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Effect of coir pith on biodegradability of styrene butadiene rubber by tensile and hardness measurements

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ABSTRACT

The biodegradability of various rubbers and rubber products plays an important role from the view of improving rubber goods to degrade biologically and providing environmentally compatible solutions for the disposal and recycling of rubber waste. The term biodegradable polymers normally refer to an attack by microorganisms on non water soluble polymer-based materials. Environmental factors not only influence the polymer to be degraded, they also have a crucial influence on the microbial population and on the activity of the different microorganisms themselves. Parameters such as humidity, temperature, pH, salinity, the presence or absence of oxygen and the supply of different nutrients have important effects on the microbial degradation of polymers, and so these conditions must be considered when the biodegradability of polymer is tested. Lots of rubber materials are put into the soil which do not degrade and hence create lots of problems in water clogging etc. hence today's research focus on making biologically degradable polymer (rubber) which can be environmental friendly. In this research, use of coconut coir pith in rubber formulation and its role in biodegradation of rubber products in comparison with conventional carbon black fillers.

KEYWORDS

Biodegradability;
Coir pith;
Styrene butadiene rubber;
Carbon black.

INTRODUCTION

A detailed Literature survey was carried out and the finding of the same says that Coir is a coarse fiber extracted from the fibrous outer shell of a coconut. The individual fiber cells are narrow and hollow, with thick walls made of cellulose. They are pale when immature but later become hardened and yellowed as a layer of lignin is deposited on their walls. There are two varieties of coir. Brown coir is harvested from fully ripened coconuts. It is thick, strong and has high abrasion resistance. It is typically used in mats, brushes and sacking. Mature brown coir fibers contain more lignin and less cellulose than fibers such as flax and cotton and so are stronger but less flexible[1]. Coir dust is also hydrophilic (attracts water) which means that moisture spreads readily over these surfaces. The extensive film of water that is produced gives moist coir the capacity to absorb air and other gases (odors). Raw coconuts are washed, heat treated, screened and graded before being processed into coco peat products of various granularity and denseness; they are used for horticultural and agricultural applications and as industrial absorbent. Coir pith has a high lignin (31%) and cellulose (27%) content. Its carbon nitrogen ratio is around 100:1. Because of the high lignin content left to it, coir pith takes decades to decompose[2]. Techniques have been developed to speed up process of decomposition (lignin reduction by fungi and bacteria). The composted pith is used along with organic supplements in crop fields in horticulture. It is also used as a rooting and growing medium for several plants especially flowering plants. Coir pith in sterilized condition is used in mushroom cultivation. The second variety of coir is White coir fibers, harvested from the coconuts before they are ripe. These fibers are white or light brown in color and are smoother and finer, but also weaker[3]. They are generally spun to make yarn that is used in mats or rope. The coir fiber is relatively waterproof and is one of the few natural fibers resistant to damage by salt water. Fresh water is used to process brown coir, while sea water and fresh water are both used in the production of white coir. Coco peat, also known as coir pith, coir fiber pith, coir dust, or simply coir, is made from coconut husks, which are byproducts of other industries that use coconuts. It consists of short fibres (<2cm) around 2% to 13% of the total and cork like particles ranging in size from granules to fine dust. Coir dust strongly absorbs liquids and gases[4]. This property is due in part to the honeycomb like structure of the mesocarp tissue which gives it a high surface area per unit volume. S.V.Prasad et al studied on the properties of coir fiber polyester composite, in which alkali treated coir fiber is used. The coir fiber were soaked in 5% NaOH solutions for various time spans and their impact on mechanical properties were investigated. It was found that, the time span of 72 to 76 hrs gave much better properties afterwards up to 96 hrs of time span, the properties got a decreasing trend[5]. Wang Wei and Huang Gu carried out studies on coir fiber reinforced rubber composite boards. The composites were prepared using compression molding technique with layer by layer construction of coir fibers. Various temperatures viz. 130°C, 140°C 150°C and 160°C were employed for compression molding[6].

K.G.Sathynarayana et al studied on coir fiber polyester composites. Along with coir fiber, the studies are carried out in banana fibers, cotton were also used for composite preparation. The composites were prepared with an eye on end user applications like laminates, helmets, roofing, postbox, mirror casing, electrical equipment casing, paper weights etc. the composites were using coir mats incorporated in polyester resin matrix using hand lay up process[7]. R.V.Silva and co workers studied on Fracture toughness of natural fibers/castor oil polyurethane composites[8]. Sisal and coconut fibres and woven sisal mat were used for the composite preparation. 10% NaOH solution was used for the alkali treatment and finally repeated washing in water was equipped. But the properties were lesser for coconut fiber composites than that of sisal fiber ones. But as compared to the polyurethane matrix, no property enhancement was observed. In the treated fiber section the coconut fibers showed better properties.

