BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi
Tomul **LIV (LVIII)**, Fasc. 3, 2008
Sectia
CONSTRUCŢII. ARHITECTURĂ

PROPERTIES OF FIBER REINFORCED POLYMER CONCRETE

BY

MARINELA BĂRBUŢĂ[1,*] **and MARIA HARJA**[2]

Abstract. Polymer concrete is a composite material realized with resin and aggregates. In the present study the epoxy resin was used for binding the aggregates. In the composition were introduced near the fly ash, used as filler, the cellulose fibers. The mechanical characteristics such as compressive strength, flexural strength and split tensile strength of polymer concrete with fibers were investigated. The fiber percentage was constant, the epoxy resin and the filler dosages were varied. The cellulose fiber had not improved the mechanical characteristics of the polymer concrete in comparison to that of polymer concrete without cellulose fibers.

Key Words: Epoxy Resin; Polymer Concrete; Fiber; Mechanical Strength.

1. Introduction

In the modern building materials and construction industry the role of polymer is increasing day by day. The composites using polymer can be: polymer modified concrete (PMC), when the polymer is used near cement, polymer impregnated concrete (PIC), when the cement concrete is treated by soaking and polymerization, and polymer concrete (PC), when the binder is a polymer that replaces the cement paste [1], [2]. These composites have some advantages compared to ordinary cement concrete such as: rapid hardening, high mechanical strengths, chemical resistance, etc. Among the disadvantages is their high cost. The utilization domain of polymer concrete is continuously diversifying: PMC is widely used for floor and bridge overlays; acrylic latex has been used to produce mortars which can be sprayed on architectural finish [2]; PIC was first widely used in bridge decks, pipes and conduits for aggressive fluids, floor tiles, building cladding, hazardous waste containment, post-tensioned beams and slabs, and stay-in place formwork [2]; PC was used as early as 1958 in the USA to produce building cladding.; today it is used for cultured marble for counter tops, lavatories, as repair material, overlays for bridge and floors in sport arenas and stadiums, laboratories, hospitals, factories; also precast PC was used for drains, underground boxes, manholes, acid tanks and cells, tunnel lining, shells, floor tiles, architectural moldings and machine tools and bases [2].

*Corresponding author: *e-mail address:* barbuta31bmc@yahoo.com

Polymer concrete is similar to ordinary cement concrete because it contains fine and coarse aggregates, but the hydraulic binder is totally substituted with a polymer material. The aggregates are bounded together by the polymer matrix. Polymer concrete contains no cement or water. The performances of polymeric concrete depend on the polymer properties, type of filler and aggregates, reinforcing fiber type, curing temperature, components dosage, etc., [3], [4].

Polymer binder can be a thermoplastic, but more frequently a termosetting polymer. The polymers most frequently used are based on four types of monomers or prepolymer system: methyl methacrylate, polyester prepolymer-styrene, epoxyde prepolymer hardener and furfuryl alcohol [5].

The aggregates used in dry state can be silicates, quartz, crushed stone, gravel, limestone, calcareous, granite, clay, etc. In the composition can be used also the filler. Different types of fine materials can be used such as: fly ash, silica fume, phosphogyps, cinder, etc. [6], [7]. Filler, especially fly ash, can improve the properties of polymer concrete [8].

Polymer concrete can be reinforced with fibers like: glass, carbon, boron [5] or natural fibers like: coconut, banana fibers, sugar cane bagasse, [9], cellulose. Fracture properties can be improved by addition of short glass or carbon fibers [9]. In the case of natural fibers only coconut fibers can be excellent reinforcement for polymer concrete. Sugar cane bagasse can be an alternative and banana fiber is not indicated for using as reinforcement [9].

In what follows the experimental results of studies regarding polymer concrete with cellulose fibers are presented. The compositions used in the present study derive from a previous one which investigated a large number of compositions using different dosages of resin and filler [10], [11]. The mechanical characteristics such as: compressive strength, flexural strength and split tensile strength were investigated on fiber reinforced polymer concrete made with different dosages of resin and filler, the fiber dosage being constant for all mixtures.

2. Experimental

2.1. Materials

The experimental researches on polymer concrete were made by using the following materials: polymer, fly ash as filler, crushed aggregates and fiber type ARBOCEL.

The polymer was type epoxy resin, called ROPOXID, made in Romania by POLICOLOR Bucharest [9]. The hardener was type ROMANID 407, also made by POLICOLOR Bucharest [9].

The fly ash (FA) from the power plant CET Holboca, Jassy, was added to the fine aggregates [11]. The fly ash is an inorganic waste produced by burning pulverized coal in power stations [12]. Fly ash consists of many small, glass-like particles ranging in size from 0.01 to 100 μm.

