Using Finely Divided Mineral Admixtures to Improve the Properties of Polypropylene Fiber Reinforced Concrete

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Abstract

Many researchers showed that with increasing polypropylene fibers volume fraction the compressive strength decreases . The main objective of this works was to investigate the influence of two types of mineral admixtures – Rice husk ash (RHA) and Metakaolin (MK) on the properties of polypropylene fibers reinforced concrete .

The results illustrated that the reference concrete with 1.5 % and 2.5 % polypropylene fibers (ppf) showed a significant increase in impact resistance , but also showed reduction in compressive strength.

The results indicated also that the polypropylene fibers reinforced concrete that included 8% Rice husk ash (RHA) and 8% Metakaolin (MK) as a partial replacement by weight of cement showed a significant improvement in all properties , the percentage increase in compressive strength , impact resistance and the reduction in water absorption after 90 – day relative to the concrete without mineral admixture were 13.6% , 19.38 % , 9.0 % respectively for the concrete containing 8% Rice husk ash (RHA) and 2.5 % polypropylene fibers (ppf) , and 14.3 % , 20.31 % , 8.06% respectively with 8% Metakaolin (MK) and 2.5 % polypropylene fibers (ppf)

1-Introduction

Concrete a heavily used construction material. However, it has low tensile strength, low ductility , and low energy absorption. An intrinsic cause of the poor tensile behavior of concrete is its low toughness and the presence of defects[18] .In concrete construction, when cracking occurs at an early age, it can potentially reduce the life time of concrete structures and cause serious durability and serviceability problems. One of the most important causes of early-age cracking is drying shrinkage [14]. Therefore improving concrete toughness and reducing the size and amount of defects in concrete

would lead to better concrete performance. An effective way to improve the toughness of concrete is by adding fibers to the concrete mix during mixing [26]. Fibers are increasingly being added to concrete mixture to enhance the cracking resistance [15].

Fiber reinforced concrete (FRC) is concrete made primarily of hydraulic cement , aggregate and discrete reinforcing fibers . Fibers suitable for reinforcing concrete have been produced from steel , glass and organic polymers (synthetic fibers) such as polypropylene fibers (ppf) [5]

polypropylene fibers (ppf) have been used in concrete due to the unique advantages such as alkaline resistance , relatively high melting point and the low cost of the raw material [9] . Increased impact resistance , failure strain and higher resistance to plastic and drying shrinkage [8]

Numerous investigation [26,5,2,25,23] , have been reported about the behavior of (ppf) on the properties of concrete , the results of these investigation showed that the compressive strength for mixes with pp fibers was lower due to the fiber addition and many researchers concluded that compressive strength decreases with increasing fiber content. However [17] illustrated that polypropylene fibers are not known to increase compressive strength and [21] showed that the compressive strength increased up to 1.5% fiber content there after strength is decreased at 2.0% of fiber content . [22,19] indicated that the addition of ppf to plain concrete increase in compressive strength.

 The use of mineral admixtures in concrete mitigates the heat of hydration , may improve the strength and workability , increases durability , reduces the waste products , and reduces the cost of concrete construction [13] It chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementations properties [24] . The use of Rice husk ash (RHA)and Metakaolin (MK) as a mineral admixture can improve the strength and durability of ppf concrete , reduced heat of hydration and improve the performance of both fresh and hardened properties of concrete.

2-Materials

Cement

Ordinary Portland cement type 1 was used throughout this work .The chemical composition and physical properties are shown in **Table (1) (2)** , it conformed to the Iraqi specification No . 5 / 1984 [28]

Table (1) chemical composition of cement

Oxide composition	Abbreviation	Content	Limits of Iraqi specification No. 5/1984
Lime	CaO	61.5	-
Silica	SiO2	22.1	-
Alumina	Al2O3	4.4	-
Iron Oxide	Fe2O3	2.86	-
Magnesia	MgO	2.5	≤ 5.0 %
Sulfate	SO3	2.6	≤ 2.8 %
Loss on ignition	L.O.I	2.0	≤ 4.0 %
Insoluble residue	I.R	1.4	≤ 1.5 %
Lime saturation factor	L.S.F	0.94	0.66-1.02

Table (2) physical properties of cement

physical properties	Test results	Limits of Iraqi specification No. 5/1984
Specific surface area , Blaine method , m2/Kg	309	≥ 230 m2/Kg
Soundness , Autoclave method	0.20	≤ 0.8%
Setting time , Vicat ,s method Initial setting , hrs : min Final setting , hrs : min	 2 : 10 3 : 40	 ≥ 1 hr ≤ 10 hrs
Compressive strength 3 days , N/mm2 7 days , N/mm2	17.5 27.4	≥ 15 N/mm2 ≥ 23 N/mm2

