SOME PROPERTIES OF FIBER REINFORCED NO FINE CONCRETE

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ABSTRACT

This work focus on studying the mechanical characteristics of polypropylene and carbon fiber reinforced no fine aggregate concrete, containing different percentages of fiber. This work was carried out using several tests. These tests were workability fresh and hardened density, compressive strength, splitting tensile strength and modulus of rupture. Tests were performed for specimens at ages of (7, 28) days. The test results indicated that the inclusion of fiber to the pervious concrete mixes did not affect the compressive strength significantly, while the splitting tensile strength and the modulus of rupture were improved significantly. Test results indicated that, the modulus of rupture of (5%) carbon fiber pervious concrete specimens are three times that of the control specimens, while the modulus of rupture of (5%) polypropylene fiber pervious concrete specimens are two times that of the control specimens. The percentage increase in tensile strength for polypropylene mixes containing fiber by volume fraction of (1%, 3%, 5%) were (93%, 101% and 129%) respectively and the percentage increase in tensile strength for carbon mixes containing fiber by volume fraction of (1%, 3%, 5%) were (170%, 177% and 220%) respectively.

KEYWORDS: No fine concrete, Carbon fiber, Polypropylene fiber, Flexural strength.

بعض خواص الخرسانه الخاليه من الرمل والمسلحه بالالياف

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الموجز

إن هذا البحث يركز على دراسة الخواص الميكانيكية للخرسانة الخالية من الركام الناعم و المسلحة بألياف البولي بروبلين وألياف الكربون والتي تحتوي على نسب مختلفة من هذه الألياف. هذا البحث قد تم انجازه من خلال إجراء عدة فحوص وهذه الفحوص كانت كالأتي : قابلية التشغيل وكثافة الخرسانة المتصلبة ومقاومة الانضغاط ومقاومة شد الانشطار ومعامل الكسر وقد تم أجراء هذه الفحوص على النماذج بعمر معالجة (7 و 28) يوم . لقد بينت نتائج الفحوص إن إضافة الألياف إلى الخرسانة الخالية من الركام الناعم لم يوثر بشكل كبير على مقاومة الانضغاط بينما تحسنت كل من مقاومة شد الانشطار ومعامل الكسر بشكل ملحوظ. لقد أشرت النتائج لنسبة (5%) من الألياف (وهي أعلى نسبة) لكل من البولي بروبلين والكربون أن معامل الكسر قد ازداد بثلاث مرات في حالة ألياف الكربون ومرتين في حالة ألياف البولي بروبلين عن قيمة معمل

الكسر في نماذج السيطرة. إن نسب الزيادة التي تمت ملاحظتها في مقاومة الشد في حالة ألياف البولي بروبلين لنسبة ألياف (1%، 3% و5%) كانت (93%، 101% و129%) على التوالي. أما بالنسبة للزيادة التي تمت ملاحظتها في مقاومة الشد في حالة ألياف الكربون لنسبة ألياف (1%، 3% و5%) كانت (93%، 101% و129%) على التوالي

1. INTRODUCTION

No-fines concrete (NFC) is an open textured cellular concrete and it's a type of light weight concrete ,obtained by eliminating either fines or sand from the normal concrete mix. The alleged advantages of this type of light weight porous concrete include its lower cement content (resulting in lower cost), lower density, lower thermal conductivity, no segregation and, better insulating characteristics, than conventional concrete. A limited number of researches have been carried out to investigate the mechanical properties of fiber reinforced no fine concrete (NFC). However there have been many works on the mechanical characteristics of fiber reinforced normal concrete.

No-fines concrete consists solely of normal Portland cement, water and coarse aggregate. The compressive strength of no-fines concrete is considerably lower than that of conventional Portland cement concrete and varies between (4 to 25) MPa [1]. The ratio of modulus of rupture to compressive strength expressed as a percentage varies between 10.8 and 31.0 percent [2]. The principal advantages claimed for no-fines concrete are economy in materials, somewhat higher thermal insulating values, lower shrinkage, and lower unit weight. The major disadvantages are its low compressive, flexural, and bond strength, and higher permeability. The principal applications for no-fines concrete are for load-bearing cast-in-place external walls of single story and multistory housing, small retaining walls, and as a dam proofing sub-base material for concrete floors cat on grade.

