Middle-East Journal of Scientific Research 5 (4): 231-234, 2010
ISSN 1990-9233

Effect of Organic Solvent on Mechanical Properties of Epoxy Polymer Concrete

[1]M. Hoseinzadeh, [2]G.D. Najafpour and [1]M.A. Beygi

[1]School of Civil Engineering, College of Engineering,
Babol Noshirvani University of Technology, Babol, Iran
[2]School of Chemical Engineering, College of Engineering,
Babol Noshirvani University of Technology, Babol, Iran

Abstract: In the present research paper use of suitable amount of solvent for formulation of epoxy polymer concrete (EPC) was investigated. Application of 50-50% mixture of acetone-toluene as solvent and co-solvent for dissolving epoxy resin with 0.0, 0.03, 0.05, 0.08 and 0.1 g of solvent per gram of epoxy were investigated. Two types of epoxy resins Dur-42 and Dur-41 with low and high molecular weight were prepared. The best composite for the prepared sample blocks were identified to have the maximum compressive and flexural strength. Maximum compressive and flexural strength for the sample fabricated with epoxy resin Dur-42 was identified. Also maximum compressive and flexural strengths for the PC sample with composition of 0.05g solvent/g of epoxy and 10% epoxy resin of Dur-42 were 88 and 17.8 Mpa, respectively.

Key words: Solvent · Flexural strength · Compressive strength · Polymer concrete · Epoxy resin

INTRODUCTION

One of the limitations for the use of polymer systems is that they may re-emulsify in humid alkaline conditions. To overcome such problem, an epoxy emulsion based polymer system has been developed [1, 2]. The properties of cement mortar blended with epoxy emulsion enhanced the newly developed modified mortar. The results showed that the mortars with the newly developed epoxy PC have superior strength properties and better resistance to the penetration of chemical ions and carbon dioxide [3, 4].

Polymer concrete (PC) is a composite material produced as replacement concrete for conventional hydrated cements [5-7]. PC having number of advantages in terms of physical and chemical properties [8, 9]. As relatively new construction material it is used in extreme conditions because of its high performance, such as durability and excellent mechanical strength [2, 10, 11]. The PC shows high chemical resistance compared to conventional cement concrete [6, 12, 13]. The constructed structure with PC is ready after several days [14]. PC is produced from a mixture of fine sands and gravel which are cemented with epoxy resin which is dissolved in a chemical solvent with additional hardening chemical agents [1, 15, 16]. The role of solvents has been investigated by a number of scientists for improving the mechanical strength [9, 17]. With the penetration of epoxy in solvent the physical properties, mechanical strength, durability and workability of PC are extensively improved [1, 10-12, 14].

The epoxy equivalent weight is one of the major parameter in formulation of epoxy adhesive compositions; that is defined as weight of resin contained in equivalent epoxy. Curing agent is used for cementation of epoxy resin, as a result cross-linking reaction caused to enhance the physical and mechanical properties of the epoxy polymer [9].

The low viscosity epoxy resin possesses additional advantages such as high wetting properties and makes reinforcement concretes. Also low viscous resin with high uniformity can easily penetrate into porous materials and may cross link much better than high viscous material [1, 16, 17].

Generally, solvents are used to lower the viscosity of epoxy resin systems either to permit easy into ingredients or to aid in application of the adhesive onto a substrate. Solvents are low-molecular-weight chemical compounds that are compatible with epoxy resins and their curing agents. Solvents have relatively high vapor pressures as easily vaporized and leave the material while their actions are preformed. One of the property of solvent is dispersing, mixing and wetting of components in the resin

Corresponding Author: M.A. Beygi, School of Civil Engineering, College of Engineering,
Babol Noshirvani University of Technology, Babol, Iran, E-mail: m.beygi@nit.ac.ir

system at the formulation stage [9]. Solvent can lower the viscosity to provide easier mixing of multicomponent adhesive systems and dispensing at the application stage. Organic solvent has the ability to dissolve epoxy resins and hardeners for many applications [9, 17].

Typical solvent used in epoxy adhesive systems are acetone, methyl ethyl ketone (MEK), toluene, xylene, glycol ethers and alcohols. Solvents are commonly used to reduce the surface tension of the adhesive formulation [9, 16]. Solvents are not involved in chemical equilibrium or surface energy of the system. They only solvency provided by the mixed solvents properties was to lower the viscosity and the wetting properties are established in a high rate [9].

The purpose of this paper was to investigate application and impact of solvents on mechanical strength of PC sample. The effect of solvent blended with epoxy resin on compressive and flexural properties of PC were investigated. Five ratios of solvent to epoxy resin for preparation of PC samples were utilized for identification and use of suitable amount of solvent in preparation of epoxy adhesives.

