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Effect of Agro-Waste Ash on Mechanical Properties of Epoxy Polymer Concrete

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Abstract: This paper focuses on addition of fillers in epoxy resin and aggregate for polymer concrete (PC) preparation. For the preparation of PC, two kinds of fillers, i.e. rice husk ash and broom stem ash were used. According to experimental results, addition of fillers had a positive impact on the physical and mechanical properties of the PC. In the PC sample with rice husk ash, with the filler/aggregate ratio of 0.075 and 18.4% polymer, maximum compressive strength of 86.41 Mpa was obtained; while the compressive strength of the polymer concrete without filler was 71.2 Mpa. The PC sample with broom stem ash, with the filler/aggregate ratio of 0.12 and 23% polymer showed the maximum flexural strength.

Key words: Aggregate · Flexural strength · Compressive strength · Filler · Polymer concrete · Epoxy resin

INTRODUCTION

Polymer concrete (PC) is a composite material produced as replacement concrete for conventional hydrated cements. The PC having shown a number of advantages in terms of physical and chemical properties [1, 2]. Special attention has been drawn to PC as construction material for its multiple properties [3]. As relatively new construction material it is used in harsh conditions for its high performance, such as durability and excellent mechanical strength [4, 5]. The PC shows high chemical resistance compared to conventional cement concrete [6]. The constructed structure with PC is ready after one day [7, 8]. In addition, PC has fast curing time and is often used in offshore platforms. PC is produced from a mixture of fine sands and gravel which are cemented with a polymer such as epoxy resin or recycled polyethylene terephthalate (PET), with addition of hardening chemical agent and fillers such as calcium carbonate and fly ash [2, 9-11].

Fillers are used in polymer matrix to improve mechanical properties. Use of fillers to certain extend may enhance the mechanical strength. Fillers are also used in polymer matrix to lower the curing reaction rate and reduce the degree of exotherm. Based on the fact fillers in PC are also helpful to enhance the quality of the material [12]. The role of the filler has been investigated by a number of scientists for improving the mechanical strength of PC [13]. The use of the filler is meant to occupy the void spaces between the polymer matrix and the aggregates provided by the firm structure of PC. With fillers the physical properties, mechanical strength, durability and workability of PC are extensively improved [11, 14]. The use of fillers creates an environment for the PC to be impermeable to any interaction of an external agent [15]. Gorninski and his coworkers [15] have demonstrated that by addition of fillers from 7 to 14wt% into a mixture of 11% polyester resin of unsaturated isophthalic acid; about 18.8% of PC compressive strength has been improved. Another independent experiment was

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conducted by Harja and his research team [14]; they have found that the PC compressive strength with 6.4 to 12.8% fly ash in a mixture of 12.4% epoxy resin had shown significant improvement in physical and mechanical properties of the PC sample. Silicon oxide and fine sands are also used as fillers in concrete. Rice husk and broom stem are agro-waste materials used for preparation of ash in a combustion chamber. The ash is used as filler in PC and rice husk ash (RHA) contains highly reactive pozzolanic compound normally used in concrete to give it high performance [16-18]. Several researches have been conducted on preparation of ash from rice husk [19, 20]. The silicon content of rice husk ash may be identified as amorphous silica. Since rice husk ash is successfully used in concrete, it can also be used in PC. The pozzolanic composition of the ash may not have much influence on the PC properties, but it is utilized as high quality filler in PC. The composition of the filler may have interaction with various concentrations of resins. In order to define the suitability of the filler, extensive research needs to be conducted for finding the chemical composition desired of resins.

The purpose of present research was to identify the effect of fillers on mechanical properties of polymer concrete. Addition of polymer and fillers were also examined for improvement and enhance the resistances in the PC. The fillers obtained as ash from the burned rice husk and broom stem were blended with epoxy resin and fine sands.

MATERIAL AND METHODS

Resin and Hardener: Epoxy resin Aerosil R805 based on diglycidyl ether of Bisphenol A, was selected for the preparation of the samples. Non-reactive solvent was used to reduce the polymer viscosity and a hardening agent was added in proportion of 1:2, hardeners: resin, respectively. Epoxy equivalent weight is in the range of 185- 192 with viscosity of 11000-15000 centipoise (cP). The resin and hardener specific gravities were 1.15 and 1.03 g/cm^3, respectively.

