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Tejraj M. Aminabhavi[a]; Ningond S. Biradar[a]
[a] Department of Chemistry, Karnatak University, Dharwad, India

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Lightweight Polymer Composites from Waste Materials: A Solution to Environmental Pollution*

TEJRAJ M. AMINABHAVI† and NINGOND S. BIRADAR

Department of Chemistry
Karnatak University
Dharwad 580003, India

ABSTRACT

Several new lightweight polymer concretes derived from industrial, agricultural, and naturally occurring waste materials were investigated. Various physicomechanical properties of these materials were studied. Such inexpensive and lightweight polymer composites, which have properties superior to ordinary reinforced cement concrete, may find wide applications in building technology and related areas and may serve as better substitutes for cement. Furthermore, recycling of such wastes from various sources may help to solve the present environmental pollution problems.

INTRODUCTION

Intensive research in the last two decades on the commercial applications of lightweight polymer composites in various disciplines has led to the development of new experimental methods to make such com-

*This paper is dedicated to Professor Ningond S. Biradar, U.G.C. professor, on his sixty-fifth birthday.

†To whom correspondence should be addressed.

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posites [1-10]. During the period 1965-1975 there were substantial advances in incorporating polymeric materials into concrete mixes to achieve an optimum strength-to-weight ratio and better durability than found in normal reinforced cement concrete [4, 11]. Two approaches have been attempted in this direction: one is to add a monomer to the concrete mix and subsequently to effect polymerization either by radiation or by thermal methods to yield a composite. This method has been extensively exploited by the researchers at Brookhaven National Laboratory, Upton, New York. The second approach is to add a thermosetting polymer, such as an epoxy resin, to the mix and cure the composites at room temperature. The former method is very expensive, which severely limits its use on a routine basis. The latter technique is somewhat cheaper to carry out on a laboratory scale, and has been extensively employed.

In an effort to develop cheaper products of better strength and durability than normal concrete, we have undertaken a project to recycle available waste products to make lightweight polymer concretes. This paper summarizes some experimental results on the properties of a few polymer composites derived from agricultural, industrial, and naturally occurring waste materials. Furthermore, we hope that recycling of such waste products might help to solve problems of environmental pollution [12, 13].

EXPERIMENTAL

Six agrowaste materials (rice,husk, paddy husk, maize cobweb, coconut shell, groundnut shell, and jute) were collected from rural agricultural areas in the southern part of India. Four industrial waste products (saw dust, fly ash, cinder, and coke) were obtained from the waste disposal areas near heavy industrial sites. Five naturally occurring materials (Fuller's earth, graphite, asbestos, vermiculite, and mica) were obtained from various natural resources. All these waste materials were dried completely, finely powdered, and stored in a dry place. Phenol formaldehyde (PF) and diglycidyl ether of bisphenol A (DGB) were the resins used in this research. The liquid hardeners, triethylene tetramine (TETA) and diethylene tetramine (DETA), were used as binders. The linseed oil and urea formaldehyde used were of purest quality.

The mix proportioning procedures, compositions of the mixes, and sample preparation remained exactly the same as outlined in our earlier papers [1-3]. All the specimens were cured at room temperature for 28 d and the mechanical tests were performed as per standard specifications [14]. In all these mixes about 20% fine silica, 15% epoxy resin with either DETA or TETA, and about 65% of the waste materials were used. Test samples were cubes (2.54 cm × 2.54 cm × 2.54 cm) and the number of specimens in each case was three.

RESULTS AND DISCUSSION

Results of the measurements of all the physicomechanical properties of polymer composites derived from industrial, agricultural, and naturally occurring waste products are summarized in Table 1. In general, such properties as compressive strength, tensile strength, modulus of elasticity, heat conductivity, and fire resistance were found to be better than for ordinary reinforced cement concrete for the majority of composites. The only exceptions were jute, vermiculite, and mica, where the properties were somewhat poorer. Another advantage is that all of the composites (except the aggregate containing paddy husk) are lighter than cement concrete as evidenced by their unit weight measurements. The heat conductivity for all samples remained more or less the same; the percent of water absorption was found to be around 2-3%, and even smaller values (up to about 0.5%) were observed for aggregates containing fly ash and coke.

When the same experiments were repeated by replacing the expensive epoxy resin with either linseed oil or urea formaldehyde, drastic changes in properties were observed. The relevant data for oil-modified composites are presented in Table 2. Such properties as unit weight, water absorption, and fire resistance did not change much. However, a drastic reduction in other mechanical properties was seen. This might be due to the fact that the molecules of linseed oil have partly replaced the molecules of epoxy resin, and the presence of the oil might inhibit the complete polymerization of the epoxy in the mixes. Nevertheless, it is heartening to note that the mechanical properties are superior to those of ordinary cement concrete.

Table 3 presents the results of tests on urea formaldehyde modified polymer composites. A drastic reduction in such properties as unit weight, compressive strength, tensile strength, modulus of elasticity, heat conductivity, and fire resistance is observed. However, the percent of water absorption increased greatly. This might be due to the presence of hydroxyl groups on the formaldehyde moiety which has a greater affinity for water molecules, thereby increasing the amount of intake water. Because the properties of these composites are poorer than those of cement concrete, their applications in structural work are restricted. However, their superior thermal insulating properties and fire resistivity might help in situations where such properties are required.

In general, the properties of all the composites studied here are better than those in the previously published data [15].

CONCLUSIONS

Several lightweight polymer concretes derived from waste materials from various sources were investigated and their properties studied.