Chemically FA contains oxides, hydroxides, carbonates, silicates, and sulfates of calcium, iron and aluminum. The content in carbon is given from loss ignition. FA is a heterogeneous mixture of amorphous and crystalline phases and is generally considered to be a ferroaluminosilicate element. The mineralogical, physical and chemical properties of FA depend on the nature and composition of the coal, conditions of combustion, type of emission control devices, storage and evacuation methods. Storage methods may affect weathering rates, especially under humid conditions where soluble constituents may be leached. The principal characteristics of FA are: colour gray to black, function of carbon unburned, particles sizes between 0.01 to 100 μm; the shape of particles is spherical, specific surface is between 4,800...5,200, the density is between 2,400 and 2,550 kg/m^3 [12].

The aggregates were used in two sorts: 0...4 mm and 4...8 mm, with continuous granulosity, obtained from crushed river gravel by S.C. EMBERON SRL Jassy.

The ARBOCEL fibers are natural cellulose fibers, produced by J. Rettenmaier & Söhne GMBH. ARBOCEL is produced from cellulose in various qualities (fiber lengths, thicknesses, purities, etc.) The properties of ARBOCEL cellulose fibers are: mean fiber length of 10 μm, completely safe, insoluble in water and organic solvents, resistant to dilute acids and bases. The fiber was used in proportion of 3% from the mass of resin plus the hardener.

2.2. Experimental Samples

For the study of polymer concrete properties nine compositions (BPFF) were prepared in the experimental program (Table 1).

Table 1
Polymer Concrete Mixtures, [%]

Types	Resin	FA	Aggregate Sort I	Aggregate Sort II	Fiber ARBOCEL
BPFF1	1 2...4	1 2...8	37.4	37.4	3
BPFF2	1 2...4	6...4	43.8	37.4	3
BPFF3	1 5...6	9...6	37.4	37.4	3
BPFF4	1 5...6	6...4	40.6	37.4	3
BPFF5	1 2...4	9...6	40.6	37.4	3
BPFF6	1 6...4	7...2	38.2	38.2	3
BPFF7	1 3...2	1 0...4	38.2	38.2	3
BPFF8	1 3...2	7...2	41.4	38.2	3
BPFF9	1 4...0	8...0	39.0	39.0	3

The polymer concrete with different compositions as is given in Table 1, was prepared by mixing firstly the resin with hardener, then after complete homogenization the fibers were introduced in the mixture (Fig. 1).

Fig. 1. – Cellulose fiber mixing with resin.

The fly ash was added to the mix of aggregates and the resin and aggregates were mixed by the mechanical mixer. After complete mixing, the polymer concrete was poured in formworks.

For each composition the density was determined. The following mechanical characteristics were experimentally tested: compressive strength on cube sample of 70.7 mm sizes, flexural strength and split tensile strength on prismatic samples of sizes $210 \times 70 \times 70$ mm, according to standard prescriptions [13], (Fig. 2).

Fig. 2. – Samples of polymer concrete with fibers.

3. Results and Discussions

According to EN 12390/2001 the mechanical characteristics of polymer concrete with cellulose fiber, experimentally determined namely: compressive strength (fc), flexural strength (fti) and split tensile strength (ftd) are given in Table 2.

Table 2
Mechanical Characteristics of Polymer Concrete with Fibers

Composition	fc, [MPa]	fti, [MPa]	ftd, [MPa]
BPFF1	55.02	14.69	6.92
BPFF2	46.41	14.18	6.91
BPFF3	56.5	17.09	6.50
BPFF4	51.84	14.09	5.85
BPFF5	49.47	14.60	6.39
BPFF6	46.53	17.03	6.50
BPFF7	62.62	15.35	4.29
BPFF8	50.41	13.55	5.10
BPFF9	57.02	17.57	6.94

From the experimental results the following observations can be made:

a) The values of **compressive strengths for polymer concrete with fibers** (Fig. 3) vary between 62.62 MPa (for BPFF7) and 46.41 MPa (for BPFF2).

