Research Article

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Influence of Sand Size on Mechanical Properties of Fiber Reinforced Polymer Concrete

<https://doi.org/10.1515/eng-2019-0066>

Received Apr 12, 2019; accepted Oct 12, 2019

Abstract: The deterioration of concrete in places exposed to sulphate salts, chlorides and groundwater movement is a major problem. In this research, polymer concrete was produced by testing four mixtures using different sizes of aggregates with epoxy adhesive and two mixtures were reinforced with polypropylene fibers (0.5 and 1)% by weight of Epoxy in addition to the reference mix consisting of cement and sand. Compressive strength, electrical resistivity, ultrasonic pulse velocity, flexural and porosity testing were performed at ages 7, 14, 28, and 60 days. The highest compressive strength, electrical resistance, ultrasonic pulse velocity and zero porosity for mixture had a maximum size of sand less than 600 microns and more than 150 microns, where the rate of increase (272.9, 635.9, 45.9 and 57.7)% respectively compared to the reference mixture. The results showed also that the highest flexural strength was for the mix reinforced with 1% polypropylene fiber. In addition, the specimens at age 28 day submerged in the diluted solution of sulfuric acid at 5 and 10% for 11 weeks. The results showed that there were no change in the volume and weights of the specimens that were submerged.

Keywords: Polymer Concrete, Epoxy, Compressive Strength, Electrical Resistance, Ultrasonic Pulse Velocity, Flexural Strength, Sulfuric Acid

1 Introduction

Polymer concrete is a composite material consisting of well graded inorganic aggregates bound by using a resin instead of the water and cement binder typically used in traditional cement concretes [1, 6]. Conventional concrete contains a small amount of fine aggregates or does not contain adequate amount of cement paste to encapsulate and bind the total particles together to create a system of high porosity and interconnected spaces that can quickly dispose water. In general, the content of voids in conventional concrete ranges between 15% and 25%, and water permeability is usually about 2-6 mm/s. However, strength is usually associated with porosity in concrete where strength decreases with high porosity [6–10]. At present, due to fast treatment, excellent bonds, reinforcing steel, high strength and durability of polymer concrete was widely used instead of ordinary concrete. Precast polymer concrete has been used to produce a variety of products such as; acid tanks, inspection rooms, drains, highway barriers and so on [11, 12].

The aggregates are usually taken as materials inert dispersed throughout the polymer molding. Usually, the aggregates are added into two groups, coarse aggregates contain material larger than 5 mm and fine aggregate size of less than 5 mm. Grading is not estimated in the case of polymer concrete until the present time and varies widely from one system to another. In addition to coarse and fine aggregates, filler materials are also sometimes added to the polymer concrete system primarily to fill the micro voids. Polymer concrete can also be enhanced to improve its mechanical properties with different types of fibers used of steel fibers, polypropylene, glass and nylon [13]. One of the most important characteristics required for materials that are used in civil and construction industries are durability [14, 15]. Durability is known as the ability of material to withstand environmental loads without distorting the shape or changing the properties. Due to the high durability gained in early polymer concrete as well as high strength and chemical resistance, it is used in a wide variety of industries far beyond the construction industry [16]. The advantages of polymer concrete has low price, the pos-

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sibility of controlling many of its characteristics and its ability of cold formation (setting), it also can resist chemical substances with high values [17]. These specifications made us to search more and more to know its characteristics and the possibility of using it in places that need such a type of concrete. The production of conventional concrete causes the emission of carbon dioxide (CO₂) with large quantities, while the resin materials is emission less, that makes it Eco-friendly, in addition to it, the ordinary concrete deteriorates after 20 years unlike the polymer concrete that has a high durability. So, the search started about another materials more effective than conventional concrete, it is the polymeric concrete, that its main bonding material is a type of polymers (including Epoxy) with using different fillers such as; sand, with different ratios.

2 Materials

2.1 Sand

Akhaither sand was used, which is compatible with British specifications number 882, for a year 1995, listed below in Table 1.