Figure 1 : Coir pith

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TABLE 1 : Formulation for rubber compounds based on SRF and Coir pith

Ingredients	B	CP30	CP40	CP0	SR30	SR40	SR50
SBR	100	100	100	100	100	100	100
ZnO	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Stearic Acid	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Coir pith		30	40	50			
SRF					30	40	50
GPF							
Sulphur	2.0	2.0	2.0	2.0	2.0	2.0	2.0
MBTS	0.8	0.8	0.8	0.8	0.8	0.8	0.8
TDQ	1.0	1.0	1.0	1.0	1.0	1.0	1.0
6PPD	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Note:	Mentioned values are in "phr" parts per hundred rubber and B - Blank, CP - Coir Pith, SR - Super Reinforced Furnace Black						

O.Owolabi and co workers studied on the radiation treated coir fiber based thermoplastic composites. Pre radiation was given to the coir fiber to get better adhesion properties to the system. But from the results obtained the pre irradiation hasn't provided much property enhancements[9]. J Rout et al studied on the morphological properties of the treated coir fibers using SEM studies. The various treatments were alkali treatment, cyanoethylation, bleaching and vinyl grafting etc. The 10% alkali treated, cyanoethylated and MMA grafted fibers gave better results[10]. S.N.Monteiro and coworkers studied on the coir fiber Polyester composites. From the studies it was found that, while using fiber loading less than 50% rigid composites and above 50% agglomerates were formed. Either the cases the mechanical properties were less than that of the virgin polyester[11]. Nilza G.Justiz Smith et al incorporated banana fiber, coir fiber and bagasse as filler material in composite preparation. In this the physical and chemical properties of the individual fibers were studied and from the results obtained it was found hat, all the three fiber species are capable of acting as good fillers in the composite preparation[12].

MATERIALS AND METHODS

Materials

The Styrene Butadiene Rubber (SBR) used in this study was supplied by B.P Chemicals, Mumbai. Carbon black - SRF was procured from Cabot. Zinc Oxide (ZnO), Stearic Acid (SA) and Sulphur was obtained from SRI Impex Pvt Ltd. MBTS a accelerator, TDQ and 6PPD antidegradants were procured from NOCIL Ltd.

Preparation of SBR compounds

Styrene Butadiene Rubber master batch were prepared on a two roll mixing mill, at a temperature of 120°C. The prepared Styrene Butadiene Rubber masterbatch was then converted into final batch by addition of sulphur and accelerator. Immediately after mixing, the compound was passed through the cold two-roll mill to chill it and sheet it to about 2 mm thick.

Rheological studies

Rheological studies were carried out using Oscillating Disc Rheometer (Monsanto R100), as per ASTM D 2084 01 at a temperature 150°C. The cure

Figure 2 : SBR compound mixed on two roll mill

Figure 3 : Oscillating disc rheometer

characteristic of SBR is found to be Marching. Since, it is said to have slow and steady curing character. The Monsanto rheometer is shown in figure 3 given below. This is an oscillating disc type rheometer where the disc rotates in 3 degree arc there by producing shearing action in the rubber compound. Oscillating disc rheometer will measure the plasticity of the compound before the onset of cure as well as the increase in stiffness as curing takes place. We obtain optimum cure time at a temperature of 150^{o}C for curing rubber compound.

Molding and sample preparation

Based on the cure characteristics obtained, the rubber compound is sent for molding specimen at 150^{o}C. Molding is a process by which the rubber compound is cured and shaped to the desired shape of product. For example, rubber compound is cured in a mould of 150mm*150mm*2mm cavity mould to obtain the rubber sheet of same size for testing purpose.

After molding three samples for tensile strength per slab is punched and tested. Tensile strength and Elongation at break testing were carried out on Instron machine -Universal Testing Machine as per ASTM D412 standards at a cross head speed of 500mm/min. Thickness of sample is measured.

The tensile tests are universally used as a means of determining the effect of various compounding ingredients and are particularly useful when such ingredients affect the rate and state of vulcanization of rubber. These tests are sensitive to changes in manufacturing conditions and can be used to identify under or over vulcanization characteristics, improper incorporation blending and the presence of foreign matters as well. Tear strength is carried out

Figure 4 : Mold used for making standard sheet

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Figure 5 : Universal testing machine

Figure 6 : Hardness testing machine

as per the ASTM standards D 624 This test is widely accepted and carried out by industrial specifications. The test specimens are punched with a standard tear punch die. Thickness of the specimen is measured using the thickness gauge, in order to maintain the uniformity. The tear strength is also measured with the help of UTM and the results are reported as load per unit thickness. Hardness of the sample is measured using the hardness tester. It is expressed as Shore-A hardness as per the ASTM D 2240. It is one of useful parameter for a rubber technologies to see consistency in mixing and curing process while making any rubber products. If large variations in hardness are found in batch to batch, there is a problem in the process which has to be checked.

