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Evaluation of Mechanical Strength of Epoxy Polymer Concrete with Silica Powder as Filler

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Abstract: Silica powder as filler was used in preparation of polymer concrete. Utilization of waste silica powder as a filler in polymer concrete is promising, it may enhances the physical properties and mechanical strength of the polymer concrete. The mechanical properties of PCs with variation of filler compositions (100, 150, 200%) and resin (10, 15, 20%) were investigated. The compressive strength of polymer concrete with silica powder as filler in comparison with cement concrete was enhanced by four folds. The casted PCs were also investigated for their compressive, flexural and tensile strengths. Samples with 15 and 20% epoxy resin and 200% filler (15% fine silica powder, 25% medium size silica powder and 60% coarse silica powder) had maximum mechanical strengths. The values of compressive, flexural and tensile strengths were 128.9, 22.5 and 16.2 MPa, respectively.

Key words: Polymer concrete · Filler · Silica powder · Compressive strength · Tensile strength

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 application [1, 2]. However, it has disadvantages and some serious limitations. Its low tensile strength, weak flexural strength, poor resistance to freeze-thaw phenomena and destruction by sulfate and acid attack has limited extensive use of concrete [3-5]. In order to improve concrete properties, polymer concrete was introduced in material and structural industries [6, 7]. The polymer concrete (PC) is a composite material in which aggregates are bonded together with resins in a polymer matrix [8, 9]. 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 [10-12]. Performance of PC is strongly dependent on various types and mixed 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 [13]. Several investigations have been carried out to evaluate performance of PCs with various resins and mix proportions of aggregates.

Muthukumar and Mohan [14] have prepared Polymer concretes based on furan resin using aggregate mix proportion of fine fillers with minimum void content. The fine fillers has resulted in low usage of binder content without affecting the polymer concrete properties and make it cost-effective product.

Abdel-Fattah and El-Hawary [15] have studied the flexural behavior of epoxy and polyester polymer concretes. It was found that the modulus of rupture was 3 times higher than ordinary concrete.

Varughese and Chaturvedi [16] have used fly ash as fine aggregate in polyester based polymer concrete. Mechanical strength and resistance to water absorption with addition of fly ash as filler were improved up to 75%.

Gorninski *et al.* [17] have assessed and compared polymer concrete with Portland cement concrete. The modulus of elasticity of polymer concrete compounds has been measured. Based on reported data, there was an increase in axial compressive strength as concentrations of fly ash increased. Furthermore, high modulus of elasticity values was obtained and the peak value was 29 GPa.

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The purpose of present research paper was to evaluate compressive, flexural and tensile strengths of epoxy polymer concrete with variation of resin and filler compositions. The goal of the experimental investigation was to obtain PC samples with superior characteristics and high mechanical strength.

MATERIALS AND METHODS

Materials

Resin and Hardener: Several specimens were prepared utilizing epoxy resin based on Bisphenol A (Honsman, Germany). No solvent or dilutor was added to prevent any possible changes in chemical properties of the samples. Tetra-amine 3-ethylene with commercial code of HA-11 (Merck, Darmstadt, Germany) was used as hardening agent. The ratio of resin: hardener as recommended by the manufacturer and also based on literature for polyamine as curing agent was 2:1 [18]. The speciic gravities of hardener and resin at 25°C were 1.07 and 1.18 g/cm^3, respectively.

Filler and Aggregate: Three levels of silica powder gradation were applied as filler in sample preparation. The particle size of the supplied fillers is defined as follows:

- Fine silica powder (S_1) with average particle size of 50-60 µm
- Medium size Silica powder (S_2) with average particle size of 600 µm
- Coarse Silica particle (S_3) with average particle size of 1100 µm

Three combinations of fillers were prepared for the experiments. Type Sa was a mixture of S_1 and S_2 silica powder. Type Sb was a blend of all silica powders and Sc was a blend of S_2 and S_3. The compositions of mixed fillers are summarized in Table 1.

Dolomite aggregate of Ganjafrouz Lahimchi's crusher (Babol, Mazandaran, Iran) was used in this experiment with respect to gradation curve of ASTM C33 [19]. The aggregates were in the standard range and the Particle size was less than 4.75 mm.