Fillers: Two kinds of fillers, i.e. rice husk and broom stem ash, were used in preparation of the samples. The content of Si in the ash was affected by the combustion temperature of the rice husk and broom stem. The weight fraction (g ash/g initial biomass) of the ash obtained from broom stem was much less than the ash resulted from rice husk. The filler was primarily sieved (sieve no. 30, size: 600μm) and then the fine powder sieved with sieve no. 100; the particle size of less than 150μm was used for the sample preparation. Table 1 shows the characteristics of the fillers used in the PC sample.

Table 1: Characteristics of fillers

	Density (g/cm^3)	Bulk volume (g/cm^3)	Specific surface (Blain cm^2/g)
Rice husk ash	2.05	0.35	4400
Broom millet ash	2.16	0.27	3900

Aggregate: River sand with particle size of less than 5 mm and specific gravity of 2.82 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, Filler and Polymer: To prepare PC samples, several combinations of rice husk and broom stem ash were mixed with epoxy resin and aggregate. Several weight percentages of filler were used and then the dried samples were tested. The effect of polymer-filler interactions on mechanical properties of the prepared PC samples with 13-23% of polymer was also investigated. To certain extend with addition of filler into PC samples increased the strengths of PC samples; but behind the optimum amount of filler the mechanical strength did not improve.

Testing Methods: The prepared samples were tested according to ASTM C-579 method for compressive strength for the sample size of 50 × 50 × 50 *mm* [21]. The ASTM C-580, method A, was used for flexural strength with the sample size of 25 × 25 × 254 *mm* [22]. 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 [23].

RESULTS AND DISCUSSIONS

Once the PC samples were prepared, several effective parameters on physical and mechanical properties, compressive and flexural strengths of PC samples were investigated. The polymer content (wt %) with suitable hardening agents and various percentages of fillers were also studied. Besides the compressive and flexural strengths, the weight changes in the prepared PC samples were also monitored. Table 2 shows the wt% and composition of the prepared samples with the variation of 13 to 23% polymer content. Addition of certain amount of filler to polymer in PC samples may gradually increase the

Table 2: Composition of the PC specimens (wt%)

Polymer (13%)			Polymer (18.4%)			Polymer (23%)		
Sample no.	Aggregate (%)	Filler (%)	Sample no.	Aggregate (%)	Filler (%)	Sample no.	Aggregate (%)	Filler (%)
1	86.99	0	7	81.60	0	15	77.00	0
2	85.69	1.29	8	80.40	1.2	16	75.83	1.16
3	84.44	2.54	9	79.23	2.37	17	74.74	2.26
4	83.23	3.75	10	78.10	3.51	18	73.67	3.34
5	82.05	4.93	11	77.01	4.61	19	72.63	4.37
6	80.89	6.06	12	75.91	5.69	20	71.61	5.38
			13	74.87	6.74	21	70.62	6.38
			14	72.86	8.74	22	68.74	8.26