Table 1: Particle Size of Sand

Size of sieve (mm)	Gradient area number 2
4.76	90-100
2.4	75-100
1.2	55-90
0.6	35-59
0.3	8-30
0.150	0-10

2.2 Epoxy

It is an organic particular that has the ability to combine with similar and different particulates to produce a high partial weight material (double origin compound). Specifications of Epoxy comply with ASTM D-543 and ASTM C 881-87 is listed in Table 2 below.

2.3 Polypropylene Fibers

It is an artificial fiber that is added to concrete to increase tension resistance, impact resistance and to reduce shrink-

Table 2: Specifications of Epoxy

Density (g /cm ³)	1.05
Mix ratio (by weight)	3:1
Mix ratio (by volume)	5:2
Minimum hardening temperature °C	8
Bone dry at 200 C (hours)	2
Thorough hardened at 20°C (days)	7
Volume Shrinkage (%)	3.5
compressive (N/mm ²)	85
Bending (N/mm ²)	45
Tension force (N/mm ²)	45
Flexure (%)	4
E-module (N/mm ²)	2800
Storage life in months at 20°C	12
Colour	Colourless

Table 3: The characteristics of polypropylene

0.91 g/cm	Specific weight
18 Micron	Diameter of fibers
12 mm	Length of fibers
230 m ² /kg min	Surface area
Min 350 MPa	Tension force
160°C	Melting point

age. The characteristics of polypropylene are listed in Table 3 below.

2.4 Polyethylene

Very thin polyethylene nylon was used to ensure that the mixture won't stick to the surfaces of molds

2.5 Proportion of Materials

This research included six mixtures in the polymer concrete reinforced or unreinforced with polypropylene fiber (0.5 and 1)% by weight of epoxy at a ratio of 1:1.3 in addition to reference mix as follows:

1. Used Portland cement with sand pass from sieve 4.75 mm and residual on sieve 150 micron at a ratio of 1:1.3 and water/cement ratio 0.5 (Reference) (Re)
2. Used epoxy + hardener with sand pass from sieve 4.75 mm and residual on sieve 150 micron at a ratio of 1:1.3 (PC1)

Figure 1: Influence of Epoxy on Compressive Strength of Polymer Concrete with Age

- Used epoxy + hardener with sand pass from sieve 2.4 mm and residual on sieve 150 micron at a ratio of 1:1.3 (PC2)
- Used epoxy + hardener with sand pass from sieve 1.2 mm and residual on sieve 150 micron at a ratio of 1:1.3 (PC3)
- Used epoxy + hardener with sand pass from sieve 600 micron and residual on sieve 150 micron at a ratio of 1:1.3 (PC4)
- Used epoxy + hardener with sand pass from sieve 600 micron and residual on sieve 150 micron at a ratio of 1:1.3 and 0.5% polypropylene fibers (PC5)
- Used epoxy + hardener with sand pass from sieve 600 micron and residual on sieve 150 micron at a ratio of 1:1.3 and 1% polypropylene fibers (PC6).

Figure 2: Influence of Sand Size on Compressive Strength of Polymer Concrete with Age

Figure 3: Influence of Polypropylene Fibers on Compressive Strength of Polymer Concrete with Age

3 Experimental Analysis and Result Discussion

3.1 Compressive Strength

The compressive strength was performed for specimens that contained sand with particle size passing from sieve 4.75 mm and residual on sieve 150 micron (PC1) and cement mortar (R). The results showed that specimens PC1 had a considerable increase in compressive strength at all ages. In spite of slight increase in strength at ages between 14 and 60 days, where the percentage of increase were (44, 307.5, 245.6, 234.1)% at ages 7, 14, 28 and 60 days respectively, compared with (R) specimens, the reason of that due to the final setting time of epoxy approximately was during 14 day.

