cioffi, R., "Recycled plastic aggregate in mortars composition :Effect on physical and mechanical properties," Materials and Design Journal ,“ V. 52,2013, pp.916-922.
30.Iraqi standard specification, No(5). "Portland Cement," 1999.
31.British Standard Institute BSI , "B.S. 12, part 2. Portland Cement" . British Standards Institution, 1971.
32.B.S. 882. , "Aggregates from natural sources for concrete," 1992 British Standards Institution,.
33.Iraqi standard specification,"Water used in concrete," No(1703).1992.
34.ASTM CI92-88., "Standard practice for making and curing test specimens in the laboratory," Annual Book of ASTM Standard, Philadephia, 1988. 04-02. pp.112-118.

35.British Standard Institute BSI, “Method for Determination of Compressive Strength of Concrete Cubes”, B. S. 1881, Part 116, 1983.
36.ASTM 78-1994, “Standard Test Method For Flexure Strength of Concrete {Using Simple Beam with Third-Point Loading},” Annual Book of ASTM Standard, American Society for Testing and Materials, Philadephia, Pennsylvania. Vol.04-02, 1994 .
37.Song, P.S., Wu, J.C,, Hwang, S., and Sheu, B.C. ,” Assessment of statistical variations in impact resistance of high-strength concrete and high-strength steel fiber-reinforced concrete,” Cement and Concrete Research, 2005, Vol.35. pp. 393-399.
38.ACI Committee 544, ”State-of-the-art report on fiber reinforced concrete”. ACI Committee 544 report 544.1R-96. Detroit . 1996. American Concrete Institute.
39.Al-Hadithi, Abdulkader Ismail and Al-Barazanji , S.M.H. ,” Some mechanical properties of polymer modified concrete reinforced with a waste plastic fiber,” Iraqi Journal for Mechanical And Material Engineering, Special Issue for the Papers Presented in 1st Annual Scientific Conference of the College of Engineering 17-18 May 2009, Part (D),pp.653-664.
40.Ohama, Y. , and Sugahara, T. “Impact resistance of steel fiber reinforced polymer concrete,” Proceedings of the the Twenty Fourth Japan Congress on Materials Research. The Society of Material Science, Japan, 1981, pp.254-257.

Table 1-Properties of wire mesh

Diameter of wire mesh (mm)	Yield stress MPa	Failure stress MPa	Deformation %
1.8	443	732	3.18

Table 2-Details of the cement mortar mixes investigation throughout this work.

Symbol	No. of layers reinforced of wire mesh	Cement content for one cubic meter (kg)	Proportion cement: sand (by weight)	Fiber : Mix Ratio % V_f(by volume)	W / C Ratio %	Number of low velocity slabs	Number of high velocity slabs
R1	0	655	1 : 2	0	0.45	2	1
R2	1	655	1 : 2	0	0.45	2	1
R3	2	655	1 : 2	0	0.45	2	1
R4	3	655	1 : 2	0	0.45	2	1
F1R1	0	651.725	1 : 2	0.5%	0.45	2	1
F1R2	1	651.725	1 : 2	0.5%	0.45	2	1
F1R3	2	651.725	1 : 2	0.5%	0.45	2	1
F1R4	3	651.725	1 : 2	0.5%	0.45	2	1
F2R1	0	648.450	1 : 2	1.0%	0.45	2	1

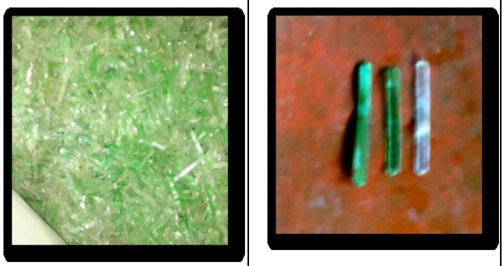
F2R2	1	648.450	1 : 2	1.0%	0.45	2	1
F2R3	2	648.450	1 : 2	1.0%	0.45	2	1
F2R4	3	648.450	1 : 2	1.0%	0.45	2	1
F3R1	0	645.175	1 : 2	1.5%	0.45	2	1
F3R2	1	645.175	1 : 2	1.5%	0.45	2	1
F3R3	2	645.175	1 : 2	1.5%	0.45	2	1
F3R4	3	645.175	1 : 2	1.5%	0.45	2	1

Table 3 - Number of blows that caused first crack, ultimate failure and applied kinetic energy of various concrete slab specimens for 2.4 m height of falling mass.