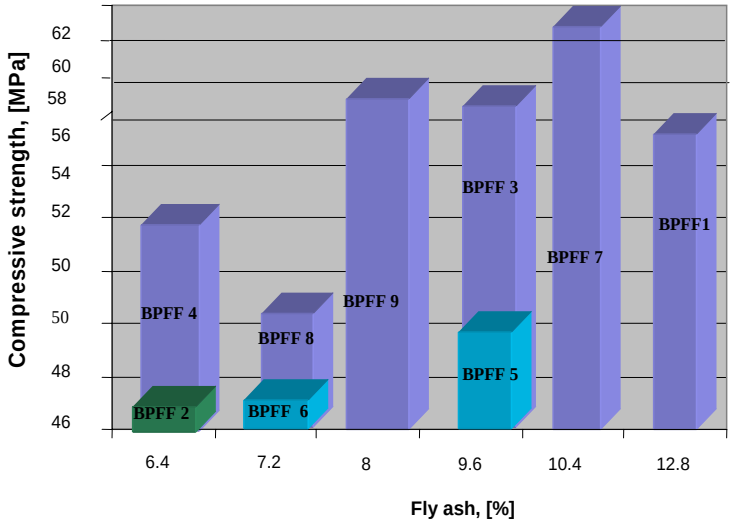


Fig. 3. – Variation of compressive strength for polymer concrete with fiber.

b) With the increasing of resin and fly ash dosage the **compressive strengths** increase (Figs. 4 and 5).

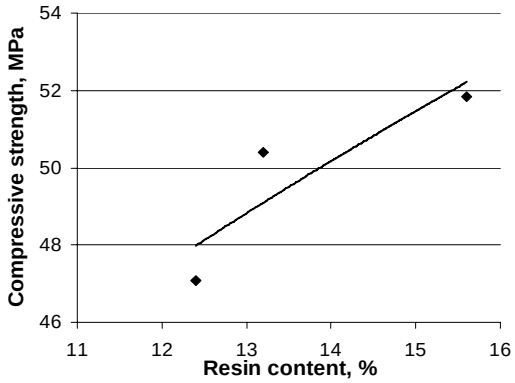


Fig. 4. – Variation of compressive strength for polymer concrete with fiber *vs.* the resin content, for 6.4% FA.

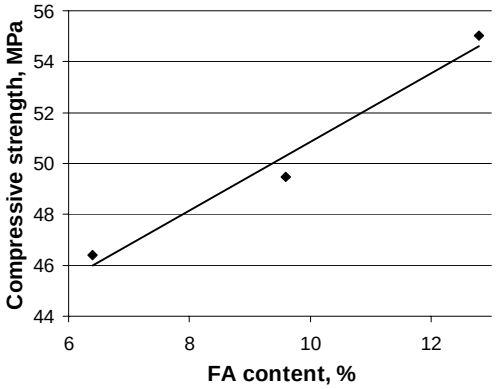


Fig. 5. – Variation of compressive strength for polymer concrete with fiber *vs.* the FA content, for 12.4% resin.

c) The values of **flexure strengths for polymer concrete with fibers** (Fig. 6) vary between 17.57 MPa (for BPFF9) and 13.55 MPa (for BPFF8), so, the decrease of resin dosage results in the increase of flexure strength.

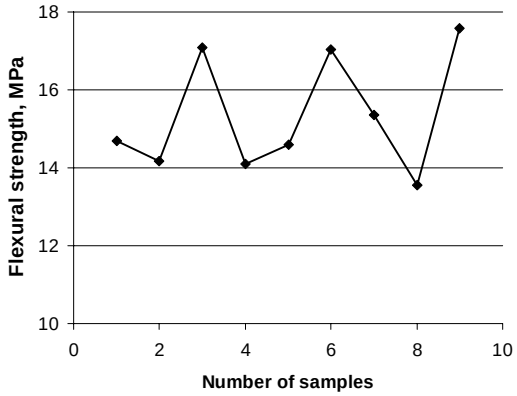
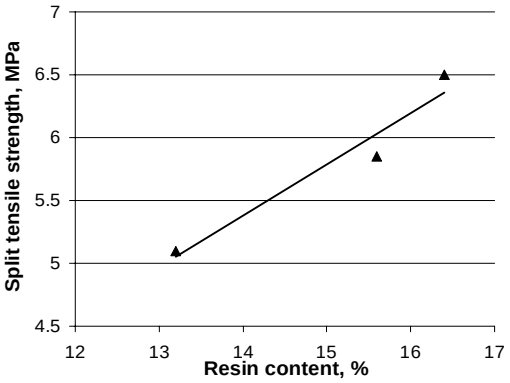
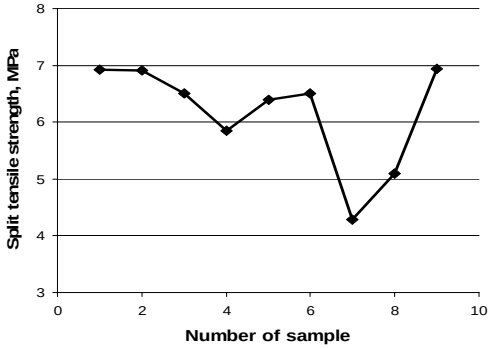


Fig. 6. – Variation of flexural strength for polymer concrete with fiber.



a



b

Fig. 7. – Variation of split tensile strength for polymer concrete with fiber: *a – vs.* the resin content; *b – vs.* the sample number.

d) The values of split tensile strengths for polymer concrete with fibers (Fig. 7) vary between 6.94 MPa (for BPFF9) and 4.29 N/mm^2 (for BFF7); the increase of resin dosage results in the increase of split tensile strength.

