Iraqi Journal of Science

ISSN: 0067-2904

A Study of compression strength and flexural strength for Polymer Concrete

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Abstract

Polymer concrete were prepared by mixing epoxy resin with sand particles in three different grain size (150-300) , (300-600) and (600- 1200) µm respectively. The percentage of epoxy was 15%, 20 %, 25% and 30% wt 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 voids between particles sand 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.

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

دراسة خاصية الانضغاط وخاصية الانحناء للبوليمر كونكريت

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الخلاصة

حضر البوليمر كونكريت بواسطة خلط راتنج الايبوكسي مع الرمل فقط لثلاث احجام حبيبية مختلفة هي (150−300) و(300−600) و (600−1200) مايكرون على التوالي , حيث كانت نسبة الايبوكسي 15% ,20% ,25% ,30%نسبة وزنية من الوزن الكلي , ثم تم اجراء فحوصات مقاومة الانضغاط والانحناء للعينات المحضرة, وقد اظهرت النتائج بأن نسب راتنج الايبوكسي عند20 % و25% تمثل افضل خصائص ميكانيكية لكل الاحجام الحبيبية . تم اختيار هذه النسب لملئ الفراغات بين حبيبات الرمل التي تمتلك حجمين مختلفين(150−600) و{(150−300) &(600−1200)} مايكرون على التوالي للحصول على مادة ذات كثافة اكبر. اظهرت النتائج بأن مقاومة الانضغاط والانحناء للعينات عند النسبة 20% كانت اعلى من تلك عند 25% .

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

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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] In the composition of polymer concrete there is not cement and water , the aggregates are bonded by the resin. 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 dependent 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].

Literature Review

In (2007) Ferreira and Seabra, have studied the Flexure strength, Compression elasticity modulus, compression strength and tensile strength of epoxy polymer concrete with foundry sand in maximum grain size of 342μm.The percentages of epoxy were 14% ,16%,18% and20% of the total weight .The result shows the best mechanical properties of those percentages when epoxy resin of 18% wt was used. The values of the flexure strength, compression elasticity modulus, compression strength and tensile strength were 36.5 MPa , 12.0GPa , 81.8MPa and 10,9MPa respectively [9].

In (2008) Marinela and Maria have studied the effect of silica fume filler on the strength for polymer concrete of epoxy resin, crushed aggregates and silica fume as filler was added to the composition without replacing the fine part of aggregate. The grain size of aggregate was (<4mm) and (4-8) mm in concert. The percentage of epoxy varied from maximum 18.8% to minimum of 12.4% , the percentage of aggregate was varied from minimum 37.4% to maximum 39.0% of coarse aggregate and minimum 37.4% to maximum 39.% to fine aggregate . In addition the silica fume content was varied between 6.4% to 9.6%.The results showed that the mechanical characteristics were influenced by all mixture factors: the compressive strength increases with the increased of silica fume percentage, and the flexure strength and split strength increase with the decreasing of silica fume percentage [10].

In (2013) Daghash , investigated the mechanical properties of PC incorporating Multi-Walled Carbon Nano-Tubes (MWCNTs). Four mixes of PC with 0.0 (neat), 0.5, 1.0, and 1.5% MWCNTs by weight of the epoxy resin, respectively, were prepared using (17% wt) low modulus polysulfide epoxy mixed with coarse aggregate used as bauxite-based aggregate with a maximum size of 4.75 mm .It was found that PC mixes with 1.5%wt MWCNTs proved to have significantly higher young's modulus of elasticity compared with neat specimens. The compressive strength was decreased by 6.7% by adding 0.5% wt MWCNTs increased by 6.7% with 1.0wt % MWCNTs and again significantly increased by 153% with 1.5%wt MWCNTs and incorporating 0.5 and 1.0 wt % MWCNTs in the PC mix increased the ultimate flexural strength by 41 and 26%, respectively, while the 1.5wt % MWCNTs decreased it by 2%. It can be observed that adding MWCNTs decreased the shear modulus of PC. The decrease was found to be 18, 35, and 32% with 0.5, 1.0, and 1.5%wt MWCNTs, respectively [11].

Experimental

Materials

Epoxy Resin

Epoxy type (Quick mast 105) is produced by (Don Construction Product Ltd. Company, Jordon), the resin physical properties are low viscosity , non-shrink ,exhibit good chemical resistant. . Epoxy resin system in the form of the transparent liquid which 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 epoxy listed by company.

Table 1 - physical properties of epoxy

Compression strength	> 72MPa after 7days at 25 ºC
Flexural strength	> 50MPa after 7days at 25 ºC
Density	1.1 g/cm^3
Viscosity	1.0 poise

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.

Preparation specimens of polymer Concrete.

Polymer concrete Specimens were prepared according to ASTM standards. Initially epoxy resin and hardening agent were weight and blended. Sand only was added to the mixture with appropriate proportion illustrated in Table -2 and gently mixed. These mixtures were placed in molds. 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.