Fiber reinforced No Fine Concrete (NFC) has a little application in Iraq. However, light weight carbon fiber reinforced concrete with micro balloons as aggregate has been successfully used in the construction of AL-Shaheed monument in Iraq [3].

The Density of NFC depends on the properties and proportions of the materials used. Also it depends of the compaction procedure used in placement; generally the density ranges in1600-2000 Kg/m^3 [4]. The tensile and flexural strength is increases with increasing fiber content (2 to 10%) by volume. The handling and the fabrication create some problems at volume fraction above 10% [5].

2. EXPERIMENTAL PROGRAM

Ordinary Portland Cement and crashed coarse aggregate of (14 mm) MAS was used to produce structural no fine concrete, carbon and polypropylene fibers were also used in this study with different volumetric percentages to improve the flexural strength of no fine aggregate concrete.

3. MATERIALS

3.1 Cement

Ordinary Portland cement (Type I) was used in all mixes throughout this investigation. It was stored in air – tight plastic containers to avoid exposure to atmospheric conditions. The percentage oxide composition indicated that the adopted cement conforms to the Iraqi specification No. 5/1984 [6], **Table 1 and 2** shows the physical and chemical properties of OPC.

3.2 Coarse Aggregate

Crushed gravel of two different maximum aggregate sizes (MAS) (10) mm from Wasit, Badra region is used. **Table 3** shows the grading of these aggregate, which conforms to the Iraqi specification No. 45/1984[7]. The specific gravity, sulfate content and absorption of coarse aggregate are illustrated in **Table 4**.

3.3 Carbon Fiber

The properties of carbon fibers, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in civil engineering and other fields. However, they are relatively expensive when compared to similar fibers, such as glass fibers or polypropylene fibers. **Table 5** shows the general properties of the used carbon fiber.

3.4 Polypropylene Fiber

The properties of polypropylene fibers, such as fiber shape and dimensions, tensile strength, density, Elastic modulus and elongation are illustrated in **Table 6**.

4. CONCRETE MIXES

Concrete mixes with no fine aggregate as a type of light weight concrete should have a dry density less than (2000 kg/m³) and a compressive strength great than (15 MPa) to produce structural concrete. These mixes were obtained by several trial mixes. The mix proportions of all concrete mixes are shown in **Table 7.**

5. MIXING, CASTING AND CURING OF SAMPLES

All concrete samples (cubes, cylinders and prisms) are casted in steel molds. They were cleaned and oiled before casting. The fresh concrete was placed inside the molds with approximately three equal layers and compacted by means of vibrating table. Care was taken to avoid segregation of mixes as shown in **Plate 1**. After the top layer had been compacted, it was smoothed and then the mold covered with wetted gunny sheets for 24 hours to prevent evaporation of water so as to avoid the plastic shrinkage cracks as shown in **Plate 2**. After 24 hours the specimens were demolded and completely covered with wetted gunny sheets until the day of testing.

6. TESTING PROGRAM

6.1 Unit Weight

The unit weight of hardened concrete were measured according to ASTM C567 [8] specifications respectively.

6.2 Compressive Strength

Compressive strength tests were conducted using (150) mm cubes using an electrical testing machine with a capacity of (2000 KN) at loading rate of (15 MPa) per minute. This test was determined according to B.S. 1881: part 116: 1984[9].The average of three cubes was adopted for each test. The test was conducted at ages of (7 and 28) days as shown in **Plate 3.**

6.3 Splitting Tensile Strength

Splitting tensile strength test was performed according to ASTM C496/C496 M-04 [10] using of (150× 300) mm cylinder. The test was conducted at age of (7 and 28) days. The average splitting tensile strength of three cylinders was adopted, as shown in **Plate 4.**

6.4 Modulus of Rupture

Modulus of rupture of concrete was measured on (100 ×100× 500) mm specimens according to ASTM C78-02[11]. The prisms were subjected to two- point loading. Specimens were tested at age of (7 and 28) days as shown in **Plate 5**.