Fine Aggregate

Natural sand with grading limits in zone 3 was used in this work, **Table(3)** showed the grading of fine aggregate. The specific gravity of fine aggregate is(2.60) It conformed to the Iraqi specification No. 45 / 1984 [29]

Coarse Aggregate

Crushed aggregate was used. The grading of coarse aggregate is shown in **Table(4)** .The specific gravity of coarse aggregate is (2.63)It conformed within the requirement of the Iraqi specification No. 45 / 1984 [29]

High Range Water Reducing Admixture (HRWRA)

To improve the workability of fiber mixes. A sulphonated melamine formaldehyde condensate type F was used throughout this work, it conformed to ASTM C 494-89

polypropylene fibers (ppf)

Polypropylene fibers (ppf) were used in this work with espect ratio L/D of 50 . **Table(5)** indicated the properties of ppf

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Table (3) Grading of fine aggregate

Sieve size (mm)	Cumulative passing (%)	Limits of Iraqi specification No. 45/1984
4.75	100	90 - 100
2.36	92.5	85 - 100
1.18	81.6	75 - 100
0.6	64.1	60 – 79
0.3	20.8	12 – 40
0.15	7.2	0 - 10

Table (4) Grading of coarse aggregate

Sieve size (mm)	Cumulative passing (%)	Limits of Iraqi specification No. 45/1984
14	100	100
10	86.2	85 - 100
5	15.4	0 - 25
2.36	0.8	0 - 5

Table (5) physical properties of Polypropylene fibers (ppf)

physical properties	Test results
Density (Kg/m3)	0.91
Length (mm)	30
Diameter (mm)	0.6
L/D	50
Tensile strength (psi)	5
Melting point (c°)	170

Mineral Admixtures

A) Rice Husk ash (RHA)

Rice Husk ash (RHA) are the shells produced by dehusking process of paddy rice. (RHA) was prepared by burning the rice husk in a controlled temperature furnace in order to get a pozzolanic material . Generally the optimum burning condition was 500^0C for 2 hours [4] . The RHA used in this work conforms to the chemical and physical requirements of ASTM C 618 Class N pozzolan [6] . **Table(6)** showed the chemical analysis of RHA , and **Table(7**) illustrated the results of pozzolanic activity index (P.A.I) according to ASTM C 311-87a [7] as follows :-

$$P.A.I = (A / B) \times 100$$

Where :-

A= Average compressive strength of test mix cubes

B= Average compressive strength of reference mix cubes

Table (6) chemical analysis of Rice Husk ash (RHA) and Metakaolin (MK)

Oxide composition	Oxide Content	
	RHA	MK
SiO_2	86.3	57.5
Al_2O_3	0.25	35.8
Fe_2O_3	0.43	1.87
MgO	1.07	0.09
CaO	1.55	0.81
L.O.I	2.79	1.44

Table (7) Pozzolanic Activity Index (P.A.I) for tested morter

Index	RHA% by weight of cement	MK% by weight of cement	Pozzolanic Activity Index%
M – RHA	8	-	102
M – MK	-	8	110

B) Metakaolin (MK)

Metakaolin (MK) is an aluminosilicate pozzolan , prepared by heating bad – crystallized and fine grain size of kaolin clay in the temperature at 700^0C [3]. The MK used in this work conforms to the chemical and physical requirements of ASTM C_{618} Class N pozzolan [6] **Table (6**) showed the chemical analysis of MK , and **Table(7)** illustrated the results of pozzolanic activity index (P.A.I) according to ASTM C 311-87a [7]

3-Tests

Workability

Based on B.S. 1881 : part 104 [10] . the workability was determined by vebe – time test.

Compressive Strength

The compressive strength of 100 mm cube concrete specimens was measured in accordance with B.S. 1881 : part 116 [11] .

Impact Resistance

According to ACI committee 544 on fiber reinforced concrete [1] , the Impact resistance was measured in this study .

Absorption

Absorption test was performed according to B.S. 1881 : part 122 [12] .

4- Mix Design

Concrete with (cement : sand : gravel) ratio of (1 : 1.34: 1.45) were prepared. The design was made accordance with Building Research Establishment Method .

5- Results and Discussion

Compressive Strength

Table (8) and **Fig. (1) , (2)** , illustrated the values of compressive strength for various types of concrete .

According to the results , by increasing the amount of ppf in
matrix , the compressive strength of specimens reduced, the percentage decrease in compressive strength after 28-day with 1.5%ppf and 2.5%ppf were 4.96% , 9.93% respectively , and after 90-day with 1.5%ppf and 2.5%pf were 3.08% , 8.02% respectively . The compressive strength improved by addition 8%of RHA [27] and 8% of MK [3] (by weight of cement) due to high pozzolanic reactivity of RHA and MK which is react with calcium hydroxide producing additional gel and reduces the amount of voids in the matrix . Accordingly , reducing the absorption of the matrix phase and reducing the microcracks in the transition zone [20] .

