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Strength Prediction of Polypropylene Fiber Reinforced Concrete

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Abstract

The main purpose of this investigation is to study the effects of polypropylene fiber on the compressive and flexural strength of normal weight concrete. Four mixes used polypropylene fiber weight with 0.4, 0.8, 1.0 and 1.5% of cement content. To provide a basis for comparison, reference specimens were cast without polypropylene fiber. The test results showed that the increase of mechanical properties (compressive and flexural strength) resulting from added of polypropylene fiber was relatively high. The increase was about 64 percent for compressive strength, while, in flexural strength was about 55.5 percent.

Keywords: polypropylene fiber, strength of concrete, fiber reinforced concrete.

مقاومه الخرسانة المسلحة بألياف البولي بروبلين

الخلاصة

ان الهدف الرئيسي من البحث هو دراسة تاثير الياف البولي بروبلين على مقاومة الانضغاط ومقاومة الانحناء للخلطات الخرسانية. استخدمت نسب وزنية من الياف البولي بروبلين بمقدار 0.4، 0.8، 1.0 و1.5% من المحتوى الوزني للاسمنت. استخدمت خلطات خالية من الياف البولي بروبلين وذلك لغرض استخدامها كأساس للمقارنة. أظهرت نتائج الدراسة بان اضافة الياف البولي بروبلين سبب زيادة في الخواص الميكانيكية (مقاومة الانضغاط ومقاومة الانحناء) للخلطات الخرسانية، حيث كانت الزيادة في مقاومة الانضغاط بمقدار 64%، بينما في مقاومة الانحناء كانت 55%.

1. Introduction

Concrete is widely used in structural engineering with its high compressive strength, low cost and abundant raw material. But common concrete has some shortcomings, for example, low tensile and flexural strength, poor toughness, high brittleness, and so on that restrict its application. To overcome these deficiencies, additional materials are added to improve the performance of concrete. Fiber reinforced concrete is a composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural tensile strength, permeability …and so on. Short fibers have been known and used for centuries to reinforced brittle material like cement or masonry bricks. At that time, fibers were

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natural fibers, such as horse hair, straw, etc. Now, days numerous fiber types are available for commercial uses, the basic types begin steel, glass, synthetic materials (polypropylene, carbon, nylon, etc.) and some natural fibers. Extensive research on fiber reinforced began in 1960[1] and since then a substation amount of researches development, applications and commercialization have occurred[2].

Wu 2002[3], investigated the strength and deformation characteristics of polypropylene fiber reinforced concrete (PFRC) beams. Two kinds of polypropylene fibers with different fiber contents (0.2%, 0.5%, l.0% and 1.5%) by volume were used in the beam. It was found that the strength of the reinforced concrete beams was significantly increased, the flexural toughness was also improved, compared to those unreinforced concrete beams.

Sukontasukkul 2004[4] , used two different methods (ASTM C1018 and JSCE SF-4) measure the toughness of steel and polypropylene fiber reinforced concrete subjected to bending. Results indicated that in the JSCE method, the information obtained by only one specified deflection toughness seemed to be insufficient in reflecting the characteristics of the load-deflection curves of both fiber reinforced concrete. On the other hand, in the ASTM method, the obtained information using the four toughness values at different deflections appeared to better clarify the characteristics of both fiber reinforced concrete.

Ali, and Mahoutian 2006[5], investigated the effects of steel fibers and polypropylene (PP) fibers on the splitting tensile, compressive strength stress–strain relationship (stiffness) and energy absorption capacities (toughness) of concretes. Steel or polypropylene fibers are used to enhance the ductility/toughness of the hardened concrete. Concrete mixtures comprised a concrete mix, prepared without any fibers, and concrete mixes reinforced with either or both steel fibers and polypropylene (PP) fibers. Obtained results show that polypropylene (PP) fibers reinforced LWAC has high compressive and tensile strength.

Polypropylene fiber is a synthetic fiber with low density, fine diameter and low modulus of elasticity. It has some special characteristics such as high strength, ductility and durability, abundant resources, low cost, and easily physical and chemical reformations according to certain demands. Thus it can be widely utilized in the field of concrete products[6]. This study will discuss the compressive and flexural strength of polypropylene fiber reinforced concrete beams. This study was performed by test cube specimens and two point load beam.

2 Aim of Study

The aim of this investigation is to study the effect of polypropylene fiber on the compressive and flexural strength of normal weight concrete.