Methods: Specimens were prepared according to ASTM standards with several combinations of filler and aggregates. Initially, epoxy resin and hardening agent were weighed and blended. Filler and aggregates were added to the mixture with appropriate proportion and were gently mixed. In three steps, the mixture was 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. Three different ASTM tests were carried out. Compressive and flexural strength of fabricated PCs was measured according to ASTM C 579-01 [20] and C 293-02 [21] , respectively. The uniform shaped specimens were cubed (50 × 50 × 50 mm). Tensile strength was measured according to ASTM C 496-04 [22] for cylindrical polymer concrete samples (76.2 mm diameter and 152.4 mm height). Furthermore, the recorded data were the mean of triplicate values for all specimens.

Table 1: Percentage of mix proportion of fillers

	S_1	S_2	S_3
Sa	20	80	-
Sb	15	25	60
Sc	-	40	60

RESULTS AND DISCUSSION

The results of the compressive, flexural and tensile strength of epoxy PC using 100, 150 and 200% of silica powder are summarized in this section. The fabricated PCs were coded to record their chemical compositions. The specimen type is represented by a code in which EP stands for the type of resin (epoxy) and its subscript indicates the percentage of epoxy used in PC sample. The last entry in coding represents the type of the filler and the subscript shows weight percentage of the filler in PC. For instance, the composition of a specimen (EP_{15}-Sb_{200}) is shown in Table 2.

Compressive Strength: Fig. 1 shows the effect of resin and filler compositions on compressive strength of PC specimens. The obtained values for compressive strength were quite high in compare to conventional concrete. The highest compressive strength was related to PC sample EP_{15}-Sb_{200} (128.9 MPa). This value was 4 folds higher than compressive strength of Portland cement concrete (32.5 MPa). This was probably due to the maximum compactness of the aggregate and filler in the mixture also as reported in the literature [4]. Furthermore, it was found through experiments that optimum amount of resin was 15 wt% of total weight of sample.

Flexural Strength: Results of flexural strength test are summarized in Table 3. The obtained values for this experiment showed that these polymer concrete compositions reached to great flexural strength.

Table 2: Polymer concrete composition of a fabricated sample

Polymer matrix components (EP_{15}-Sb_{200})	Composition	Total mass %
Resin	Epoxy, Bisphenol-A (Honsman)	10[a]
Hardening agent	Tetra-amine 3-ethylene with HA-11 (Merck co.)	50[b]
Sand	Aggregate of Babol Ganjafrouz Lahimchi	55[a]
Filler	Silica powder	200[c]

a Percentage in relation to the mass (resin + hardening agent + sand + filler)

b Percentage in relation to the resin mass

c Percentage in relation to the mass (resin + hardening agent)

Table 3: Flexural strength of the fabricated PCs

PC type	Flexural Strength (MPa)	PC type	Flexural Strength (MPa)	PC type	Flexural Strength (Mpa)
EP_{10}-Sa_{100}	8.50	EP_{15}-Sa_{100}	13.12	EP_{20}-Sa_{100}	14.3
EP_{10}-Sa_{150}	9.25	EP_{15}-Sa_{150}	16.30	EP_{20}-Sa_{150}	15.5
EP_{10}-Sa_{200}	11.70	EP_{15}-Sa_{200}	14.30	EP_{20}-Sa_{200}	18.5
EP_{10}-Sb_{100}	14.00	EP_{15}-Sb_{100}	18.17	EP_{20}-Sb_{100}	16.5
EP_{10}-Sb_{150}	10.50	EP_{15}-Sb_{150}	20.10	EP_{20}-Sb_{150}	17.5
EP_{10}-Sb_{200}	11.20	EP_{15}-Sb_{200}	22.50	EP_{20}-Sb_{200}	11.3
EP_{10}-Sc_{100}	11.30	EP_{15}-Sc_{100}	12.30	EP_{20}-Sc_{100}	13.3
EP_{10}-Sc_{150}	8.71	EP_{15}-Sc_{150}	11.40	EP_{20}-Sc_{150}	14.5
EP_{10}-Sc_{200}	6.48	EP_{15}-Sc_{200}	10.13	EP_{20}-Sc_{200}	16.1