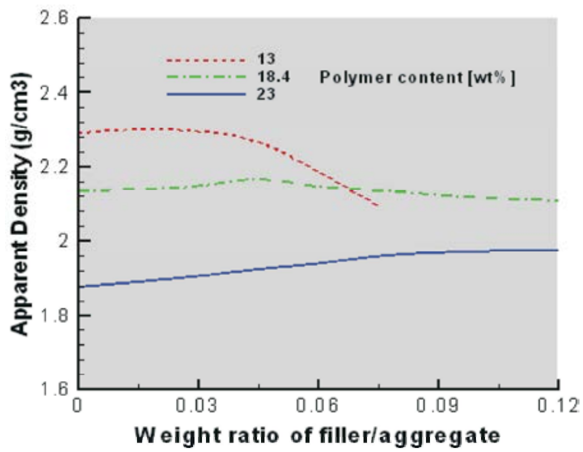

Fig. 1: Apparent density of PC with rice husk ash as filler

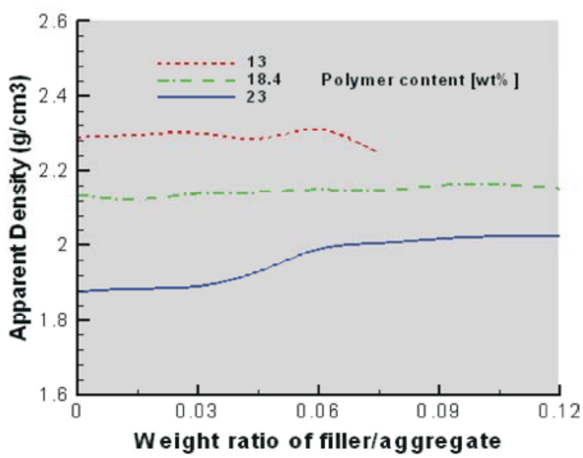

Fig. 2: Apparent density of PC with broom stem ash as filler

strengths of PC samples till the amount filler reach to an optimum value then the strengths were decreased as the amount filler was exceeded the desired value.

Figure 1 shows the apparent density of PC with respect to the ratio of rice husk ash as filler/aggregate. As the weight percent of the polymer increased, the apparent density of the PC was decreased. In PC samples with low percentage of polymer (13%), with an increase in mass of fillers the apparent density of the PC was decreased. There were no significant changes in the apparent density of the PC with 18.4% polymer, while there was a slight increase with 23% polymer. The resulted samples of PC had lower weight compared with conventional concrete.

The apparent density of PC with broom ash as filler and various polymer contents is shown in Figure 2. The trends for the curves with the filler/aggregate ratio are almost similar to Figure 1.

Figures 3 and 4 show the variation of compressive and flexural strengths of PCs with 13, 18.4 and 23% of polymer along with a variation of rice husk ash as filler. An additional weight percent of the polymer in the samples without any filler reduced the compressive and flexural strengths. That was due to a replacement of the polymer with aggregates. In samples with 13% of polymer, an addition of a small amount of filler, the mechanical strength was slightly improved. Samples with extra fillers caused a reduction in strength. An addition of filler (filler/aggregate ratio of 0.075) to 18.4% increased the mechanical strength of polymer by 22%. For the filler/aggregate ratio greater than 0.075 there was a slight decrease in mechanical strength. For PC samples with 23% polymer, the compressive strength was increased by 41%. The flexural strength of PC sample with filler/aggregate ratio of 0.12 was improved to 44%. The maximum compressive and flexural strengths of the epoxy concrete were 86.41 and 27.65 Mpa, respectively.

Figures 5 and 6 depict the effect of fillers on compressive and flexural strengths of PC with broom stem ash. Addition of broom stem ash to PC samples with 13% polymer was experimented. There was no significant improvement on compressive and flexural strengths of PC samples by addition of broom stem ash to 13% polymer. Extra amount of broom stem ash to PC and with the filler/aggregate ratio of 0.045 the PC strength remained constant and eventually extra amount of ash may improve