7. RESULTS AND DISCUSSIONS

7.1 Unit Weight

The 7 and 28 day air dry density of all types of concrete mixtures is presented in **Table 8**. Results show that the 7 and 28 day air dry densities of (NFC) mixes produced from local naturally aggregate are conformed to the requirement of ACI 213-R-87. For structural pervious concrete, the air dry densities should be ranged between (1821-1854) Kg/m^3, however all concrete mixes conform to the requirements of (LWC) according to ACI limits the maximum density to 2000 Kg/m^3. Results show that (NFC) mixes without fibers have higher density than fiber reinforced (NFC) mixes containing polypropylene and carbon.

7.2 Compressive Strength

The compressive strength development for all types of mixes is presented in **Figure 1**. Test results illustrate that in general, reference pervious concrete and polypropylene and carbon fiber reinforced pervious concrete specimens exhibited continuous development in strength up to 7 and 28 days of curing. There is a considerable improvement in strength for mixes containing fibers. There was a slight increase in the compressive strength with increasing the fiber volume fraction, unless the fiber volume is so high leading the air voids content to become excessively high. The air voids tends to have a negative effect on the compressive strength.

7.3 Splitting Tensile Strength

Results of splitting tensile strength of various types of reinforced fiber concrete mixes cured with per lab sheets up to 7 and 28 days are demonstrated in **Figure 2**. The incorporation of polypropylene and carbon fiber leads to higher splitting tensile strength compared to their corresponding reference concrete. The tensile strength of the fiber concrete mixes increases with the increase of fiber volume content. This is due to the nature of binding effect of fiber available in concrete matrix. The control batch specimens containing no fiber failed suddenly once the concrete cracked, while the fiber reinforced concrete specimens were still intact together. This shows that the fiber reinforced pervious concrete has the ability to absorb energy in the post- cracking state. The comparison of percentage difference in splitting tensile strength for both polypropylene and carbon fiber reinforced pervious concrete to its control batch is presented below, for example the percentage increase in tensile strength for polypropylene mixes containing fiber by volume fraction of (1%, 3%, 5%) were (93%, 101% and 129%) respectively and the percentage increase in tensile strength for carbon mixes containing fiber by volume fraction of (1%, 3%, 5%) were (170%, 177% and 220%) respectively.

7.4 Flexural Strength

The influence of fiber content on the modulus of rupture for all types of fiber reinforced pervious concrete specimens is presented in **Figure 3**. Results demonstrate that all concrete specimens exhibited considerable increase in flexural strength with increasing fiber content.

The modulus of rupture trend for carbon fiber varies as the volume fraction of fiber is increased. It is found that, the modulus of rupture increases as the fiber volume fraction is increased. The concrete specimens containing no carbon fibers are cracked and failed in a brittle manner when strain in concrete reached its ultimate value. However, fiber reinforced concrete also cracked at ultimate strain, but the section is still capable to carry the load well after the initiation of the first crack .Test results indicated that, the modulus of rupture of (5%) carbon fiber pervious concrete specimens are three times that of the control specimens, while the modulus of rupture of (5%) polypropylene fiber pervious concrete specimens are two times that of the control specimens.

8. CONCLUSIONS

On the basis of seven mixes described in the text, using three variables: two types of fiber (polypropylene and carbon), three different percentages for each of fiber (1, 3 and 5 %), and these mixes are tested in compressive, flexural and splitting tensile strength at age of 7 and 28 days, main conclusions can be summarized, as follows:

8.1 Density

Results show that the pervious concrete mixes without fibers have higher density than fiber reinforced pervious concrete mixes containing polypropylene and carbon. However, the air dry densities should be ranged between (1821 - 1854) kg**.**

8.2 Compressive Strength

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8.3 Flexural Strength

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8.4 Splitting Tensile Strength

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9. RECOMMENDATIONS FOR FUTURE WORKS

The work carried out in this work can be considered as a key for further work such as:

1. Studying the mechanical properties of polypropylene and carbon fiber with light weight aggregate concrete.
2. Studying the durability of fiber reinforced no fine aggregate concrete.
3. Studying the effect of addition pozolanic materials on the properties of no fine aggregate concrete.