3 Materials and Experimental Details

The experimental investigation was carried out in the Construction Materials Laboratory of the collage of Engineering University of Basrah.

Concrete mixes containing ordinary Portland cement, washed sand, crushed coarse aggregate, water, admixtures and different percentage of polypropylene fiber content were studied.

The used ordinary Portland cement satisfies the ASTM C 150[7] requirements. Locally washed marine sand was used, which had specific gravity of 2.66 and its grading fell within ASTM C33/86[8]. Crushed coarse aggregate had specific gravity of 2.70. The sieve analysis of coarse aggregate is carried out according to ASTM C33/86. The fibrillated polypropylene fiber was used, the properties of this fiber are illustrated in Table (1).

Five identical concrete mixes having different percentage of fiber content as given in Table (2) were used in this investigation. The same mix, which is obtained according to BS 5328: part 2: 1997[9], was used through the all investigation. The mix properties by dry weight was 1 cement : 1.5 sand : 2.25 gravel and water cement ratio (W/C) was 45%.

4 Preparation of test specimens

Aggregate and cement were first mixed, and water was progressively added until a homogeneous concrete was obtained. Then, the fibers were added, and concrete was mixed for at least 3 minutes in order to allow a sufficient time for fiber even distribution in the mixture. For each mixture six concrete cubes with dimensions of 100x100x100 mm and three beams with dimensions 100 x100x100 mm were cast into molds consolidated by vibration to decrease the amount of air bubbles. The specimens were remodeled after 24 hour and then placed in curing tank under laboratory conditions for 14 days for compressive concrete strength at age 14 days and 28 days for compressive strength of concrete and flexural strength at age 28 days.

5 Test Methods

The compressive strength test was carried out on 100x100x100 mm cube specimens and determined according to BS 1881 part 116 [10]. The cubes were loaded in a compression testing machine at rate of 0.3 MPa/s until failure.

The flexural strength test were conducted on 100x100x500 mm prismatic beam specimens under two point loading, and determined according to BS 1881 part 117 [11]. The beam was loaded gradually to increase deflection at constant rate.

Torsee's universal testing machine with capacity of 2000 kN was used to apply the load. During test, the beam specimens were placed on a simple support with a clear span of 420 mm, and then subjected to a two point loading, Fig.(1).

6 Results and Discussion

Results of compressive strength after 14 and 28 days and flexural strength after 28 days of water curing for mixes are shown in Table 3 and discussed in the following section separately.

7 Compressive Strength

Compressive strength values obtained after 14 and 28 days are summarized in Fig.(2). Figure 2 shows that the 28 days compressive strength for fibrous concrete increase from

39 MPa for 0.0 % fiber weight content to 43.3, 48.5, 57.0, and 61 MPa for 0.4%, 0.8%, 1.0%, and 1.5% fiber weight contents, respectively. The increase in the compressive strengths for fibrous concrete compared to non-fiberous concrete is 11%, 24.35%, 46.0%, and 56.4% for 0.4%, 0.8%, 1.0%,

and 1.5% fiber content, respectively. This behaviour is also noted by Ali and Mohutain[4] for light weight concrete.

From the compressive strength test results, the compressive strength f'_c of concrete was predicted in term of fiber content W_f as:

$$f'c(MPa) = A + B \cdot W_f + C \cdot W_f^2 + D \cdot W_f^3 \quad .....(1)$$

and applying regression analysis gave

$$f'c(MPa) = 39.216 - 3.838W_f + 35.039W_f^2 - 15.146W_f^3 \quad ....(2)$$

The compressive strength predictions from Eq.(2) matching with measurements and root of mean square prediction error is 2.63% as in Fig.(3).

8 Flexural Strength

Figure 4 show the flexural strength values of specimens which were measured at 28 days after modeling. It can be seen that the 28-days flexural strength measured for fibrous content increase from 3.925 MPa for 0.0% fiber contented to 4.9% MPa, 5.87 MPa, 6.18 MPa, and 7.27 MPa for 0.4%, 0.8%, 1.0%, and 1.5% fiber weight contents, respectively. These values represent percentage increase of 24.6%, 49.36%, 57%, and 85% for 0.4%, 0.8%, 1.0%, and 1.5% fiber weight contents, respectively. The magnitudes of this increase are some what higher than these in compressive strength.

