EPOXY MATRIX COMPOSITES CONTAINING UREA FORMALDEHYDE WASTE PARTICULATE FILLER

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ABSTRACT

For decades different kinds of waste materials have been successfully used as filler in polymer matrix composites. This not only reduces the production costs but also reduces environmental pollution by utilizing waste materials. In the present study, industrial toilet seat wastes which contain 70 wt% urea formaldehyde and 30 wt% cellulose were used as particulate reinforcement in epoxy matrix and their mechanical and physical properties were investigated. The usage of urea formaldehyde and cellulose mixture as filler of polymer composite materials is a novel study. Initially toilet seat wastes grinded and particulates in the required size range were obtained. The characterization of waste particulate filler was carried out by scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques. Optimum concentration of the filler had been determined as 40 wt% because of the increase in viscosity at higher waste concentration. The effect of particle size on mechanical properties such as hardness, bending strength and elastic modulus was evaluated. These are the key properties most likely to be affected by incorporation of reinforcement phase. Experimental results showed that elastic modulus and hardness increased and bending strength decreased with filler addition into epoxy resin. With the increase in filler content both porosity and bending strength decreased and elastic modulus increased. On the other hand increase in particle size led to the enhancement of bending strength and elastic modulus while accompanied with a decrease in porosity. Incorporation of urea formaldehyde wastes basically resulted in the reinforcement of the epoxy matrix. This allows for the recycling of the residues as well as improves some mechanical properties of the composites.

Keywords: epoxy; urea formaldehyde waste; bending strength; elastic modulus; hardness

1. Introduction

It was known that composite materials are made from two or more constituent materials/phases which have different mechanical, physical or other properties, that when combined, produce a material which shows different characteristics form the individual components [1,2]. The combination of different materials/phases with polymer matrices can produce polymer matrix composites. These materials are important for many industrial applications [1,2]. The role of the reinforcement phase in a composite material is fundamental to enhance the mechanical and other properties.

In order to produce a low cost composite, the use of cheap and easily available fillers like industrial wastes is a viable option for the production of particle-reinforced polymer composites. Huge amount of waste is released by industries and they leads to serious environmental problems. Eco-consciousness and government regulations forced the researchers to study on the use of industrial wastes as a reinforcement phase in polymer matrix composites. Industrial wastes as a reinforcement phase provide low cost, ease of manufacturing and high mechanical and other properties [3,4]. Industrial waste such as , metallurgical slag, waste glass, waste rubber, gypsium-fiber waste, red mud, blast furnace slag, fly ash, flue dust e.g. has been used as filler to reinforce polymer [3-6]. Toilet seat is an industrial waste which contains 70 wt.% urea formaldehyde and 30 wt.% cellulose. The major advantages of the waste as a reinforcement phase are low density, fiber like microstructure of cellulose. Up to now, there is no study available for use of toilet seat as a reinforcement phase. So the study is novel. Therefore in this study, the use of toilet seat waste as a reinforcement phase was evaluated in epoxy resin. The effect of filler content and particle size on mechanical and physical properties was determined. The study was also aimed at eliminating the waste from the environment.

2. Experimental studies

2.1. Materials and Methodology

Matrix material consists of epoxy resin and hardener was supplied by Smoth-on Limited, Canada. The mixing ratio of the epoxy and hardener was taken as 73:27 by weight. Toilet seat was an industrial waste, taken from ceramic company, Bilecik, Turkey. Waste material was grinded and sieved to obtain a particle size in the range of 45, 90 and150 μm. Theoretical density of waste was measured by Micromeritics Accupyc II 1340 model He-gas picnometer and found as a 1,47 g/cm^3. The types of phases were determined by means of X-ray diffraction analyses (XRD-Panalytical, Empyrean with Cu-Kα radiation). Figure 1 represents the XRD pattern of waste material. The graph showed that guanidine (1,3,4 and 5 coded arrows indicated the phases) and dinitrogen tetraoxide (2 and 4 coded arrows indicated the phases). Secondary electron scanning electron microscopy images of waste material are given in Figure 2. Particles are in irregular shape and in different size after grinding.