Ageing was carried out at 70° C for 14 days, 100°c for 28 days as per the ASTM standard D 573 to study the aging characteristics of rubber products. Air, oxygen and ozone affects the unsaturated rubbers like NR, SBR, NBR etc., to a greater extend. As a result the specimen is subjected ageing under a specific temperature conditions period. Then the physical properties like Tensile Strength, Elongation, Hardness are measured and retention of properties are calculated. Retention of tensile properties is very much important for a rubber. Hardness measurement after ageing gives idea about cure status of the products.

Biodegradation studies

Test methods to determine biological action on man-made materials have been available for many years, and for different classes of materials. Nowadays, the evaluation of the degradability of chemicals in the environment (and especially in waste water) as one important aspect of the ecological impact of a compound has become very important when attempting to bring a new chemical product to the marketplace. For this reason, a large number of standardized tests have been developed for different environments, and with the use of different analytical methods When testing the degradation phenomena of rubber in the environment, there is a general problem concerning the type of tests to be applied, and the conclusions which can be drawn. In principle, tests

Figure 7 : Biodegradation test

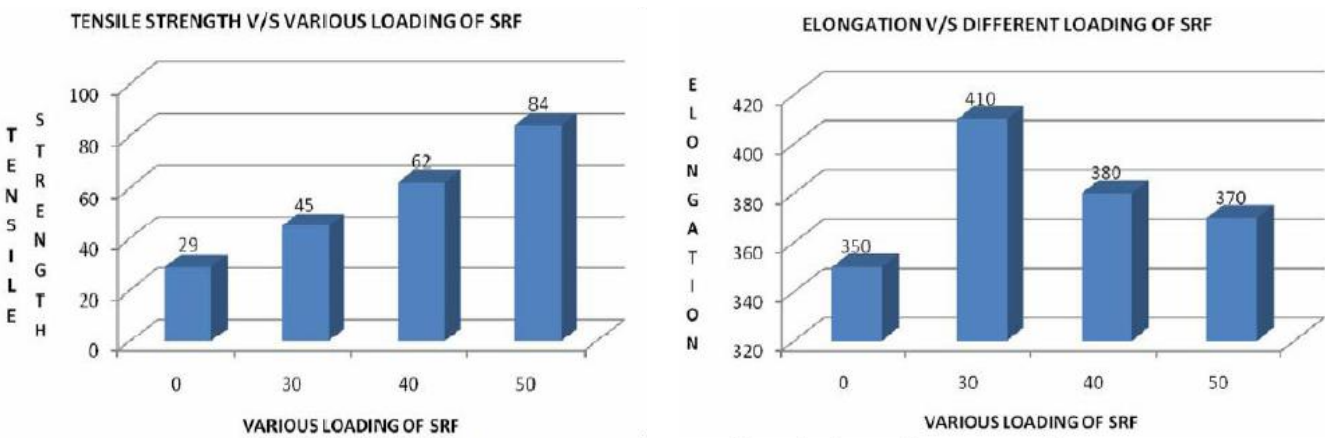

Figure 8a : Effect of SRF on tensile strength and elongation properties

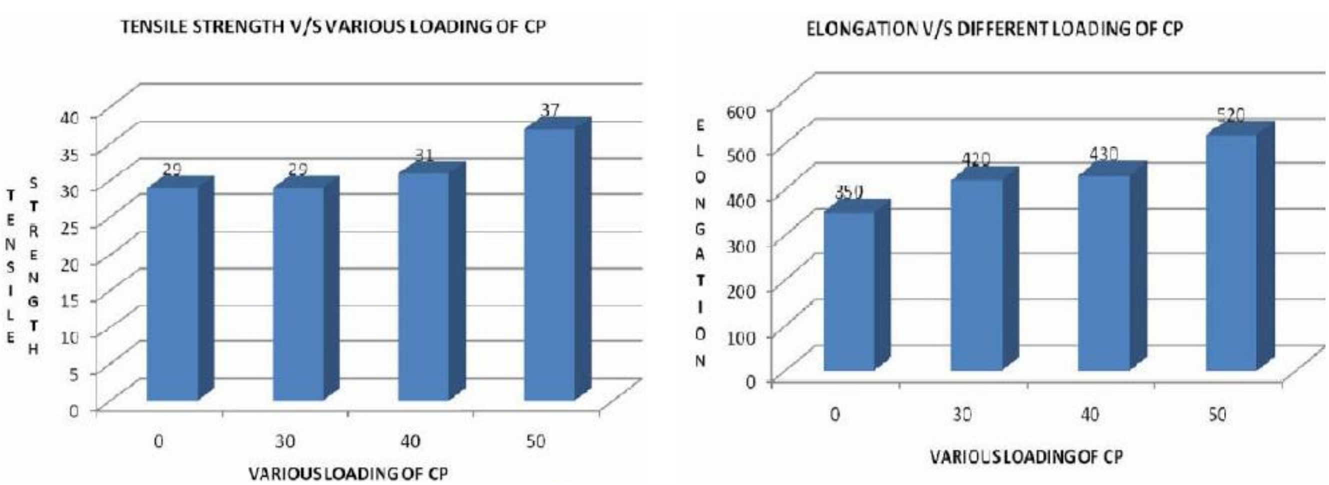

Figure 8b: Effect of coir pith on tensile strength and elongation properties

can be subdivided into three categories: field tests; simulation tests; and laboratory tests. Although field tests, such as burying rubber samples in soil, placing it in a lake or river, or performing a full-scale composting process with the biodegradable rubber, represent the ideal practical environmental conditions, there are several disadvantages associated with these types of test. One problem is that environmental conditions such as temperature, pH, or humidity cannot be well controlled; secondly, the opportunities to monitor the degradation process are limited. In our case it was only possible to evaluate visible changes on the polymer specimen, or perhaps to determine disintegration by measuring weight loss. The latter approach is problematic however if the material breaks into small fragments that must be quantitatively recovered from the soil, compost or water. The analysis of residues and intermediates is complicated by the complex and undefined environment.

Actual process which we carried out for observing biodegradation properties