RHA and MK concretes showed improvement in compressive strength over those of ppf concrete without RHA and MK . The percentage increase in compressive strength after 90-day relative to 1.5%pf were 15.9% , 13.4% , and to 2.5%ppf were 13.6% , 14.3% respectively

Table (8) Compressive strength of various types of concrete at different ages

Mix description	Compressive Strength (N / mm^2)			
	28 – day	Rate of increase compared with Ref. concrete %	90 - day	Rate of increase compared with Ref. concrete %
Reference (Ref.)	42.3	---	48.6	---
Ref.+ +1.5% ppf	40.2	- 4.96	47.1	- 3.08
Ref.+ 1.5% ppf + 8% RHA	42.8	1.18	54.6	12.34
Ref.+ 1.5% ppf + 8% MK	41.9	- 0.94	53.4	9.87
Ref.+ 2.5% ppf	38.1	- 9.93	44.7	- 8.02
Ref.+ 2.5% ppf + 8% RHA	40.5	- 4.26	50.8	4.53
Ref.+ 2.5% ppf + 8% MK	40.0	- 5.44	51.1	5.14

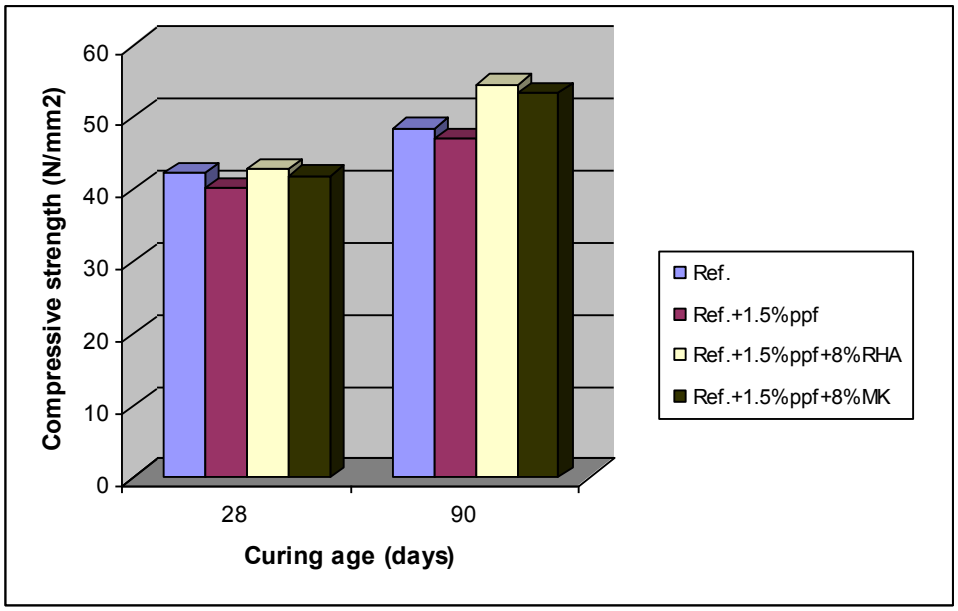

Fig. (1) Compressive strength of concretes with 1.5% ppf cured at different ages .

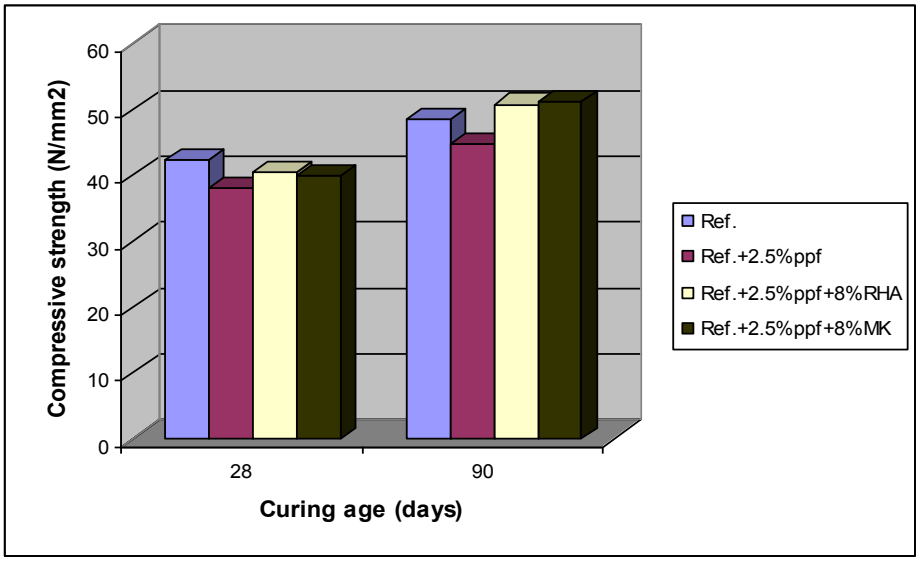

Fig. (2) Compressive strength of concretes with 2.5% ppf cured at different ages .