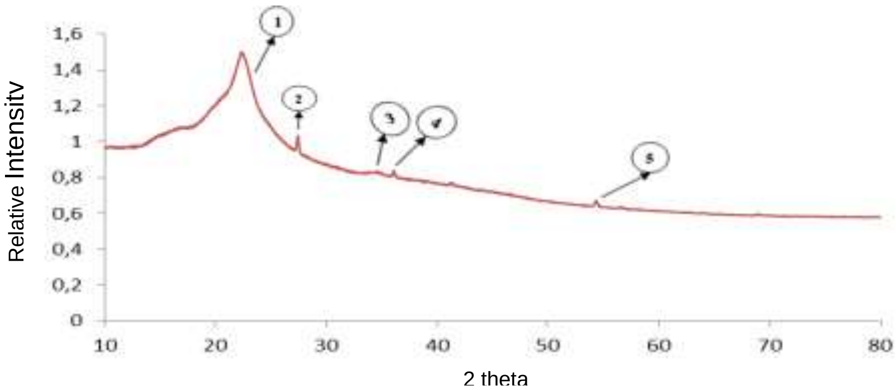


Figure 1: XRD pattern of waste material

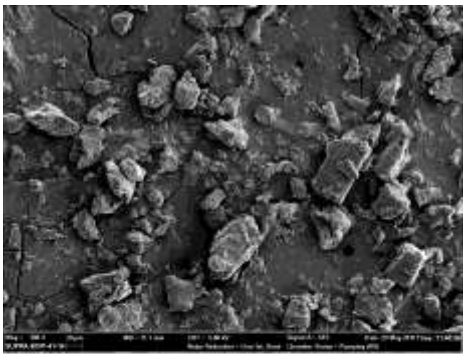


Figure 2: SE-SEM image of waste material

Monolithic epoxy resin and composite materials with different epoxy: waste ratio (wt%. 70:30, 60:40, 50:50) and different waste particle size was prepared (Table 1). Epoxy and waste particulates had been blended together at 500, 1000 and 1500 rpm for 5 minutes, respectively. After that hardener was added into mixtures and again blended for 5 minutes. The blended mixtures were poured into a silicon moulds. The epoxy resin-waste particulate blend was left for 24 hours in the mould at room temperature for curing after which the epoxy resin-waste particulate composite was carefully removed from the mould.

Table 1: Specifications of prepared composite materials

Code	Epoxy: Waste ratio (wt%)	Particle size of waste (μm)
W4530	70:30	<45
W4540	60:40	<45
W4550	50:50	<45
W9030	70:30	<90
W9040	60:40	<90
W15040	60:40	<150

The microstructural investigation of the polished surfaces of samples was performed by means of a scanning electron microscope (SEM-ZEISS Supra 40VP). Shore-D hardness was measured of samples with 5x5 cm in size. At least five measurements were made for each sample and average was taken. 3 point- bending strength tests of samples was done according to TS 985 EN ISO 178 standard. At least three samples were used for test. After that bending strength, elongation, elastic modulus was determined.

3. Results

3.1. Determination of optimum epoxy:waste ratio

One of the objectives of the study is producing low cost composites. Therefore waste amount should be as high as possible. For the determination of optimum epoxy:waste ratio for casting, particle size of waste kept in constant as 45 μm. Varying amounts of waste (epoxy:waste ratio 70:30, 60:40, 50:50) was added into epoxy resin. As waste ratio in mixture increases, casting behavior of mixture was getting worse. As a result of casting studies, 60:40 epoxy:waste ratio in weight was found to be optimum for casting.

3.2. Physical properties of composites

Table 2 shows the bulk density, theoretical density, % theoretical density and %total porosity of composite materials. When increase in waste content and particle size of added waste material, bulk density, theoretical density, % theoretical density and %total porosity values increased.

Table 2: Bulk density, theoretical density, % theoretical density and %total porosity of composite materials

	W4530	W4540	W4550	W9030	W9040	W15040
Bulk Density (g/cm³)	1,17	1,18	1,19	1,21	1,22	1,25
Theoretical density	1,48	1,49	1,49	1,50	1,49	1,49
% T.D.	77,34	78,99	79,40	80,65	81,61	83,42
% Total porosity	22,66	21,01	20,60	19,35	18,39	16,58

3.3. Shore-D Hardness

Shore-D hardness results of samples are given in Table 3. Addition of waste particles into epoxy resin caused increase in hardness, so monolithic epoxy material showed lower hardness than composite material.