Table 2- polymer concrete mixtures (wt. %).

Sand particle Size	**Percent of epoxy (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**	-

Two different ASTM tests were carried out. Compression and flexural strength of fabricated PC was measured according to ASTM C579-01 [12] and C 293-02 [13], respectively. The uniform shaped specimens were cubed (50 × 50 × 50 mm) for compression strength and prisms 25.4×25.4×116 mm (1×1×5 in) for flexural strength.

Results and Discussion

compression Strength Results

Table -3and Figure -1show the results of compression strength of various mixtures of polymer concrete with different grain sizes of sand particles.

Table- 3 (a) compression strength results for different percentage of epoxy with fine size of sand

Mixtures	**Compression strength** MPa
F_{15}	49.78
F_{20}	76.22
F_{25}	75.26
F_{30}	85.4

Table -3 (b) compression strength results for different percentage of epoxy with medium size of sand

Mixtures	**Compression strength** MPa
M_{15}	51.35
M_{20}	80.7
M_{25}	78.9
M_{30}	81

Table -3 (c) compression strength results for different percentage of epoxy with coarse size of sand

Mixtures	**Compression strength(**MPa)
C_{15}	48.42
C_{20}	65.46
C_{25}	63.4
C_{30}	66.25

Table -3 (d) compression strength results for different percentage of epoxy with two mixture of sand.

Mixtures	**Compression strength (**MPa**)**
$(M\&F)_{20}$	84.2
$(C\&F)_{20}$	84
$(M\&F)_{25}$	77.8
$(C\&F)_{25}$	77.78

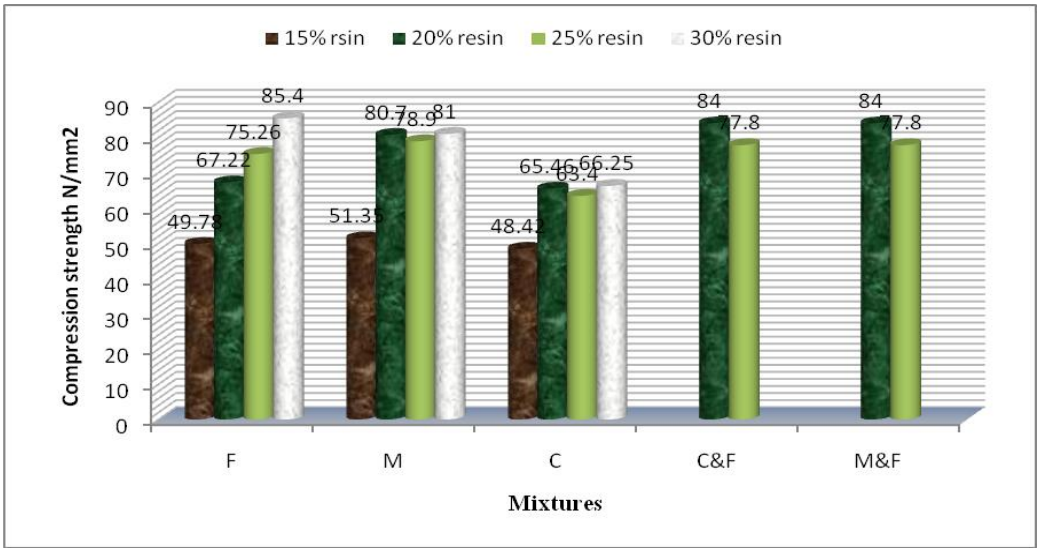
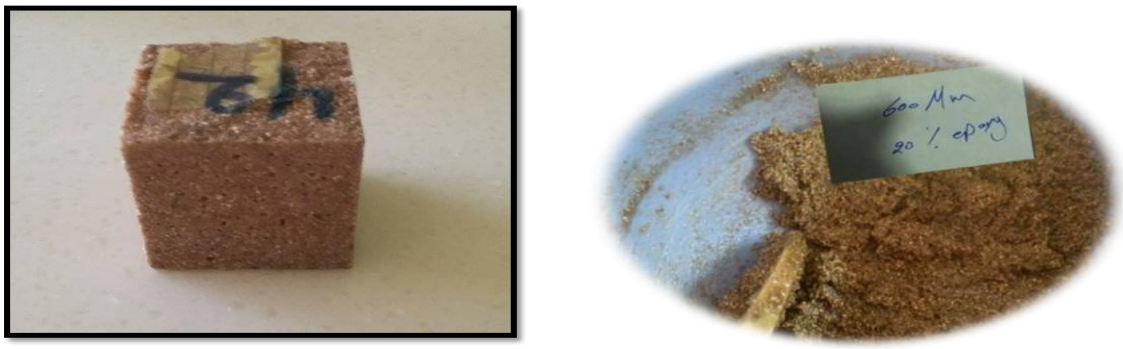


Figure -1 compression strength results of polymer concrete .