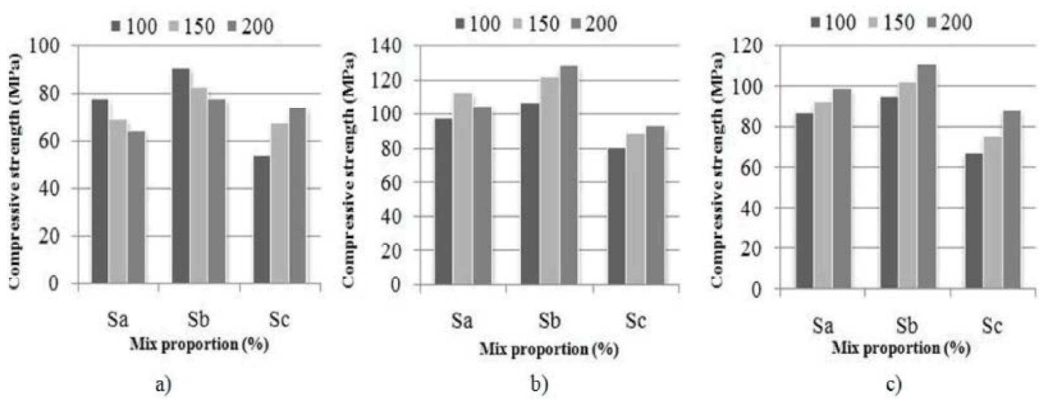

Fig. 1: Compressive strength of PC samples with a) 10 b) 15 and c) 20% resin content

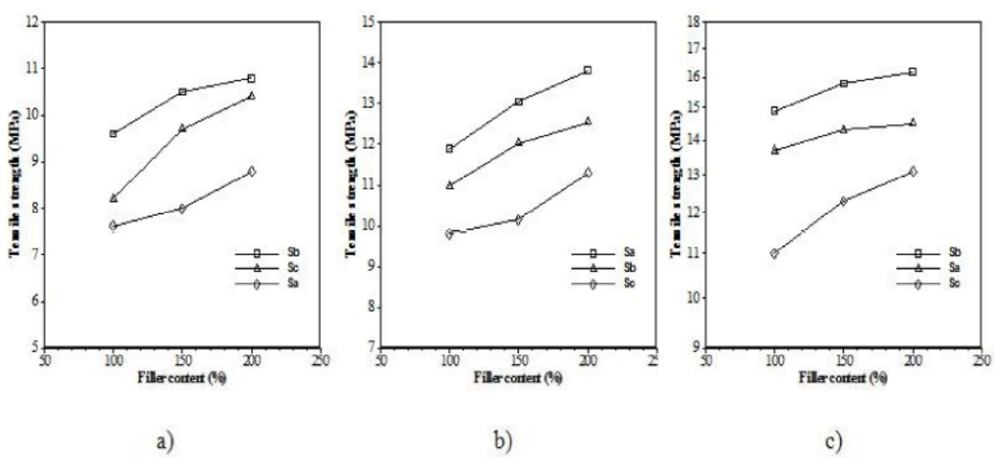

Fig. 2: Tensile strength of PC samples with a) 10 b) 15 and c) 20% resin content

The highest value for flexural strength related to EP_{15}-Sb_{200} sample was 22.5 MPa which was about 5 folds greater than the flexural strength of conventional concrete (4.5 MPa). Another considered parameter is increase in resin content of polymer concrete from 10 to 15%, had great effect on flexural strength of the specimens. However, additional amount of resin (20%) had no positive impact but it rather caused reduction in the flexural strength. It was concluded that use of 15% resin (weight of total sample) was desirable composition for PC fabrication. This value was found through actual experimental runs and data analysis.

Tensile Strength: Fig. 2 illustrates tensile strength values for epoxy polymer concrete samples with various compositions of resin and filler. It was clear to observe that changes in resin and filler compositions resulted in variation of tensile strength. Overall, higher concentrations of filler and resin yielded high strength. The tensile strength of EP_{20}-Sb_{200} sample was 16.2 MPa. This value was considerably higher than tensile strength of all other samples. The maximum tensile strength value is about 5 folds higher than the flexural strength of conventional concrete (3.42 MPa). This finding came out of experimental results obtained and also shown in Figure 2. Furthermore, it was found that an increase in amount of resin had favorable effect on tensile strength of the specimens.

CONCLUSIONS

It was concluded that the amount of resin and filler in chemical composition of the fabricated PCs had great influence on identification of the maximum physical strength. The PC specimen with 15% resin and 200% filler resulted in maximum compressive and flexural strength. The tensile strength was maximized with 20% resin and 200% filler. Generally, fine fillers may result in high mechanical strength as the fine fillers have high molecular compaction. The compressive, flexural and tensile strengths were 128.9, 22.5 and 16.2 MPa, respectively. The mechanical strength of fabricated PCs was 4-5 folds higher than Portland cement concrete.

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