6-Absorption

The water absorption test results for all types of concrete are presented in **Table(9)**. Results showed that the water absorption of ppf in concrete is increased , the percentage increases in water absorption after 90-day compared with reference concrete were 4.29%,7.14% for 1.5% , 2.5% ppf respectively .

Results also showed that the use of mineral admixture improve the

water absorption, the percentage reduction in water absorption after 90-day relative to that without mineral admixture were 8.78 % , 9.0 % for 1.5% , 2.5% ppf concrete with 8% RHA replacement by weight of cement and 10.73 % , 8.06 % for 1.5% , 2.5% ppf concrete with 8% MK replacement by weight of cement , this may be attributed to pozzolanic activity . The RHA and MK plays the roles of fillers , due to its fine particles size , and pozzolanic material due to its ability to react with free lime , leading to the formation of hydro-silicates

Table (9) Absorption of various types of concrete

Mix description	Absorption %	
	28 – day	90 - day
Reference (Ref.)	2.10	1.95
Ref.+ +1.5% ppf	2.19	2.05
Ref.+ 1.5% ppf + 8% RHA	2.12	1.87
Ref.+ 1.5% ppf + 8% MK	2.14	1.83
Ref.+ 2.5% ppf	2.25	2.11
Ref.+ 2.5% ppf + 8% RHA	2.20	1.92
Ref.+ 2.5% ppf + 8% MK	2.22	1.94

7- Conclusions

1) The compressive strength decreases with increasing fiber content .The percentage decrease in compressive strength after 90-day compared with reference concrete were 3.08% , 8.02% for 1.5% ppf , 2.5% ppf respectively .

2) The addition of ppf to the reference concrete increased the water absorption . The percentage increase in absorption after 90-day compared with reference concrete were 5.13% , 8.21% for 1.5% ppf , 2.5% ppf respectively .

3) Impact resistance improved due to the addition of ppf ..

4) The use of mineral admixtures (RHA and MK) as a partial replacement by weight of cement improve the properties of concrete, increases compressive strength , impact resistance and enhance water absorption .

RHA and MK concretes showed improvement in compressive strength over those of ppf concrete without RHA and MK . The percentage increase in compressive strength after 90-day relative to 1.5%ppf were 15.9% , 13.4%, and to 2.5% ppf were 13.6 % , 14.3% respectively, and the percentage increase in impact resistance after 90-day relative to 2.5% ppf were 19.38% , 20.31% respectively

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أستخدام المضافات المعدنية الدقيقة التجزئة لتحسين خواص الخرسانة المسلحة بألياف البولي بروبلين

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الخلاصة

وضح الكثير من الباحثين أنه مع زيادة نسبة الياف البولي بروبلين , أن مقاومة الانضغاط تقل . ان الهدف الأساسي من هذا البحث هو دراسة تأثير نوعين من المضافات المعدنية وهي رماد قشور الرز والميتاكاؤلين على خواص الخرسانة المسلحة بألياف البولي بروبلين .

بينت النتائج ان الخرسانة المسلحة بنسبة 1.5٪ و 2.5٪ من الياف البولي بروبلن تبدي زيادة ملحوظة من مقاومة الصدم ولكن ايضا بينت انخفاض في مقاومة الانضغاط .

كما بينت النتائج ايضا ان الخرسانة المسلحة بألياف البولي بروبلين الحاوية على 8٪ رماد قشور الرز و 8٪ ميتاكاؤلين كأستبدال جزئي من وزن السمنت تبدي تحسنا ملحوظا في جميع الخواص .أن النسبة المئوية للزيادة في مقاومة الانضغاط , مقاومة الصدم والانخفاض في الامتصاص بعد عمر 90 يوم مقارنة مع الخرسانة بدون المضافات المعدنية دقيقة التجزئة كانت 13.6٪ , 19.38 ٪ , 9.0٪ على التوالي للخرسانة الحاوية على 8٪ رماد قشور الرز و 2.5٪ الياف البولي بروبلين و 14.3٪ , 20.31٪ , 8.06٪ على التوالي للخرسانة الحاوية على 8٪ ميتاكاؤلين و 2.5٪ الياف البولي بروبلين.

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