No. of blows	Number of mesh Layers	(Vol. of fiber within mix) Vf%			
		0%	0.5%	1.0%	1.5%
Number of blows to cause a first crack by falling mass	0	4	16	25	18
	1	10	25	44	34
	2	16	29	72	58
	3	20	37	84	78
Applied kinetic energy N.m (J) to cause first crack by falling mass	0	131.846	527.3856	824.04	593.3088
	1	329.616	824.04	1450.31	1120.694
	2	527.386	955.8864	2373.235	1911.773
	3	659.232	1219.579	2768.774	2571.005
Increase No. of blows and applied kinetic energy over Reference Mix. (%)	0	0	300	525	350
	1	0	150	340	240
	2	0	62.5	350	262.5
	3	0	85	320	290
Number of blows to cause ultimate failure by falling mass	0	6	28	34	22
	1	13	32	50	41
	2	20	37	81	67
	3	25	44	99	90
Applied kinetic energy N.m (J) to cause ultimate failure by falling mass	0	197.77	922.9248	1120.694	725.1552
	1	428.501	1054.771	1648.08	1351.426
	2	659.232	1219.579	2669.89	2208.427
	3	824.04	1450.31	3263.198	2966.544
Increase No. of blows and applied kinetic energy over Reference Mix. (%)	0	0	367	467	266
	1	0	146	285	215
	2	0	76	305	235
	3	0	76	296	260

Table 4- Number of blows that caused first crack, ultimate failure and applied kinetic energy of various concrete slab specimens for 1.2 m height of falling mass

No. of blows	Number of mesh layers	(Vol. of fiber within mix) Vf%			
		0%	0.5%	1.0%	1.5%
Number of blows to cause a first crack by falling mass	0	5	26	44	41
	1	16	42	60	43
	2	18	64	81	65
	3	23	73	106	92
Applied kinetic energy N.m (J) to cause first crack by falling mass	0	82.404	428.500	725.155	675.712
	1	263.6928	692.193	988.848	708.674
	2	296.6544	1054.77	1334.94	1071.25
	3	379.0584	1203.09	1746.96	1516.23
Increase No. of blows and applied kinetic energy over Reference Mix. (%)	0	0	420	780	720
	1	0	165	275	169
	2	0	256	350	261
	3	0	217	361	300
Number of blows to cause ultimate failure by falling mass	0	8	32	49	46
	1	20	44	69	53
	2	25	72	96	80
	3	29	83	124	109
Applied kinetic energy N.m (J) to cause ultimate failure by falling mass	0	131.8464	527.385	807.559	758.116
	1	329.616	725.155	1137.17	873.482
	2	412.02	1186.61	1582.15	1318.46
	3	477.9432	1367.91	2043.62	1796.41
Increase No. of blows and applied kinetic energy over Reference Mix. (%)	0	0	300	513	475
	1	0	120	245	165
	2	0	188	284	220
	3	0	186	328	276



(a) (b)

Fig. 1- Waste plastic fibers

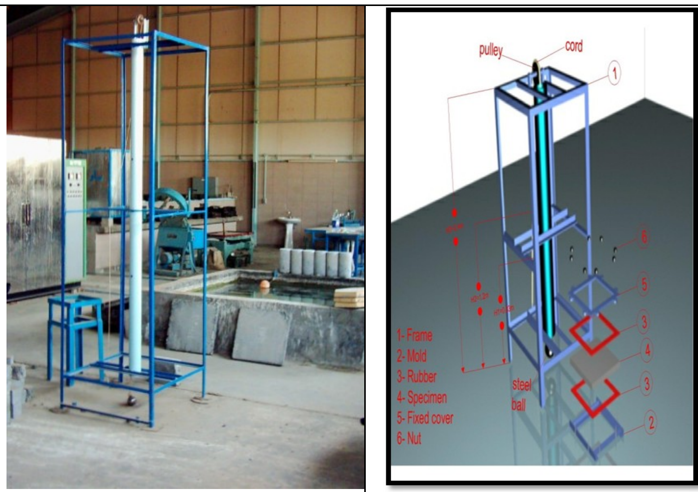


Fig. 2- Rig which is used for low velocity impact test

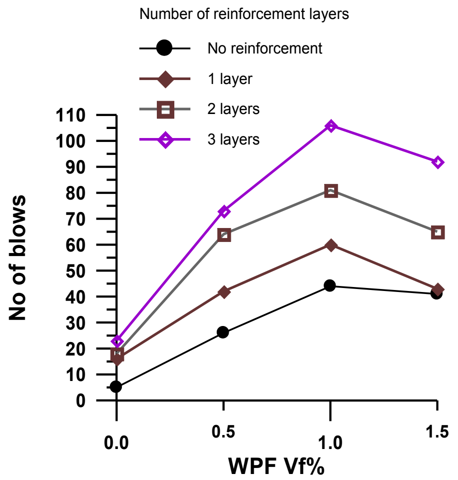


Fig. 3- Relationship between waste plastic fibers volume content ratio and number of blows to cause a first crack for 2.4 m high falling mass .

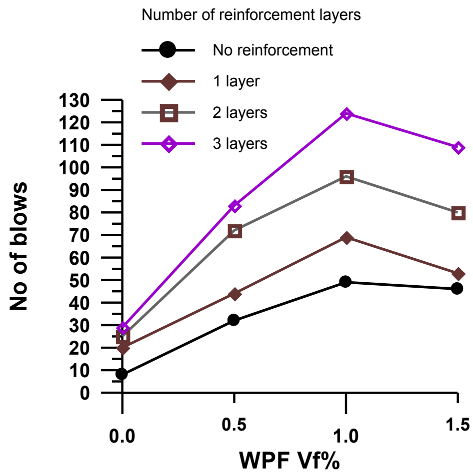


Fig.4- Relationship between waste plastic fibers volume content ratio and number of blows to cause a ultimate failure for 2.4 m high falling mass.