10. REFERENCES

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Table 1 Chemical Composition of Cement

Compound composition (Oxides)	Chemical composition	Percentage by weight	Limits of IQS 5:1984[7]
Calcium oxide	CaO	62.98	--
Silicon dioxide	SiO2	21.45	--
Iron oxide	Fe_2O_3	3.64	--
Aluminum oxide	Al_2O_3	5.63	--
Magnesium oxide	MgO	2.39	<5
Sulphur trioxide	SO_3	2.57	<2.8
Lime saturation factor	L.S.F	0.73	0.66 – 1.02
Loss on Ignition	L.O.I	2.19	<4
Insoluble residue	I.R	0.4	<1.5
Tricalicum silicate	C_3S	42.94	--
Dicalicum silicate	C_2S	29.18	--
Tricalicium Aluminates	C_3A	8.76	--
Tetracalicum aluminates ferrite	C_4AF	11.06	--

Table 2 Physical Properties of Cement

Properties	Test results	IQS 5: 1984 criteria(7)
Fineness using Blaine air permeability apparatus (m^2/kg)	464	>230
Setting time using Vicat's Method Initial (hrs:min) Final (hrs: min)	 1:45 3:45	 >45 min <10 hrs
Soundness using Autoclave Method	0.19%	<0.80%
Compressive strength 3 day 7 day 28 day*	 26.7 38.9 45.6	 >15 >23 -----

* The 28-day compressive strength is now a compulsory test in most international standards.

Table 3 Grading of Coarse Aggregate of MAS (10) mm

Sieve size (mm)	% passing by weight	Limits of the Iraqi specification No. 45/1984(8)
14	100	100
10	93	85-100
5	22	0-25
2.36	5	0-5

Table 4 Other Properties of Coarse Aggregate of MAS (10) mm

Physical properties	Test results	Limits of the Iraqi specification No. 45/1984(8)
Specific gravity	2.55	--
Sulfate content	0.06%	≤ 0.1%
absorption	1.15%	--

Table 6 Physical Properties of Carbon Fiber*

Property	Value
Nominal diameter (mm)	0.13
Tensile strength (MPa)	4300
Fiber Length (mm)	10
Density (g/cm^3)	1.76
Elastic modulus (GPa)	238
Elongation (%)	1.8

* Provided by the Manufacturer

Table 7 Characteristics of Polypropylene Fiber*

Properties	Thick fiber	Fine fiber
Nominal diameter (mm)	0.98	0.022
Tensile strength (MPa)	240	400
Fiber Length (mm)	10	10
Density (g/cm^3)	0.88-0.92	0.91
Elastic modulus (MPa)	5100	8500
Elongation (%)	24.4	12
Shape	Wavy	Flat

* Provided by the Manufacturer

Table 8 Unit Weight of All Mixes.

Mix Designation	% of fiber by volume	w/c ratio by wt.	Unit weight Air dry Density (28 days) kg/m³
NPC	0	0.3	1890
PFC1	1	0.3	1848
PFC3	3	0.3	1833
PFC5	5	0.3	1821
CFC1	1	0.3	1854
CFC3	3	0.3	1846
CFC5	5	0.3	1830