The results of Compression strength varied between (48.42 –85.4 MPa. The maximum values of compression strength were 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 of compression strength 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 best 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 mixture of particle size combined [(65%) (300-600)& (35%) (150-300)] μm and [(65%)(600-1200) & (35%)(150-300)] μm respectively for the smaller particles be 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 composite material. From table (3) it is found that compression strength value (at 20% resin) greater than the other (at 25%). The logical justification for this result that when void ratio decreased, the resin ratio increased in mix and then led to non-homogeneous distribution thereby forming weak bonded between the particle of sand in resin**.**

(a) 15% epoxy



(b) 20% epoxy

(c) 25% epoxy

(d) 30% epoxy

Figure 2- Epoxy resin of different percentage with sand particles size 600 μm

Flexural Strength Results

Analysis of the results of the flexural tests reveals that the PC behavior is similar to that in the compression tests .These results of mixes are presented in Table -4, and Figures -3 .The discussion of these results illustrated in the following points:

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

2- The decrease in amount of resin to 15% caused a reduction in the flexural strength .This was attributed to the amount of resin which was not enough to wet particles of sand .This leads to poor adhesion between the sand particles in resin [5] .

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 upon combing two sizes of sand particles this attributed to the decrease of voids between sand particles and then obtained more dense composite.

Table 4- the Values of Flexural Strength for different prepared composites

Mixtures	Flexural strength result (N/mm^2)
F_{15}	28.8
F_{20}	34.5
F_{25}	37.2
F_{30}	38.8
M_{15}	23.7
M_{20}	32
M_{25}	30.5
M_{30}	34.5
C_{15}	19.23
C_{20}	26.7
C_{25}	27
C_{30}	28
$(M\&F)_{20}$	32.5
$(C\&F)_{20}$	37.2
$(M\&F)_{25}$	30
$(C\&F)_{25}$	33

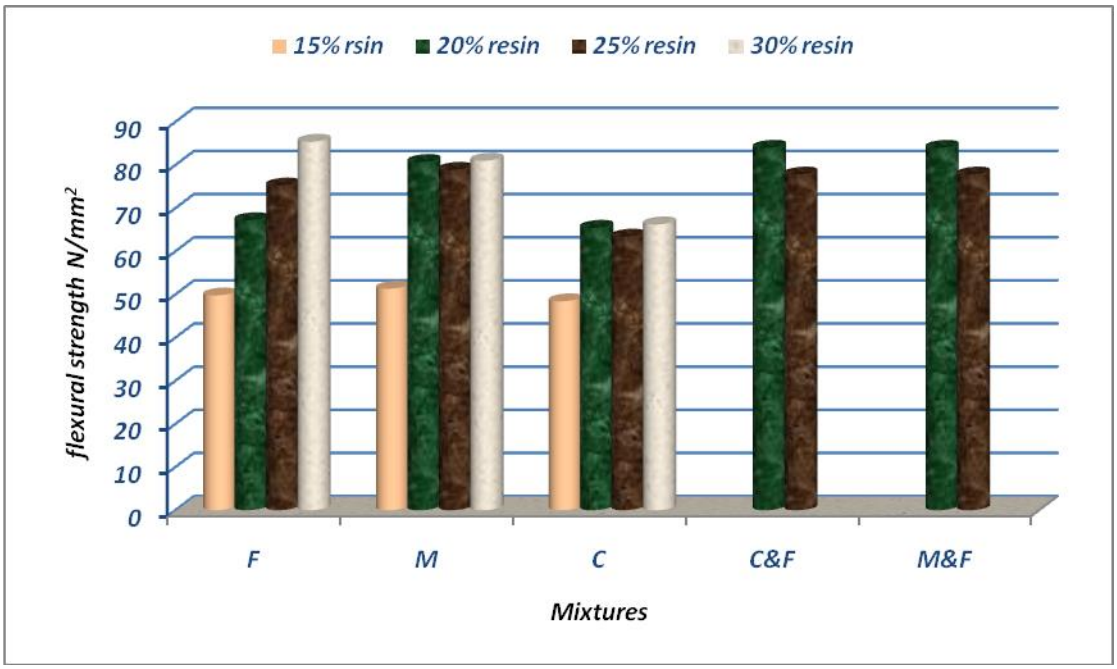


Figure 3- flexural strength results of polymer concert.

Conclusions

It may be concluded from this work the amount of resin in composition of fabricated PC shows great influence on both compression and flexural strength results The PC specimen with 20% and 25% resin has resulted in maximum compressive, flexural strength. Influence of aggregate grading on the properties of polymer concrete. The coarse and fine aggregate should be proportioned in such a way that aggregate mixture has minimum void content and maximum bulk density. This minimizes the amount of binder required to form proper bonding of all the aggregate particles. The variation in resin percentage requirements of mixture with different aggregate particle sizes and grading, from fine to coarse was reported.

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