Table 3: Shore-D hardness values of composites

Sample code	Shore Hardness
Epoxy	80,50±4,9
W4530	85,70±0,3
W4540	85,40±0,1
W4550	85,80±0,4
W9030	86,60±1,2
W9040	86,90±1,5
W15040	87,00±1,6

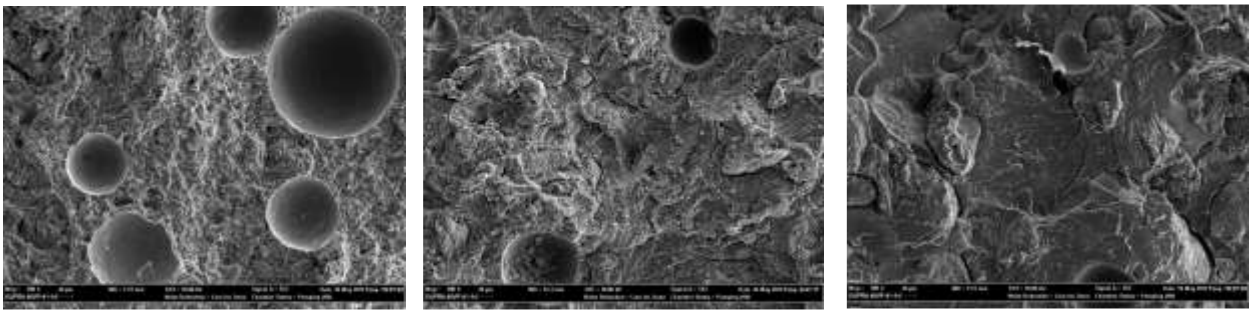
Hardness value kept almost constant when the increase in waste particles amount in composite. On the other hand hardness value showed a little bit increase when use of large particles (<150 µm) instead of fine particles (< 45µm).

3.4. Bending Strength and Elastic Modulus

Table 4 shows the force, bending strength and elastic modulus of samples. Addition of waste particles into epoxy resin caused decrease in bending strength. On the other hand, with the increase in waste amount, force and bending strength was getting high. As well as use of coarser waste particle size led to improvement of force and bending strength. Cellulose with fiber like structure in the waste material may result in enhancement of mechanical properties. The highest bending strength was obtained from W15040 material. Incorporation of waste particles into epoxy resin resulted in increase in elastic modulus. Elastic modulus increased due to decrease in %total porosity and particle size. SEM images of W4540, W9040 and W15040 sample's fracture surfaces were given in Figure 3. From the images it was obvious that porosity level was getting low with the increase in waste of particle size.

Table 4: Mechanical properties of samples

	Force (N)	Bending Strength (MPa)	Elastic Modulus (GPa)	% Total Porosity
Epoxy	228,20	106,00	2,13	24,60
W4530	130,21	66,01	3,46	22,66
W4540	128,13	65,25	3,74	21,01
W4550	93,75	62,94	4,57	20,60
W9030	137,50	69,90	3,31	19,35
W9040	139,58	73,11	4,33	18,39
W15040	177,08	91,52	4,57	16,58



(a) (b) (c)

Figure 3: Representative SEM images of fracture surface of samples (a) W4540, (b) W9040, (c) W15040

4. Conclusions

Optimum pourable epoxy:waste ratio was determined as 60:40wt%. The results revealed that elastic modulus and hardness increased and bending strength decreased with filler addition into epoxy resin. When increased in filler content both porosity and bending strength decreased and elastic modulus increased. On the other hand increased in particle size led to the enhancement of bending strength and elastic modulus while accompanied with a decreased in porosity. As a conclusion the results showed that incorporation of urea formaldehyde wastes basically resulted in the reinforcement of the epoxy matrix. This allows for the recycling of the residues as well as improves some mechanical properties of the composites.

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