MATERIAL AND METHODS

Resin and Solvents: Two types of epoxy resins commercial grade Dur-42 and Dur-41 with low and high molecular weight were selected. The density of epoxy resin Dur-42 and Dur-41 were 1.12 and 1.18 g/cm^3, respectively. A mixture of acetone and toluene 50-50% with the ratio of 0.0, 0.03, 0.05, 0.08 and 0.1g solvent/g epoxy resin were prepared. Solvents, toluene and acetone industrial grade with purity of 90% were obtained from local chemical market (Tehran, Iran). The solvent mixture was use to dissolve epoxy resin prior to mix with aggregate. Physical properties of the solvents are summarized in Table 1. Polymer concrete samples with epoxy 8 and 10% resin Dur-42 and Dur-41 were fabricated. The solvent was gradually vaporized; after 7days the solvent free sample was ready for testing. The specifications of epoxy resin Dur-42 and Dur-41 are summarized in Table 2.

Aggregate: River sand with particle size of less than 9 mm and specific gravity of 2.64 g/cm^3 was utilized as aggregate in the sample preparation. The bulk density obtained for the aggregate was 1.69 g/cm^3. Before use, the aggregate was oven-dried at 100±5°C for one day.

Mixture of Aggregate, Solvents and Polymer: To prepare PC samples, several combinations of solvents were mixed with epoxy resin and aggregate. Several weight percentages of epoxy resins were prepared and then the dried samples were tested. The effect of solvents/epoxy resin ratio with two types of resins on mechanical properties of the prepared PC samples with 8 and 10% polymer were investigated.

Table 1: Physical properties of solvents

Solvent	Density, g/cm^3	Melting point, °C	Boiling point, °C	Viscosity, cp	Solubility in water, g/l
Toluene	0.866	-95	110.6	0.59	0.47
Acetone	0.789	-95	56.2	0.31	miscible

Table 2: Specification of epoxy commercial epoxy resins

Epoxy resin	Density, g/cm^3	Potlife, min	Setting time, h	Ratio of Curing agent/ resin	Viscosity, p
Dur-42	1.12	30	2	1:6	50-200
Dur-41	1.18	30	2	1:4	50-225

ASTM: The prepared samples were tested according to ASTM C 579 method for compressive strength for the sample size of 50×50×50 *mm* [18]. The ASTM C 580, method A, was used for flexural strength with the sample size of 25×25×254 *mm* [19]. Based on ASTM C 905, method B, the apparent density of the air-dried samples was determined by the weight difference between wet and dried samples [20].

RESULTS AND DISCUSSIONS

In preparation of the PC samples, solvents and epoxy resin as effective parameters on physical and mechanical properties, compressive and flexural strengths of PC were investigated. The polymer content (wt %) with 5 ratios of solvent/ epoxy resin were also studied. Besides the compressive and flexural strengths, the weight changes in the prepared PC samples were also monitored. As the percentages of epoxy resin increased to 10%, the strengths of PC samples were improved.

Figure 1 shows the apparent density of PC with respect to the ratio of solvent/epoxy resin. Two types of epoxy resins with combination of 8 and 10% epoxy resin were used. Epoxy resin with lower specific gravity (Dur-42) showed slightly higher apparent density than high specific gravity (Dur-41). The PC sample with the ratio of 0.05 g solvent/g of epoxy resin and 10% of epoxy Dur-42, maximum apparent density of 2.21g/cm^3 was obtained. The apparent density for epoxy resin with high specific gravity is also reached to maximum value of 2.21 with solvent/epoxy ratio of about 0.08. Additional solvent ratio caused slightly decrease in apparent density.