The flexural strength were predicted using measured values of flexural strength and fiber content W_f,

$$f'c(MPa) = A + B \cdot W_f + C \cdot W_f^2 + D \cdot W_f^3 \quad ......(3)$$

and applying regression analysis gave

$$f'c(MPa) = 3.925 + 3.733W_f - 1.948W_f^2 + 0.742W_f^3 \quad .....(4)$$

The flexural strength predictions from Eq.(4) matching with measurements and rote mean square prediction error is 1.28%.

The test results show that the compressive strength and flexural strength values are increased as the fiber content increased. The average ratio of flexural strength to compressive strength is shown in figure 5.It can be concluded that the compressive and flexural strength are consistent since the strength variation between various fibrous and non-fibrous content mixes are relatively high.

9 Conclusions

A series of tests carried out to examine the effect of polypropylene fiber on the compressive and flexural strength of concrete. The following conclusions have been drawn from this work:

1- Polypropylene fiber inclusions in amount of 0.4% and 1.5% increased the compressive strength up to 11% and 56% respectively.

2- When polypropylene fibers was used in amount of 0.4% and 1.5% the increase of flexural strength 24.6% and 85% respectively.

3- The average ratio of flexural strength to compressive strength is about 11.18%.

4- Strength models established by regression analysis give predictions matching the measurement values.

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[7]ASTM C33/86 Standard specification for concrete aggregate.

[8]ASTM C150 Standard specification for Portland cement.

[9]A.M. Neville, "Properties of Concrete", Person Prentice Hall, 2005.

[10]BS 1881-116 Method of Determination of Compressive Strength of Concrete Cubes, 1983.

[11]BS 1881-118 Method of Determination of Flexural Strength, 1983.

Table (1) Properties of Fibers[4]

Material	Density kg/m^3	Length Mm	Diameter Mm	Tensile Strength MPa	Geometry Mm
polypropylene	900	12	0.016	400	Fibrillated

Table (2) Mixture Properties of Fiber Reinforced Concrete

Mix No.	Cement kg\m^3	Sand kg/m^3	Coarse aggregate Kg/m^3	W/C %	Polypropylene Fiber % of cement contain
M1	440	755	1060	0.45	0
M2	440	755	1060	0.45	0.4
M3	440	755	1060	0.45	0.8
M4	440	755	1060	0.45	1.0
M5	440	755	1060	0.45	1.5

Table (3) Strength of Polypropylene Concrete

Fiber content %	Compressive strength after 14 days MPa	Compressive strength after 28 days MPa	Flexural strength after 28 days MPa
0.0	30.0	39.0	4.05
0.4	35.7	43.3	4.945
0.8	40.0	48.5	5.915
1.0	47.0	57.0	6.225
1.5	50.0	61.0	7.290

Note: the values obtained for each property in this Table based on an average of three specimens for each concrete mix.