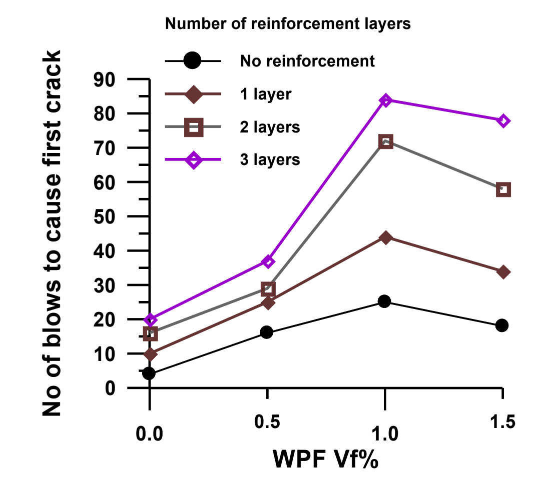


Fig. 5- Relationship between waste plastic fibers volume content ratio and number of blows to cause a first crack for 1.2 m high falling mass.

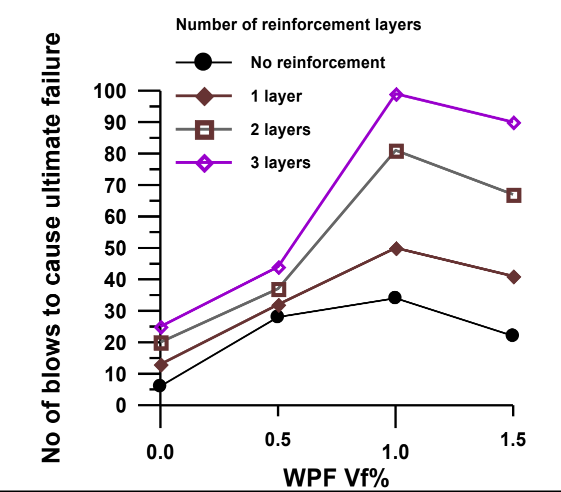


Fig. 6- Relationship between waste plastic fibers volume content ratio and number of blows to cause a ultimate failure for 1.2 m high falling mass.

V_f =0%, h=2.4m, No reinforcement

V_f =0%, h=1.2 m, No reinforcement

V_f =0% , h=2.4m, One Mesh Layer

V_f =0% , h=1.2 m, One Mesh Layer

V_f =0%, h=2.4m,Two Mesh Layers

V_f =0%, h=1.2m, Two Mesh Layers

V_f =0%, h=2.4m, Three Mesh layers

V_f =0%, h=1.2m, Three Mesh layers

Fig. 7- The mode of failure of slabs under low velocity impact

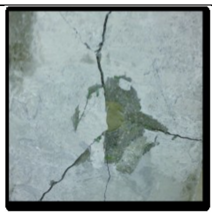
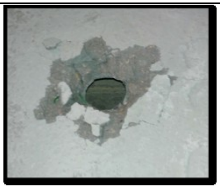
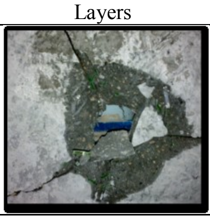
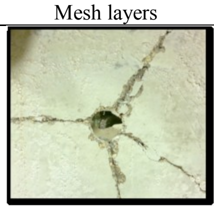
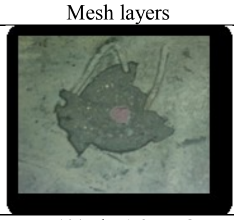
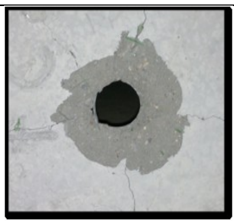
			
V_f =0.5%, h=2.4m, No reinforcement	V_f =0.5%, h=1.2 m, No reinforcement	V_f =0.5% , h=2.4m, One Mesh Layer	V_f =0.5% , h=1.2 m, One Mesh Layer
			
V_f =0.5%, h=2.4m, Two Mesh Layers	V_f =0.5%, h=1.2m, Two Mesh Layers	V_f =0.5%, h=2.4m, Three Mesh layers	V_f =0.5%, h=1.2m, Three Mesh layers
			
V_f =1%, h=2.4m, No reinforcement	V_f =1%, h=1.2 m, No reinforcement	V_f =1% , h=2.4m, One Mesh Layer	V_f =1% , h=1.2 m, One Mesh Layer
			
V_f =1%, h=2.4m, Two Mesh Layers	V_f =1%, h=1.2m, Two Mesh Layers	V_f =1%, h=2.4 m, Three Mesh Layers	V_f =1%, h=1.2m, Three Mesh Layers
			
V_f =1.5%, h=2.4m, No reinforcement	V_f =1.5%, h=1.2 m, No reinforcement	V_f =1.5% , h=2.4m, One Mesh Layer	V_f =1.5% , h=1.2 m, One Mesh Layer

Fig.7- Continued