Evaluation of Mechanical Strength of Epoxy Polymer Concrete Reinforcement with Different Types of Fibers

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Abstract

Polymer composite materials were prepared by mixing epoxy resin with sand particles in three different grain size (150-300), (300-600) and (600- 1200) µm . The weight of epoxy was 15%, 20%, 25% and 30% of the total weight. Compression strength and flexural strength tests were carried out for the prepared samples .The percentages of epoxy resin at 20% wt and 25% wt showed best mechanical properties for all grain sizes .These percentages were adopted to fill the void between particles sand which have two different size ranges (150-600) µm and {(150-300) & (600-1200)} µm respectively to obtain more dense material. The results showed that the strength of polymer composite at 20% resin is higher than 25% resin. The sample which has maximum value for compression strength and flexural strength was reinforced with fibers (glass, polypropylene and alucobond waste) by weight 1% and 1.5% respectively of the weight of epoxy resin.

Keywords: polymer concrete, epoxy resin, compression strength, flexural strength, fibers.

Introduction

Concrete is one of the fundamental materials in civil engineering especially structural industries. Conventional, concrete has many favorable advantages such as low material cost and simple applications [1]. However, it has disadvantages and some serious limitations. It's low strength, weak flexural strength,poor resistance to, freeze-thaw phenomena and destruction by sulfate and acid attack has been limited the usage of the concrete [2]. In order to improve concrete properties, polymer concrete was introduced in material and structural industries [3,4]. The polymer concrete (PC) is a composite material in which aggregates are bonded together with resin in a polymer matrix [5]. PC is being extensively used as a suitable substitution for cement concrete in variety of applications such as construction and structural repairs, highway pavements, wastewater pipe lines, bridges, floors and dams [6,7]. PC performance is strongly depending on various types and mixture proportion of aggregates and resins. The particle size of aggregates has great influence on mechanical behavior of the PC and improves its physical and mechanical strengths [8].

Experimental

Epoxy Resin

The epoxy resin used in this work (Quick mast 105) is produced by (Don Construction Product Ltd. Company), the resin physical properties are low viscosity , low creep ,non-shrink ,exhibit good chemical resistant .Epoxy resin system in the form of the transparent liquid transforms into solid state after adding the hardener type (Quickmast 105) which is produced by the same company .The mixture percentage is (3:1) respectively .Table (1) illustrates the physical properties of the epoxy .

Aggregate

AL-Ukhaider natural sand was used throughout this work .The particle size of the supplied aggregate is defined as follows:

Fine size (F) with average particle size of (150-300) μm.

Medium size (M) with average particle size of (300-600) μm.

Coarse size (C) with average particle size of (600-1200) μm.

Aggregates were washed by water and then dried in furnace at 110 ºC for one day in order to get the best bond between aggregates and resin.

Waste of Alucobond

Alucobond consists of two sheets aluminum thermo bonded to a polyethylene core in a continuous process.The remnants of alucobond after removing the particulate of aluminum by handling was used in this research as fiber with length 2-5 mm and diameter (0.5-2) mm The percentage of waste fiber was (1% and 1.5%) wt of the total weight of the resin.

Glass Fibers

The glass fibers type E- glass (electric grade) was used in random shape designated with length (4- 6) mm and diameter (10-14) μm . The percentage of glass fiber was also (1% and 1.5%) wt of the total weight of the resin.

Polypropylene Fibers

The polypropylene fibers were used with length 6mm and diameter (10-16) μm in random shape designated .The percentage of polypropylene fiber have been fixed again to (1% and 1.5%) wt of the total weight of the resin.

Preparation Specimen of Polymer Concrete

Polymer concrete specimens were prepared according to ASTM standards in two types as follows:

1- Epoxy concrete: Initially epoxy resin and hardening agent were weighed and blended. Sand was added to the mixture with appropriate proportion illustrated in table (2) and were gently mixed.

2-Epoxy concert reinforcement with fiber: epoxy resin and hardening agent were weighed and blended, fiber added to the epoxy mixture and blended after that these mixtures were mixed with sand and lightly blended.

In three steps, these mixtures were placed in molds respectively. After each step was performed the mixture was compacted using a rod to prevent any void formation. The specimens were air dried at room temperature and then the molds were removed and then tested after 7 days.

Two different ASTM tests were carried out. Compressive and flexural strength of fabricated PC were measured according to ASTM C579-01 [9] and C 293-02 [10] , respectively. The uniform shaped specimens were cubed (50 × 50 × 50 mm) for compression strength and prisms 4*25.4*116 (mm) for flexural strength.