The experimental researches lead to the following observations:

a) For the maximum epoxy resin dosage (16.4%) compressive strength is reduced near minimum value, the flexure strength is medium, but the split tensile strength has high value.

b) For the minimum epoxy resin dosage (12.4%) compressive strength is reduced under the medium value, the flexure strength is also reduced, and the split tensile strength has value over the medium.

c) For the maximum fly ash dosage (12.8%) compressive strength and flexure strength are medium, but the split tensile strength is near the highest value.

d) For the minimum fly ash dosage (6.4%) compressive strength and flexure strength are under the medium and the split tensile strength is near medium value.

e) For the same dosage of epoxy resin the maximum compressive strength and flexure strength were obtained for maximum fly ash dosage. It results that for increasing the compressive strength and flexure strength at same dosage of resin and fiber, it must be used the maximum dosage of fly ash.

f) For the split tensile strength it must be used a medium fly ash dosage;

The values of mechanical characteristics of polymer concrete are smaller then those of mechanical characteristics obtained for polymer concrete with silica fume and polymer concrete with fly ash [10], [11].

4. Conclusions

The experimental researches concerning the polymer concrete had investigated the mechanical characteristics of epoxy polymer concrete prepared with cellulose fibers and fly ash as filler.

When the same dosage of cellulose fibers is used, the content of resin must be increased. Also for obtaining good mechanical properties the filler is used with higher dosages.

The experimental values of mechanical strengths for polymer concrete with cellulose fibers were smaller then that for polymer concrete without fibers. This type of fibers is not a good choice for polymer concrete reinforcement.

Received, September 20, 2008

[1]*„Gheorghe Asachi" Technical University, Jassy,*
Department of Concrete, Materials, Technology
and Organization
and
[2]*Department of Chemical Engineering*

REFERENCES

1. Cheng-Hsin C., Huang R., Wu J.K. *et al.*, Constr. Build. Mater., **20**, 706–712 (2006).
2. Fowler D.W., Cem. Concr. Comp., **21**, 449–452 (1999).
3. Mutukumar M., Mohan D.J., Polymer Res., **12**, 231–241 (2004).
4. Reis J.M.L., Constr. Build. Mater., **18**, 523–528 (2004).
5. Blaga A., Beaudoin J.J., Building Digest, **CBD 242** (1985).
6. Aggarwal L.K., Thapliyal P.C., Karada S.R., Constr. Build. Mater., **21**, 379–383 (2007).
7. Abdel-Fattah H., El-Hawary M., Constr. Build. Mater., **13**, 253–262 (1999).
8. Varughese K.T., Chaturvedi B.K., Cem. Concr. Comp., **18**, 105–108 (1996).
9. Reis J.M.L., Constr. Build. Mater., **20**, 673–678 (2006).
10. Bărbuţă M., Lepădatu D., J. Appl. Sci., **8**, 2242–2249 (2008).
11. Harja M., Bărbuţă M., Rusu L., J. Appl. Sci., **9**, 88–96 (2009).
12. Harja M., Bărbuţă M., Rusu L. *et al.*, Environ. Eng. Manag. J., **7**, 289–294 (2008).
13. $_*{}^*{}_*$, *Testing Hardened Concrete. EN 12390/2001*. Europ. Com. for Standard., 2001.

PROPRIETĂŢILE BETOANELOR POLIMERICE CU FIBRE

(Rezumat)

Betonul polimeric este un material compozit alcătuit din răşină şi aggregate. In studiul efectuat răşina epoxidică a fost folosită ca liant pentru agregate. In compoziţie s-au folosit: cenuşă de termocentrală, ca filer şi fibre naturale de celuloză. Caracteristicile mecanice cum ar fi rezistenţa la compresiune, rezistenţa la întindere din încovoiere şi rezistenţa la întindere prin despicare ale betonului polimeric cu fibre au fost investigate. Procentajul de fibre a fost constant iar dozajele de răşină şi filer au variat. Fibrele de celuloză nu au îmbunătăţit caracteristicile mecanice ale betonului polimeric în comparaţie cu cele ale betonului polimeric fără fibre de celuloză.