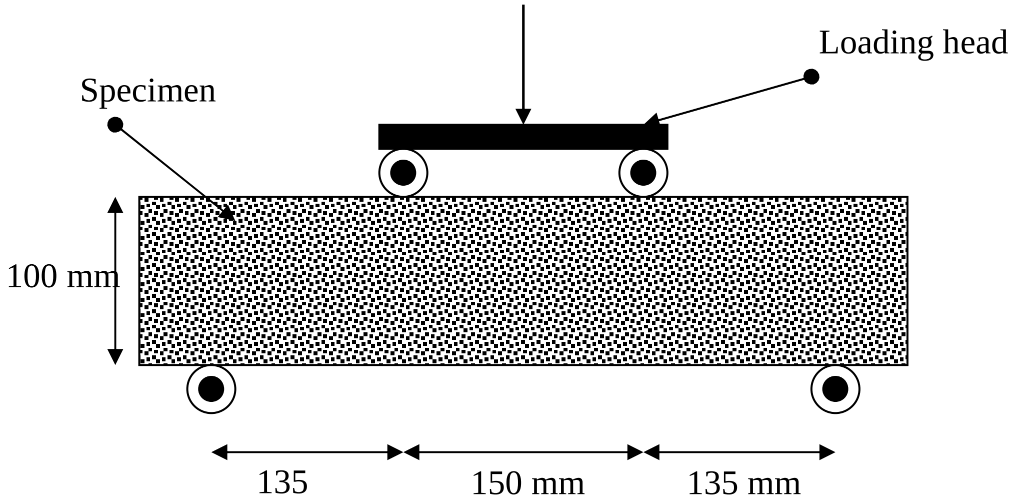

Figure (1) Flexural Test Setup

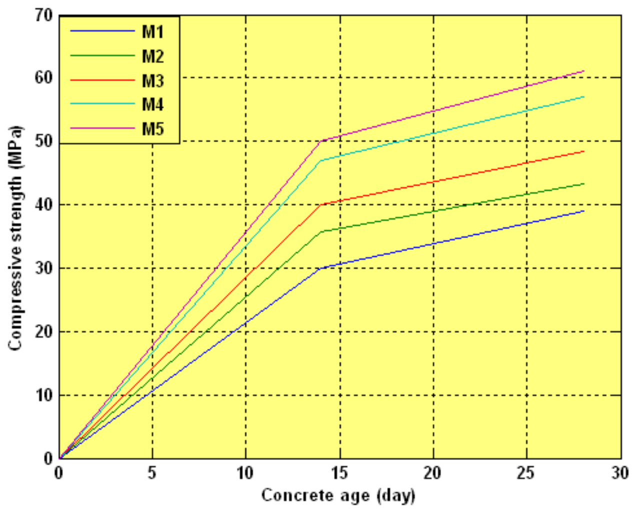

Figure (2) Compressive strength after 14 and 28 days

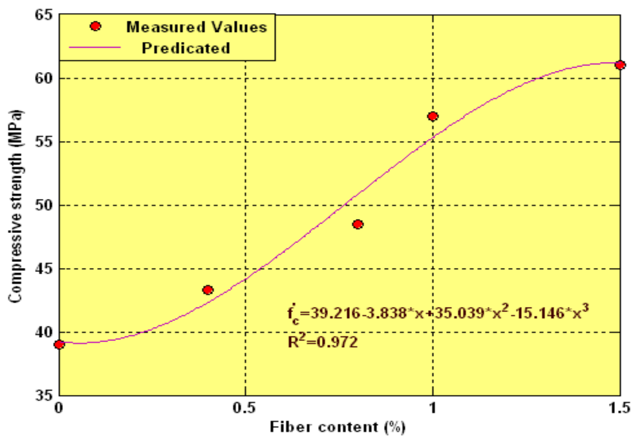

Figure (3) Effect of fiber contain on compressive strength

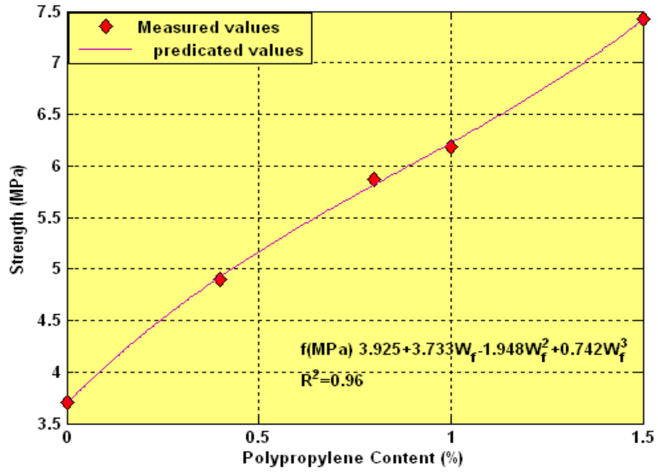

Figure (4) Effect of Fiber Contain Flexural Strength

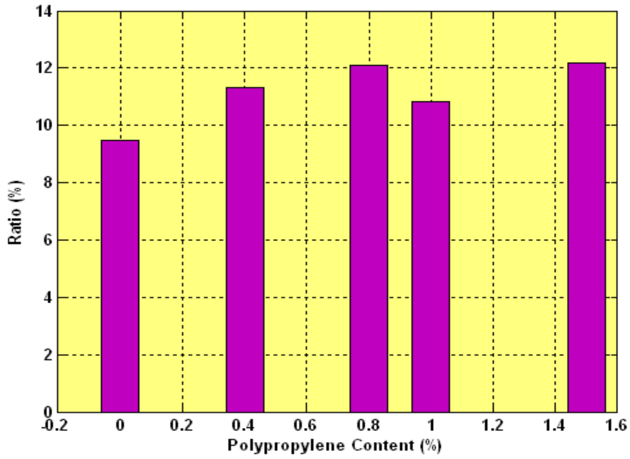

Figure (5) Ratio of Flexural Strength to Compressive Strength