Results and Discussions

Compressive Strength Test Results

Figure (1) shows the results of compression strength of various mixtures of polymer concrete with different grain sizes of sand particles.

The results of compression strength are varied between (85.4 – 48.42) Mpa. The maximum values of compression strength are (at 30% resin for all sizes of sand particles). There was no homogeneity in mixture and excessive resin samples after curing as shown in figure (2, d). The minimum values were (at 15% resin for all sizes of sand particles) because the resin ratio was not enough to wet the sand particles to provide the wished bond for aggregate also this apparent in figure (2,a). The better value of compression strength was at (20% and 25% resin) for all size particles may be the amount of resin was enough to wet the sand particle and therefore get adequate compact of sand particle in resin matrix[6] as shown in figures (2,c) and (2,d). Then two mixes of particle sizes combined [(65%) (300-600)& (35%) (150-300)] μm and [(65%)(600-1200)&(35%)(150-300)]μm respectively for the smaller particles were needed to fill the smaller voids between the neighboring aggregate particles. This would provide the graded aggregate to produce a material which is more dense, less porous and absorptive. It allows a much smaller amount of resin to be needed to fill the voids between the sand particles, thus forming stronger and impervious composite. From table (3) it is found that compression strength value (at 20% resin) is greater than the other (at 25%). The logical justification for this result that when void ratio decreased, the resin ratio was increased in mix and then led to non-homogeneous distribution thereby forming weak bonded between the particle of sand in resin **.** The final optimum results 84 Mpa , 84.2Mpa obtained by {20% resin at (M&F), (C&F) μm size} respectively, adopted and reinforced with different types of fibers (glass, polypropylene and waste) with two percents (1% and 1.5%) which represent (wt. of fiber/wt. of resin) .

Figure (3) shows that the compression strength increased to about 3% and 1% after reinforcement by (glass and polypropylene) fiber respectively at 1% percent with (C&F) μm sand. This condition can be attributed to the improvement of the mechanical bond strength when the fibers both allow the ability to delay the micro - crack formation and arrest their propagation afterward up to a certain extent [11] and the compression strength decrees at 1.5 % percent. The reason of this result is that because the fiber at (1%) had formed bulks and segregate on mix. This led to form stiff bond about these bulks [12] .In other hand, compression strength decreased in reinforcement by (glass and polypropylene) at 1% percent with (M &F) μm sand because the surface area of sand in this case is greater than the first one, the surface area is a function of particle size. [13].In another case, the waste reinforcement gives unwished results may be to low aspect ratio length/diameter of fibers .

Flexural Strength Test Results

Analysis of the results of the flexural tests reveals that the PC behavior is similar to that in the compressive tests .These results of mixes are presented in figures (4) and (5) .The discussion of these results were illustrated in the following points:

1- An increase in resin content of polymer concrete from 25 to 30% had great effect on flexural strength of the specimens, while there was an increment in resin.

2- The decrease in amount of resin to 15% caused a reduction in the flexural strength .This attributed to the amount of resin which was not enough to wish the particle of sand .This leads to poor adhesion between the sand particles in resin [14] .

3- It was concluded that the use of 20%and 25% resin (weight of total sample) was desirable composition for PC fabrication. This value was found through actual experimental work and data analysis.

4- The value of flexural strength increased when combined two sizes of sand particles this refers to obtain on compact composite material.

5- Improvement in flexural strength when reinforcement with glass and polypropylene fiber at percentage 1% this is because after matrix cracking, the fibers will carry the load that the concrete sustained until cracking by interfacial bond between the fibers and the matrix. Therefore, the fibers resist the propagation of cracks and do not fail suddenly, which causes an increase in load carrying capacity, while the flexural strength reduction at 1.5% for glass fiber and polypropylene fiber respectively ,this increment in weight of fiber led to difficult in penetration epoxy resin between this fiber and particle sand and that is viewed through preparation of specimens .This resulted to poor bond force between the resin and fiber from side and surface of sand particle with resin from other side [15].

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Table (1) Physical Properties of Epoxy

Compressive strength	> 72 N/mm^2 after 7day at 25 ºC
Flexural strength	> 50 N/mm^2 after 7day at 25 ºC
Density	1.1 g/cm^3
Viscosity	1.0 poise

Table (2) Polymer Concrete Mixtures (wt. %).