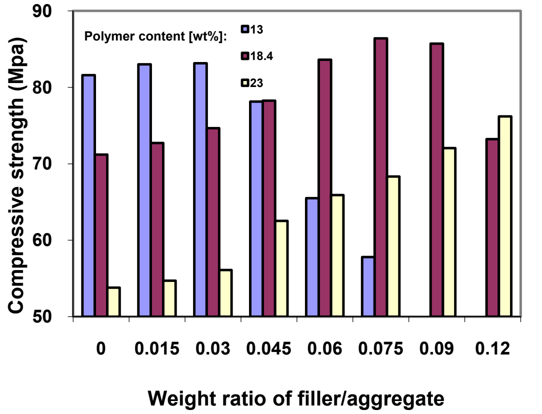

Fig. 3: Compressive strength of PC with rice husk ash

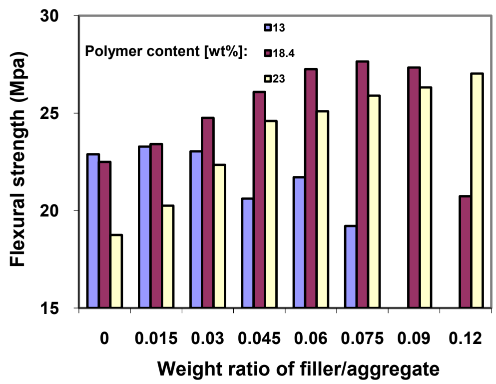

Fig. 4: Flexural strength of PC with rice husk ash

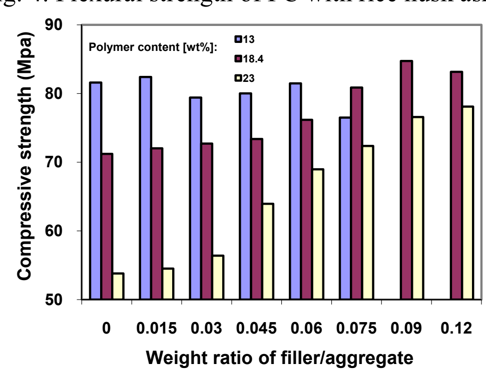

Fig. 5: Compressive strength of PC with broom stem ash

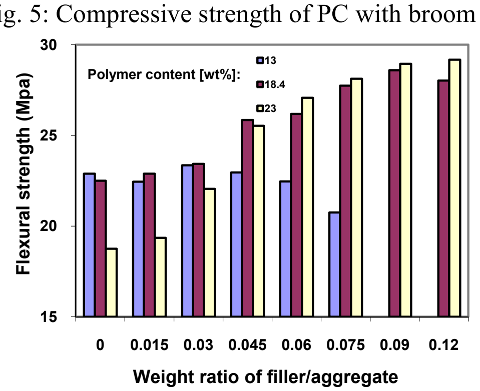

Fig. 6: Flexural strength of PC with broom stem ash

the mechanical properties. For PC samples with rice husk ash as filler, mechanical properties did not show similar behavior. Addition of fillers to PC with 18.4% polymer improved the compressive and flexural strengths of PC. More filler may improve the physical properties of PC. The use of broom stem ash added to PC with the filler/ aggregate ratio of 0.09 improved the compressive and flexural strengths by 19 and 27%, respectively. Also, the maximum flexural strength was obtained with the filler/aggregate ratio of 0.12 and 23% polymer. While, comparing the samples with 13% polymer without filler with samples that had 23% polymer and the filler/aggregate ratio of 0.12 showed that the samples without filler had higher compressive strength.

Comparing the plotted data for the filler of rice husk ash with broom stem ash showed that the rice husk ash had slightly higher compressive strength than the broom stem ash. The reduction of mechanical strength in PC with rice husk ash was sharper than in PC with other filler. Addition of broom stem ash (filler/aggregate ratio of 0.012) and 23% polymer, the flexural strength of the PC was maximized. The rice husk ash in the filler/aggregate ratio range of 0.015-0.03 flexural strength was evaluated, had fairly good strength. The rice husk ash at low weight percent of filler and the broom stem ash with high weight percent of filler were the most suitable samples prepared for exhibiting high mechanical strength. There was no reported data for the use of ash from rice husk or broom stem in PC fabrication. Certainly, there was no opportunity to compare the obtained data with the existing literatures since the type of resins and hardeners used are not in identical conditions. Most probably the comparative data may not be relevant to present work.

CONCLUSIONS

According to our experiments, it was concluded that PC without fillers did not have sufficient mechanical strength for the prepared PC samples; even the weight percent of polymer in the tested samples were relatively high. The addition of fillers had a positive impact on the physical and mechanical properties of the PC. For the preparation of PC samples; several individual batch of defined percentage of rice husk or broom stem ashes with epoxy resin and aggregate were prepared. Addition of desired amount of filler to polymer in PC samples had increased the mechanical strengths of the PC samples with an optimum value of filler. Beyond the desired value, additional filler did not influence the strength of PC sample. In the PC sample with rice husk ash, with the filler/aggregate ratio of 0.075 and 18.4% polymer, the maximum compressive strength of 86.41 Mpa was achieved. The PC sample with broom stem ash and 23% polymer showed high flexural strength.