TABLE 1. Physicomechanical Properties of Lightweight Polymer Concretes

No.	Type of waste used in the aggregate	Unit weight (kgf/m^3) $\times 10^{-2}$	Compressive strength (kgf/cm^2) $\times 10^{-2}$	Tensile strength (kgf/cm^2) $\times 10^{-3}$	Modulus of elasticity (kgf/cm^2) $\times 10^{-3}$	Heat conductivity ($kcal \cdot cm \cdot m^{-2} h^{-1} {}^\circ C^{-1}$)	Water absorption (%)	Fire resistance (sec)
1	Sawdust	16.70	9.76	6.05	16.87	0.56	2.7	24
2	Fly ash	18.76	6.41	3.97	6.40	0.69	0.80	23
3	Cinder	18.75	5.72	3.18	7.45	0.72	1.4	20
4	Coke	16.20	6.59	3.96	9.14	0.61	1.23	17
5	Rice husk	18.90	4.73	2.93	4.57	0.70	5.10	30
6	Paddy husk	21.21	6.10	3.78	5.91	0.95	0.98	22
7	Maize cobweb	16.32	4.73	2.93	4.57	0.54	2.9	26
8	Coconut shell	17.45	7.48	4.63	11.81	0.60	3.3	27
9	Jute	18.82	3.94	2.44	3.80	0.70	3.2	24
10	Groundnut shell	17.73	5.12	3.17	5.06	0.61	1.9	28
11	Fuller's earth	15.68	6.30	3.90	8.44	0.51	1.1	30
12	Graphite	19.63	4.73	2.93	4.57	0.75	1.2	26
13	Asbestos	16.34	6.75	4.19	6.47	0.54	-	-
14	Vermiculite	16.99	3.02	1.87	1.56	0.58	-	-
15	Mica	15.12	1.46	0.89	0.97	0.47	-	-

TABLE 2. Physicomechanical Properties of Oil-Modified Lightweight Polymer Composites

No.	Type of waste used in the aggregate	Unit weight (kg/m^3) × 10^{-2}	Compressive strength (kg/cm^2)×10^{-2}	Tensile strength (kg/cm^2) × 10^{-2}	Modulus of elasticity (kg/cm^2) × 10^{-3}	Heat conductivity (kcal·cm·m^{-2}h^{-1}°C^{-1})	Water absorption (%)	Fire resistance (sec)
1	Sawdust	16.58	5.12	3.18	4.92	0.55	3.9	26
2	Fly ash	19.05	4.33	2.69	4.22	0.72	0.5	28
3	Cinder	17.01	2.88	1.79	1.57	0.56	1.05	16
4	Coke	19.96	4.13	2.56	3.87	0.77	0.8	18
5	Rice husk	15.82	2.83	1.75	2.31	0.51	8.0	19
6	Paddy husk	20.33	3.94	2.44	3.97	0.80	1.90	20.5
7	Maize cobweb	14.88	2.66	1.63	2.67	0.46	3.20	29
8	Coconut shell	16.47	4.73	2.93	4.57	0.54	2.40	24
9	Jute	16.24	2.76	1.71	2.81	0.53	2.90	21
10	Groundnut shell	17.08	2.95	1.81	2.81	0.58	1.60	26
11	Fuller's earth	18.92	3.54	2.20	3.38	0.71	2.2	28.5
12	Graphite	18.63	2.76	1.71	2.81	0.68	2.2	25.0

TABLE 3. Physicomechanical Properties of Urea Formaldehyde Modified Lightweight Polymer Composites

No.	Type of waste used in the aggregate	Unit weight (kg/m^3) $\times 10^{-2}$	Compressive strength (kg/cm^2)$\times 10^{-2}$	Tensile strength (kg/cm^2) $\times 10^{-2}$	Modulus of elasticity (kg/cm^2) $\times 10^{-3}$	Heat conductivity ($kcal \cdot cm \cdot m^{-2} h^{-1} {}^\circ C^{-1}$)	Water absorption (%)	Fire resistance (sec)
1	Sawdust	14.32	2.37	1.42	2.25	0.43	6.8	25
2	Fly ash	13.07	1.84	1.14	1.76	0.38	1.0	24
3	Cinder	15.90	2.55	1.57	2.11	0.52	2.9	22.5
4	Coke	14.76	2.98	1.88	2.53	0.45	2.1	23
5	Rice husk	13.31	2.80	1.71	2.53	0.40	5.50	24.5
6	Paddy husk	17.75	2.36	1.46	2.25	0.61	3.60	23.5
7	Maize cobweb	13.42	2.90	1.71	2.95	0.40	5.90	24.0
8	Coconut shell	15.70	2.90	1.69	2.88	0.51	6.80	31.0
9	Jute	14.67	2.28	1.46	2.25	0.45	6.40	23.0
10	Groundnut shell	15.67	2.78	1.70	2.88	0.51	3.19	26.0
11	Fuller's earth	18.26	2.59	1.85	2.60	0.66	1.2	25
12	Graphite	15.90	2.28	1.41	2.25	0.52	1.6	27.5

Some of the composites were found to be better than reinforced cement concrete. The main quest in this research was to seek better ways to recycle waste materials to useful applications with particular emphasis on ecological, economical, and environmental problems. In this study it is shown that it is possible to develop inexpensive lightweight polymer composites having better properties than ordinary cement concrete. Such materials may find wider applications where lightweight and optimum strength are required.

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