Sand piratical size	**Epoxy Percent wt.%**			
	15%	20%	25%	30%
(150-300)µm Fine aggregate (F)	F_{15}	F_{2o}	F_{25}	F_{30}
(150-300)µm Medium aggregate (M)	M_{15}	M_{20}	M_{25}	M_{30}
(600-1200) µm Coarse aggregate (C)	C_{15}	C_{20}	C_{25}	C_{30}
(65%) (300-600) µm &(35%)(150-300) µm	-	(M&F)20	(M&F)25	-
(65%) (600-1200) µm &(35%)(150-300) µm	-	(C&F)20	(C&F)25	-

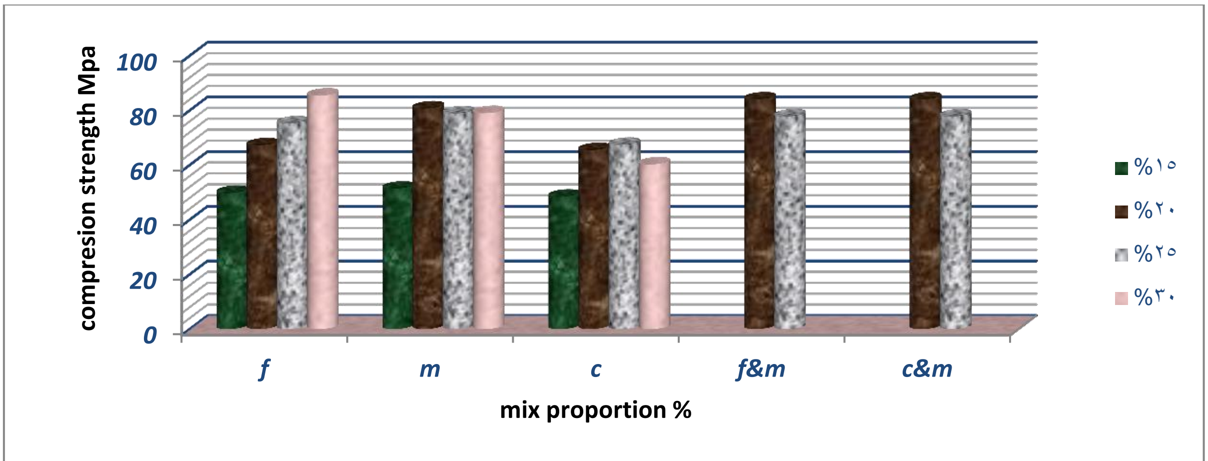
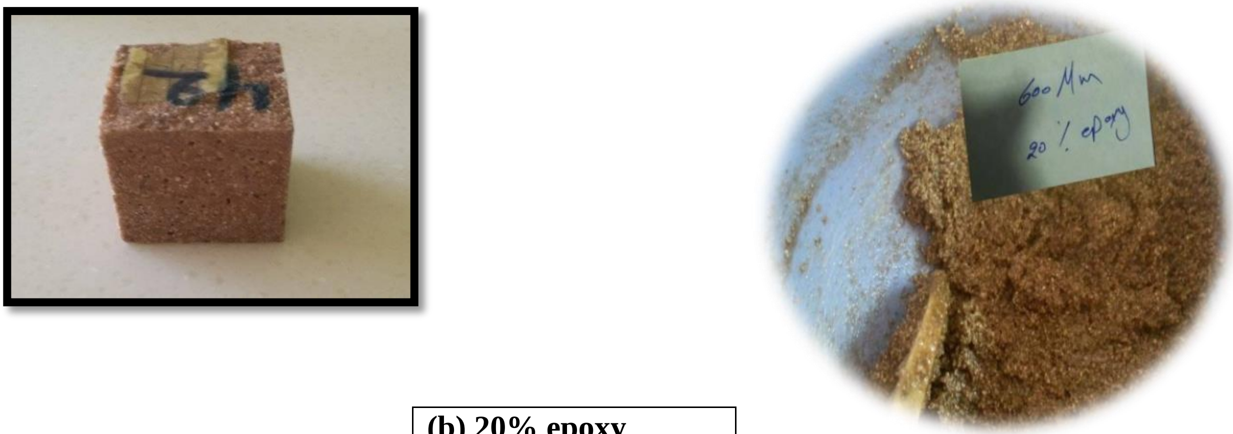


Figure (1) Compression Strength Results of Polymer Concert.