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REFERENCES

1. Gorninski, J.P., D.C. Dal Molin and C.S. Kazmierczak, 2004. Comparative assessment of the properties of polymersconcrete compounds with isophtalic and orthophtalic polyester. In: M. Maultzsch (Eds) Proceedings of the 11th International Congress on Polymer in Concrete, Berlin, pp: 256-63.
2. Blaga, A. and J.J. Beaudoin, 2010. Polymer Modified Concrete, NRC Institute for Research in Construction. National Research Council Canada, 2:4,http://www.nrc-cnrc.gc.ca/eng/ibp/irc/cbd/building-digest-241.html.
3. Fowler, D.W., 1996. PC Materials Properties and Application. Proceedings of the ICPIC Workshop Bled Slovenia, pp: 37-45.
4. Soraru, G.D. and P. Tassone, 2004. Mechanical durability of a polymer concrete: a Vickers Indentation Study of the Strength Degradation Process. Construction and Building Materials, 18(8): 561-566.
5. Bubani, M. and P. Tassone, 1998. Effect of pore size distribution on the mechanical strength of polyester concrete. Proceedings of the IXth International Congress on Polymers in Concrete.
6. Reis, J.M.L., 2010. Fracture assessment of polymer concrete in chemical degradation solutions. Construction and Building Materials, 24(9): 1708-1712.
7. Dikeou, J.T. and A.O. Kaeding, 1992. US and other specifications and standards for polymer concretes. V.V. Paturoev and R.L. Serykh, (Eds). Proceedings of the 7th International Congress on Polymer in Concrete, Moscow, pp: 9-25.
8. Rebeiz, K.S. and D.W. Fowler, 1996. Shear and flexure behavior of reinforced polymer concrete made with recycled plastic wastes. American Concrete Institute, 166: 61-78.
9. Rebeiz, K.S., D.W. Fowler and D.R. Paul, 1993. Recycling Plastic in Polymer Concrete for Construction Application. Journal of Materials in Civil Engineering, 5(2): 248-273.
10. Jo, B.W., S.K. Park and J.C. Park, 2008. Mechanical Properties of Polymer Concrete Made with Recycled PET and Recycled Concrete Aggregates. Construction and Building Materials, 22(12): 2281-2291.
11. Gorninski, J.P., D.C. Dal Molin, C.S. Kazmierczak and C. Pauletti, 2001. Polymer concrete based on polyester resin and fly ash as filler. Tenth International Congress on Polymers in Concrete, Honolulu, pp: 300-311.
12. Petrie, E., 2005. Epoxy Adhesives Formulations. McGraw-Hill, New York.
13. Soh, Y.S., Y.K. Jo and H.S. Park, 1997. Effect of Filler on the Mechanical Properties of Unsaturated Polyester Resin Mortar. In: Proceedings of Second East Asia Symposium on Polymer in Concrete (II-EASPIC), pp: 67-74.
14. Harja, M., M. Barbuta and L. Rusu, 2009. Obtaining and characterization of polymer concrete with fly ash. Journal of Applied Science, 9(1): 88-96.
15. Gorninski, J.P., D.C. Dal Molin and C.S. Kazmierczak, 2007. Strength degradation of polymer concrete in acidic environments. Cement and Concrete Composites, 29 (8): 637-645.
16. Ismail, M.S., A.M. Waliuddin, 1996. Effect of rice husk ash on high strength concrete. J. Const. Build. Mat, 10(7): 521-526.
17. Ramezanianpour, A.A., F. Gafarpour and M.H. Majedi, 1995. The use of rice husk ash in the building industry. Building and Housing Research Center (BHRC).
18. De Sensale, G.R., 2006. Strength development of concrete with rice husk ash. Cement and Concrete Composites, 28(2): 158-160.

19. Ramezanianpour, A.A., M.M. Khani and G. Ahmadibeni, 2009. The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes. International Journal of Civil Engineering, 7 (2): 83-91.
20. Gastaldini, A.L.G., G.C. Isaia, N.S. Gomes and J.E.K. Sperb, 2007. Chloride penetration and carbonation in concrete with rice husk ash and chemical activators. Cement and Concrete Composites, 29 (3): 176-180.
21. ASTM: 2001. American Society for Testing and Materials, Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars. Grouts, Monolithic Surfacing and Polymer Concretes: C 579-01, Annual Book of ASTM Standards, Pennsylvania, USA.
22. ASTM: 2002. American Society for Testing and Materials, Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes: C 580-02 Annual Book of ASTM Standards, Pennsylvania, USA.
23. ASTM: 2001. American Society for Testing and Materials, Standard Test Methods for Apparent Density of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes: C 905-01, Annual Book of ASTM Standards, Pennsylvania, USA.