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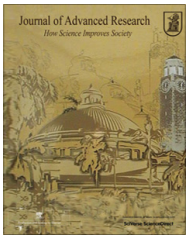

ORIGINAL ARTICLE

Hybrid composites prepared from Industrial waste: Mechanical and swelling behavior

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ABSTRACT

In this assessment, hybrid composites were prepared from the combination of industrial waste, as marble waste powder (MWP) with conventional fillers, carbon black (CB) as well as silica as reinforcing material, incorporated with natural rubber (NR). The properties studied were curing, mechanical and swelling behavior. Assimilation of CB as well as silica into MWP containing NR compound responded in decreasing the scorch time and cure time besides increasing in the torque. Additionally, increasing the CB and silica in their respective NR hybrid composite increases the tensile, tear, modulus, hardness, and cross-link density, but decreases the elongation and swelling coefficient. The degradation property e.g., thermal aging of the hybrid composite was also estimated. The overall behavior at 70 °C aging temperature signified that the replacement of MS by CB and silica improved the aging performance.

Introduction

Pollution that is created as the outcome of human activities has banged onto the environment that life is about to face unexpected calamity. At present, there are hundreds of tones of gases, liquid and solid industrial wastes that spoil the soil, water and atmospheric environment and have unhealthy effect on human.

A gigantic quantity of marble waste is generated in marble carving industry as a by-product during the cutting/polishing process of marble blocks and is carried away by the drainage system or thrown away on open grounds. Consequently, employing of marble waste in the fabrication of new substances will assist to defend the environment. Polymer composites can be the best application to utilize marble sludge waste in large quantities to substitute the conventional fillers, clay and other materials. A quite few attempts have been made to use marble waste in road making, soil filling, and building construction materials [1] and asphaltic concrete [2] but very little effort together with our own have been made to employ as filler in rubber composites [3–6].

The polymer based composites, act as matrix while carbon black, silica and clay are act as reinforcing material.

Fillers enhance the mechanical properties for example, tensile, tear, hardness and abrasion resistance of the final product. Carbon Black and silica usually plays the vital role as reinforcing material of the rubber compounding and can also reduce the production cost [7–12]. Nowadays, mineral filler also added to polymers to achieve the improved product with low cost [13–20]. It is well-known that for cured filled rubber, the worth of reinforcement depends on the interaction of various

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filler related considerations counting the particle size, shape, dispersion, surface area, surface reactivity, structure of the filler, and bonding quality between the fillers and the matrix.

Currently different hybrid filler synchronization systems have been examined by numerous researchers. CB–silica hybrid filler system glances to be the most popular and successful. The dual phase filler is at present commercially manufactured by Cabot Corporation for the applications of truck tire [21]. The CB–silica hybrid filler system recommends generally overall improved mechanical properties compared to individual one. It also illustrates the most favorable balance of various properties for example wet traction, wear resistance and rolling resistance [22].

Rattanasom et al. [23] used the CB/silica hybrid filler with natural rubber and found better overall mechanical properties at 30/20 and 20/30 hybrid filler ratio. Besides that, RNP/carbon black and RNP/silica hybrid [24] and carbon black/nanoclay [25], carbon black/clay [26] have also been evaluated as reinforced hybrid systems.

Another low cost composite is carbon black and silica amended with newspaper (recycled). The use of combined fillers in polymers has been recognized for many years [27,28] persuaded by the demand for high performance materials.

Herein the study, the effects of partial or full replacement of marble waste by carbon black as well as silica, in hybrid composite on the overall properties is reported. Tensile, tear strength, modulus, elongation at break and hardness was investigated moreover swelling properties was also carried out to calculate the swelling ratio, crosslink density and shear modulus of hybrid filled NR composites.

Experimental

Materials

The raw elastomer used was a natural rubber, NR (grade RSS-1) poly cis-isoprene, supplied by Rainbow rubber industry. The conventional reinforcing filler was carbon black (N330, particle 40–50 nm, specific gravity 1.80–1.82). Precipitated silica (Zeosil-175) by Rhodia. Marble waste as a sludge form, was obtained from home marble industry.

The MWP was dehydrated in the oven and then pulverized in finer form and passed through sieve to obtain 37 μm.

In addition to rubber, filler and other components such as Tetramethyl thiuram disulfide (TMTD), zinc oxide, sulfur as curing agent, 3-Dimethylbutyl-N-phenyl-p-phenylenediamine as antioxidant, were used as commercial grade and procured from the market.

Characterization of MWP by XRF spectrometer

The characterization of MWP was carried out with a XRF spectrometer (PIONEER with the Bruker AXS SPECTRA).

Preparation of composites

The basic formulation is given in Table 1. The composites were prepared as described previously [5,6,29].

Cure characteristics

The cure characteristics of mixes were studied as in our earlier works [30,31].

Testing of physical properties

Testing of mechanical, swelling and aging properties of MWP/CB and MWP/Silica hybrid NR composites were carried out as described previously using standard procedures [4,32].

Results and discussion

Characterization of marble waste powder

The chemical composition of MWP was analyzed by X-ray fluorescence spectrometer (Bruker AXS, Germany). The chemical examining of MWP showed the occurrence of Calcium Oxide (68.6%), Magnesium Oxide (22.13%) as main components besides with Silica (3.89%), Aluminum Oxide (2.785%), Iron Oxide (0.603%), Chromium Oxide (0.24%) Zinc Oxide (0.20%) and Titanium Oxide (0.549%).

Obviously the composition of MWP shows calcium and magnesium compound in large amount. Silica, aluminum oxide and iron oxide also present in small amount.

Curing characteristics

The values of curing characteristics were determined from the corresponding curing isotherms measured at 155 °C. Figs. 1

Table 1 Compound formulation of the constructed hybrid NR composites.

Component	Part per hundred of rubber (phr)
NR	100
ZnO	05
Stearic acid	02
TMTD[a]	2.4
Antioxidant[b]	1.5
Sulfur	1.6
Marble waste[c]/carbon black	00/00, 60/00, 50/10,40/20, 30/30, 20/40, 10/50, 00/60
Marble waste[c]/silica	00/00, 60/00, 50/10,40/20, 30/30, 20/40, 10/50, 00/60
Si-69	1.2

[a] Tetra methylthiuram disulfide.
[b] 3-Dimethylbutyl-N-phenyl-p-phenylenediami.
[c] MWP particle size, 37 μm.