(a) 15% epoxy



(b) 20% epoxy

(c) 25% epoxy

(d) 30% epoxy

Figure (2) Epoxy Resin of different percentages with sand particles size 60

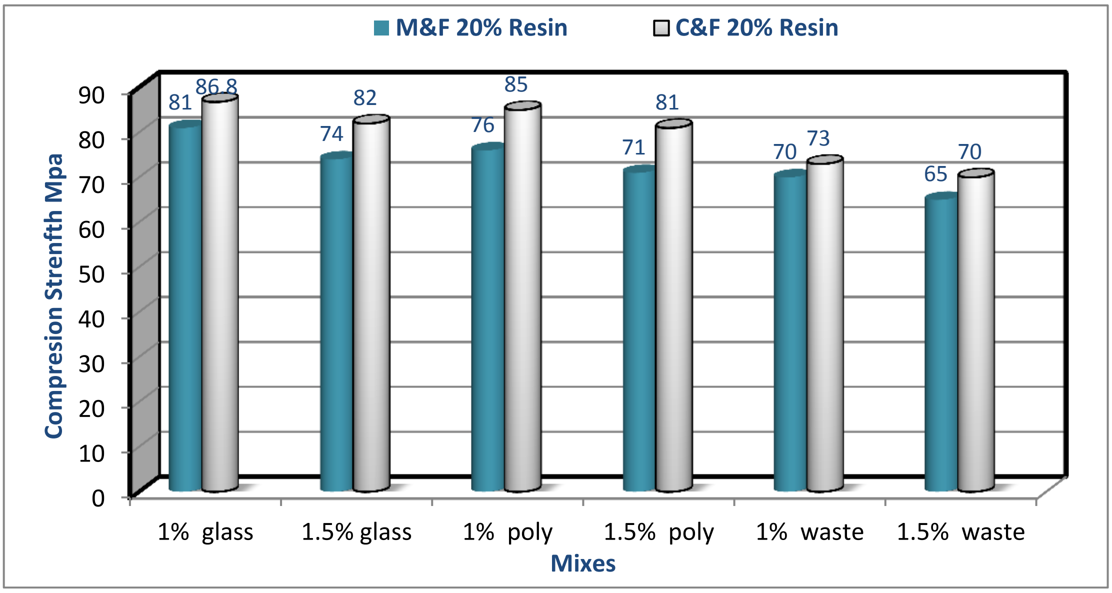


Figure (3) Compression Strength of Fibers Reinforcement PC.

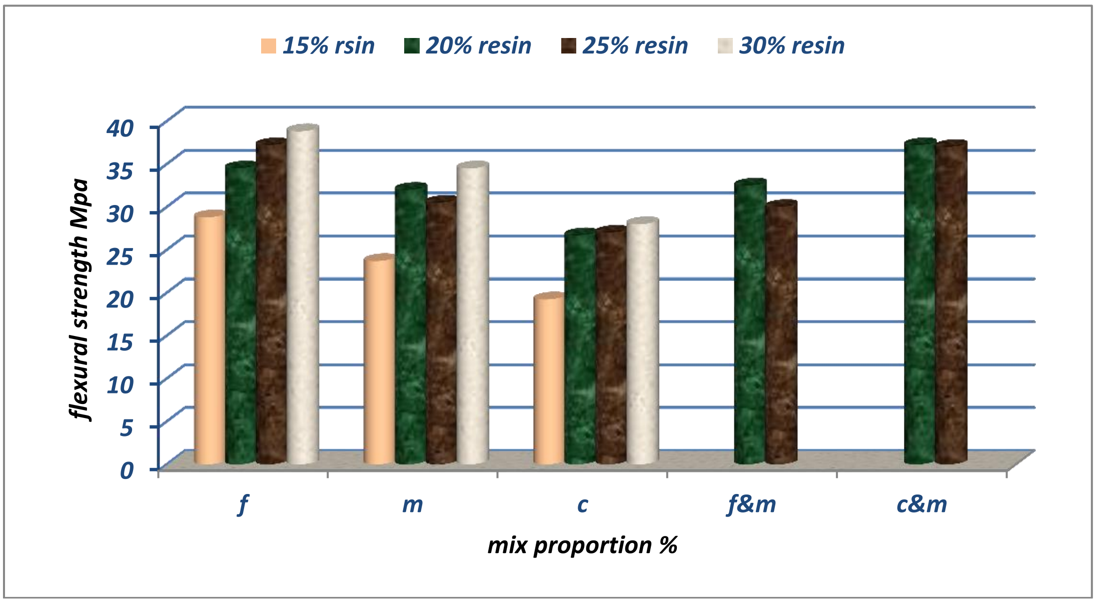


Figure (4) Flexural Strength Results of Polymer Concert.