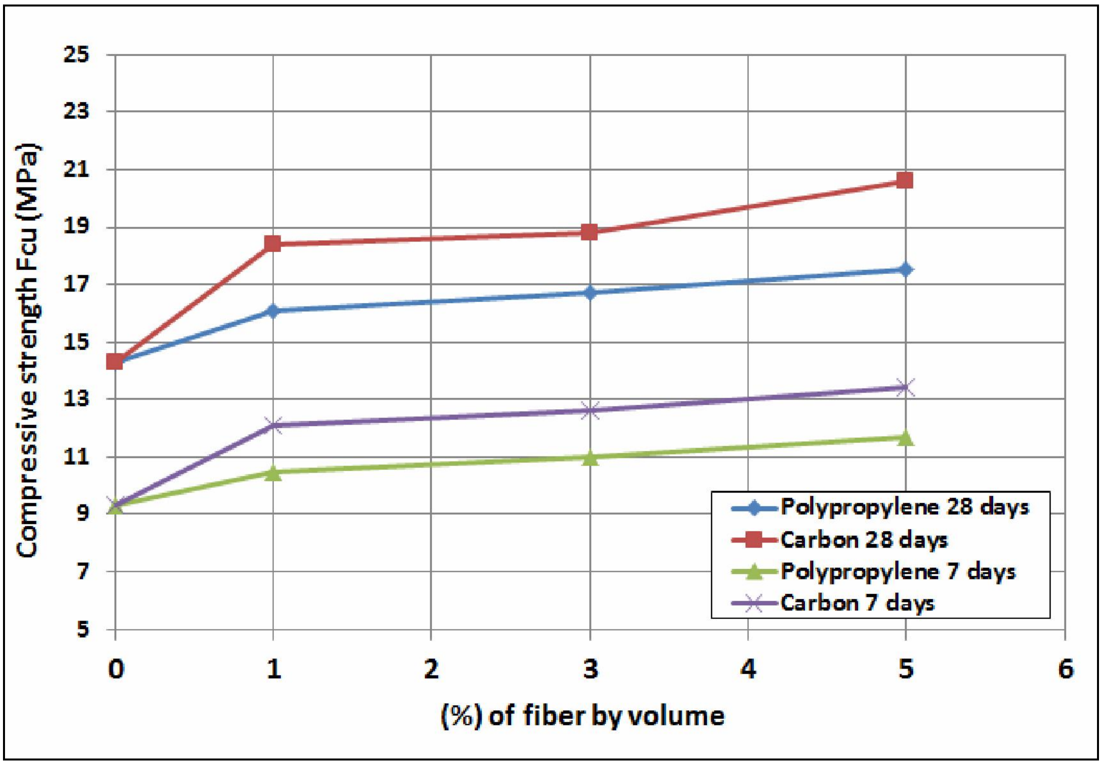

Figure 1 Relationship between Compressive Strength and Percent of fiber by volume.