The influence of using different particle size of sands have been revealed in Figure 2, where it was showed that,

there was a little increase in the value of compressive strength. The highest value of compressive strength were for PC4 specimens which were used in passing sand from sieve 600 micron and residual on sieve 150 micron, although the percentage of increase was 4.8% at 28 days with respect to PC1 specimens which were used in passing sands from sieve 4.75 mm and residual on sieve 150 micron. The effect of progress of age on compressive strength of specimens continued increasing but very little value after 14 days, for the same reason above, and in late ages, the compressive strengths were equal because the epoxy polymer became harder. Figure 3 also showed a comparison between reinforced and non-reinforced polymer concrete as there is a slight decrease in the compressive strength of polymer concrete reinforced with polypropylene fiber compared to non-reinforced polymer concrete. This decrease is increased as the percentage of fiber increase.

Figure 4: Influence of Sand Size on Electrical Resistance of Polymer Concrete at 28 Age

Figure 5: Influence of Sand Size on Ultrasonic Pulse Velocity of Polymer Concrete with Age

3.2 Electrical Resistance

The epoxy polymer actually has a plastic nature which gives it a high resistance to electricity, while cement mortar has a little resistance may be due to the internal combinations that consist of cement mortar. The variation of sand size in mixtures that used epoxy polymer showed variation in electrical resistance because of the fineness of sand size leads to reduce the voids in the sample and increase the bonding between components of mixture, which cause increasing in electrical resistance, as shown in Figure 4.

3.3 Ultrasonic Pulse Velocity

From Figure 5, it is observed that the ultrasonic pulse velocity test for the cement mortar is less than the mixtures that its bonding material is epoxy, because of the massive increasing of voids in cement mortar with respect to polymer concrete. This is due to the structure of cement mortar.

3.4 Absorption Test

When conducting the absorption test for cement mortar specimens and polymeric concrete specimens which consist of different sizes of sand, the results showed that the

Figure 6: Influence of Sand Size on Flexural Strength of Polymer Concrete with Age

absorption rate in the cement paste was 2.978% due to the open voids in the structure of the cement paste. While the absorption rates for polymeric concrete specimens were zero for being solid and non-permeable.

3.5 Flexural Strength

The results indicated a considerable increase in flexural strength due to the usage of epoxy polymer and sand with maximum size 600μ and residual on sieve 150 micron. The percentages of increase in flexural strength with respect to reference mix were 57.7% at age 28 days, in addition, the use of polypropylene fibers has largely increased the flexural value specially, when reinforced with 1% polypropylene fibers where the percentages of increase in flexural strength with respect to reference mix were 110.77% at age 28 days as shown in Figure 6.

3.6 Immersion in Sulfuric Acid

Polymer concrete specimens submerged at age 28 in diluted solution (5 and 10)% of sulfuric acid for 11 weeks, every weekend were weighed and measured the dimensions of the specimens after washing and cleaning it and then re-submerged in new concentrations to maintain the concentration (5 and 10)% of the acid in the submerged spec-

imen to study the volume and weight variation of it. The results showed that there was no change in the sizes and weights of the specimens that were submerged as shown in the Figure S1. The reason was due to the small size particles of sand and the condensed interface between the surfaces of these particles and polymer making it solid and non-permeable. While reference mixes was a loss ratio by weight and volume at the concentration of 10% up to 96.43% in the fourth week.

4 Conclusions

- The compressive strength of the polymer concrete is three times than that of the cement mortar. The different sizes of sand in polymer concrete has resulted in increased in compressive strength, electrical resistance and ultrasonic pulse velocity. The smaller sand size has led to increased values of these properties,
- Polymer concrete has no water absorption ability and is very durable and has high resistant to sulfur acid when it is concentrated (5 -10)%,
- The flexural strength of polymer concrete increases as the ratio of polypropylene fibers increases while compressive strength decreases as the ratio of these fibers increases,

- Thus the use of it as an alternative of cement is necessary in many applications due to its properties of distinctive concrete.

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Appendix

Figure S1: Specimens Submerged at Age 28 in Diluted Solution (5 and 10)% of Sulfuric Acid