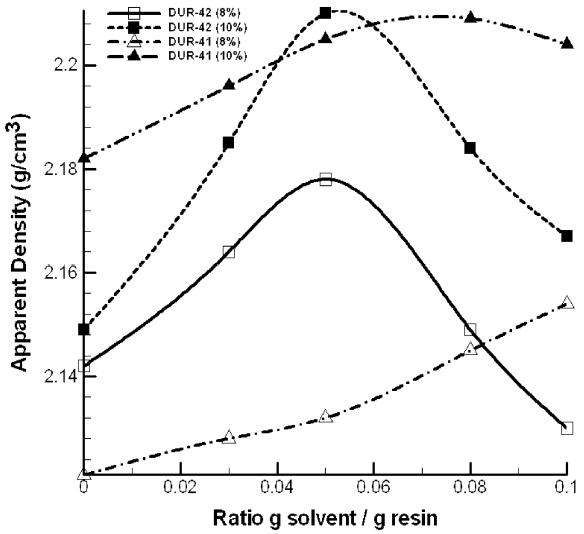

Fig. 1: Polymer concrete density with respect to solvent/epoxy ratio

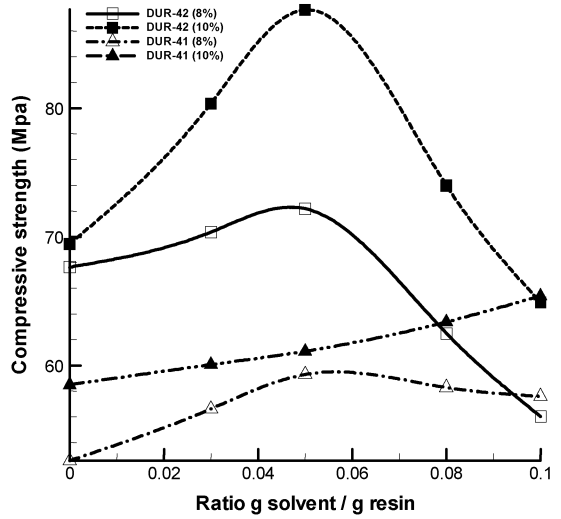

Fig. 2: Compressive strength of polymer concrete with respect to solvent/epoxy ratio

Figure 2 presents the compressive strength of epoxy resins Dur-42 and 41 with respect to ratio of solvent/epoxy resin. The highest compressive strength was obtained with PC sample make with 10% epoxy Dur-42 with solvent/epoxy ratio of 0.05. The maximum apparent density compressive strength was 88 Mpa. Generally the compressive strength for epoxy resin Dur-42 was higher than epoxy resin Dur-41. That was most probably due to epoxy adhesive penetration into the core of aggregate particles and also may create cross link as well. The ratio of solvent also has great impact on viscosity of the solution as the solvent can dissolve epoxy resin in the solution. With the great solvency the viscosity of polymer is reduced and that would assist the polymer molecules to diffuse into aggregates.

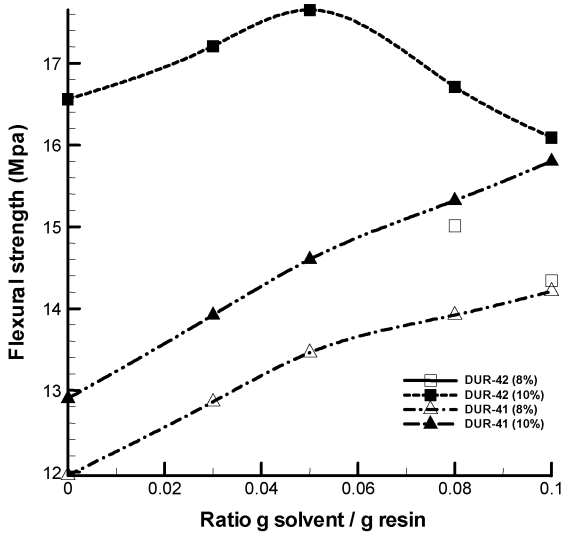

Fig. 3: Flexural strength of polymer concrete with respect to solvent /epoxy ratio

The trend of flexural strength may be similar to compressive strength and the best ratio of 0.05g of solvent/g epoxy resin given the highest flexural strength of 17.8 Mpa (Figures 3). The flexural strength of PC sample with epoxy resin Dur-41 shows increasing trends as the ratio of solvent increased. The maximum flexural strength with 10% epoxy resin Dur-42 was obtained.

In fact, solvent was the effective parameter in strength of the PC sample and also the amount of resin may improve the toughness of the fabricated samples. Extra additional epoxy resin is not recommended because of the cost effectiveness and environmental concepts. Even extra epoxy can increase the strength of PC; however the required toughness with the amount of resin can be optimized with minimum fabrication costs. Also use of minimum solvent was recommended in the literature [9].

CONCLUSIONS

According to conducted experiments, it was concluded that the solvent had great influence on penetration of epoxy resin into core matrix of the aggregates. In fact, it is believed that solvent can lower the viscosity of polymer solution. Excessive amount of solvent most probably would not let the adhesiveness of polymer to act strongly. Therefore 0.05 g of solvent assisted polymer molecules to engage with aggregates. The maximum compressive and flexural strengths for PC sample with 10% resin and 0.05g solvent/g resin were 88 and 17.8 Mpa, respectively.

ACKNOWLEDGEMENTS

The present research was made possible through a Noshirvani University of Technology (NTU) postgraduate student's research grant, sponsored by the university research committee (Babol, Iran). The authors wish to thank Dean of Civil School for the research facilities and technical assistants provided in their Concrete Lab. Department of Civil Engineering (NTU).

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