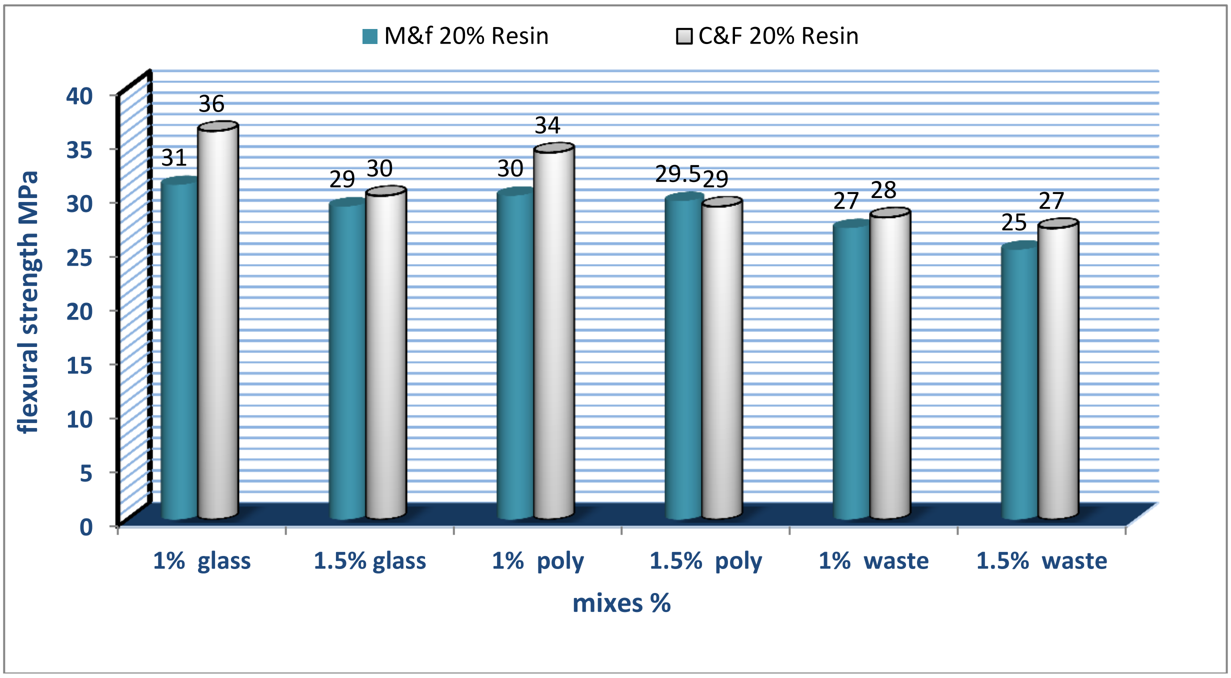


Figure (5) Flexural Strength Result of Fiber Reinforcement Polymer Concert.

قياس المقاومة الميكانيكية للايبوكسي بوليمر كونكريت مدعمة بانواع مختلفة من الالياف

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الخلاصة

حضرت مادة متراكبة بوليمرية بخلط راتنج الايوكسي مع الرمل لثلاثة احجام حبيبية مختلفة هي (150-300) و(300-600) و (600-1200) مايكرون . وزن الايبوكسي كان 15% ،20% ،25% ،30% ،من الوزن الكلي . فحصي مقاومة الانضغاط ومقاومة الانحناء اجري على العينات المحضرة. النسب الوزنية لراتنج الايبوكسي عند20 % و25% اظهرت افضل الخصائص الميكانيكية لكل الاحجام الحبيبية . اعتمدت هذه النسب لملئ الفراغات بين حبيبات الرمل التي تمتلك حجمين مختلفين(150-600) و{(150-300) &(600-1200)} μmعلى التوالي للحصول على مادة ذات كثافة اكبر. اظهرت النتائج بأن مقاومة المتراكبات البوليمرية عند النسبة20% كانت اعلى من تلك عند 25% . العينات التي تمتلك اعلى قيمة لمقاومة الانضغاط والانحناء دعمت بالألياف (ألياف الزجاج ،ألياف البوليبروبلين ،ألياف مخلفات الاليكوبوند) بنسب 1% و1.5% من وزن راتنج الايبوكسي .

كلمات مفتاحية: كونكريت بوليمر ، راتنج الايبوكسي ، مقاومة الانضغاط ، مقاومة الانحناء، ألياف .