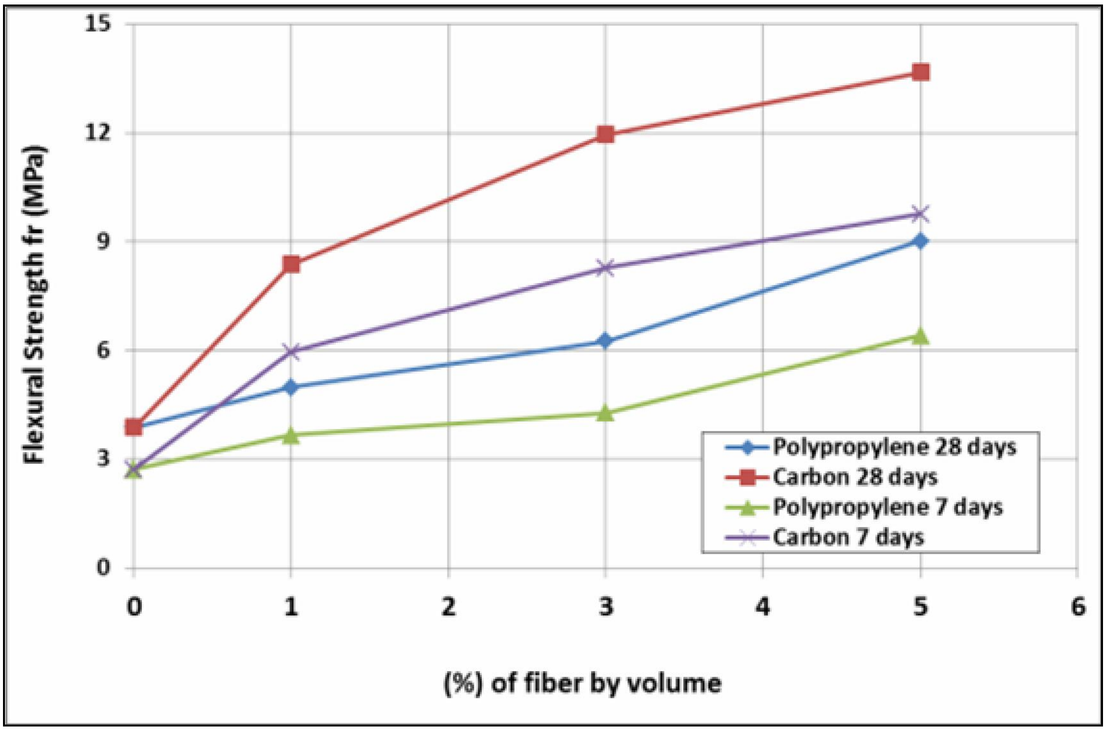

Figure 2 Relationship between Flexural Strength and Percent of fiber by volume

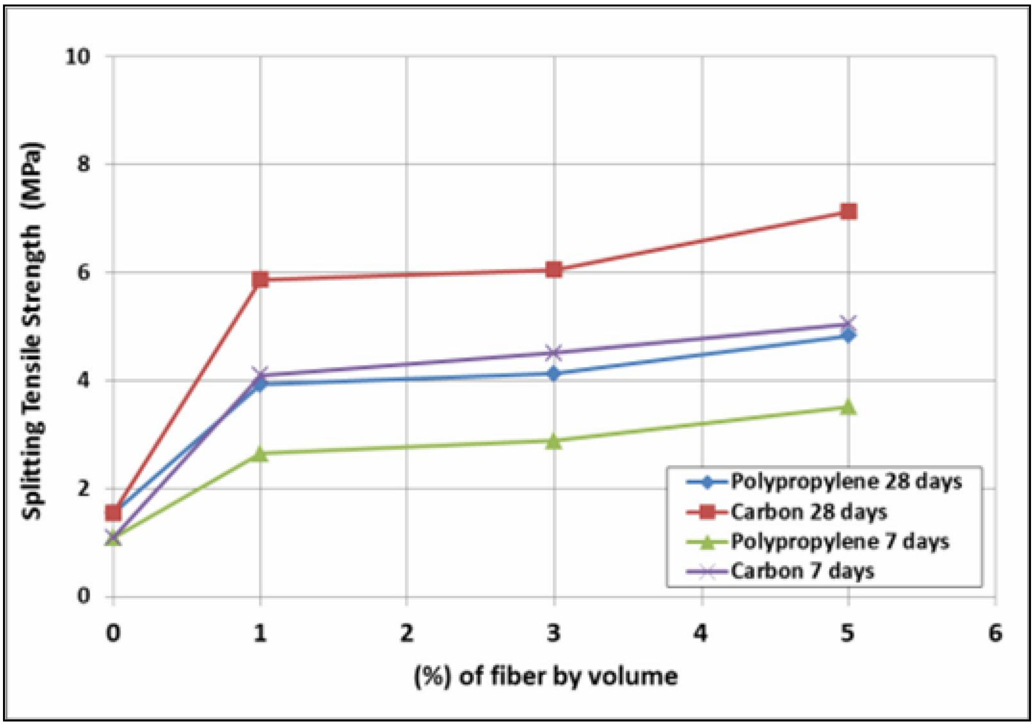

Figure 3 Relationship between Splitting Tensile Strength and Percent of fiber by volume

Plate 1 No Fine Concrete Mixture.

Plate 2 Curing of Concrete Samples with Wetted Gunny Sheets

Plate 3 Compressive Strength Test Machine

Plate 4 Splitting Tensile Strength Test Machine

Plate 5 Flexural Strength Test Machine