Initially we sorted out a set of three dumbbells from SR, CP and blank into five respective batches. So each batch among these five batches includes three dumbbells of SR30, SR40, SR50, CP30, CP40, CP50 and B respectively. SR indicates grade of carbon black used as filler in rubber compound. CP indicates coir pith used as filler in rubber compound. Blank indicates no filler. We buried these five batches in five respective burrows underground. For 34 days, these batches were kept undisturbed. After 34 days, first batch was taken out and was subjected to physical testing such as Tensile Strength, Elongation, Hardness. Before putting these dumbbells underground, their respective weights were noted down. After the removal of first batch from underground, dumbbells were again weighed to calculate weight loss which is a biodegradation test carried out by us. Similarly, we carried out the same procedure for second batch after 48 days, third batch after 62 days, fourth batch after 76days and fifth batch after 90days.

RESULT AND DISCUSSION

Tensile strength

Tensile strength testing is by far the most popular method of evaluating of filled materials. The filler particle size is the potential week point in the composite, but on contrary the matrix failure or loss of adhesion between the filler and the matrix is responsible for failure. For the concentration of filler, the respective changes of the tensile strength and elongation at break are graphically presented. In the above figure 8a and 8b, you may observe that the tensile strength values for SRF based SBR compounds are superior to coir pith based SBR compounds, these could be due to the better reinforcement of carbon black than coir pith. An increase in inter particle spacing contributes to the increased tensile strength of the composite; hence carbon black is able to reinforce comparable to coir pith. The elongation at break is inversely proportional to the tensile strength. Hence elongation at break shows an increase in coir pith SBR based compounds than SRF based compounds. Such properties can be obtained with small, interacting particles which contribute to a physical crosslinking of a relatively weak matrix. But in most cases, a reduction of elongation is an expected result of reinforcement.

Hardness

Fillers like coir pith, which have relatively large particle size do not interact and therefore their effect on hardness is due to their higher hardness. But the gain in hardness is very small because these particles are surrounded by an elastic matrix which moderates the effect of their hardness. In this case, the actual size of the particle is increased by the thickness of its adsorbed layer; therefore even small particles occupy a substantial space in composites. Reinforcing fillers introduce another variable related

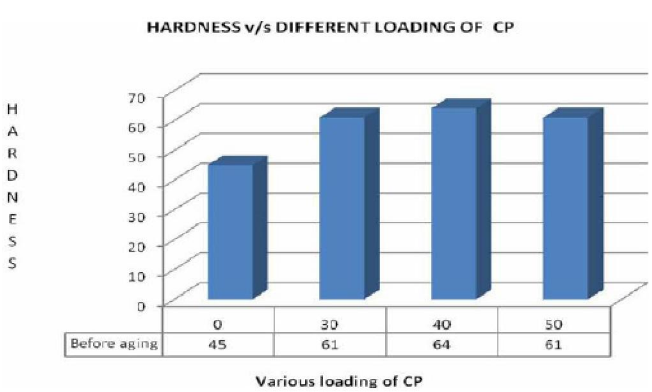

Figure 9a: Effect of CP on hardness

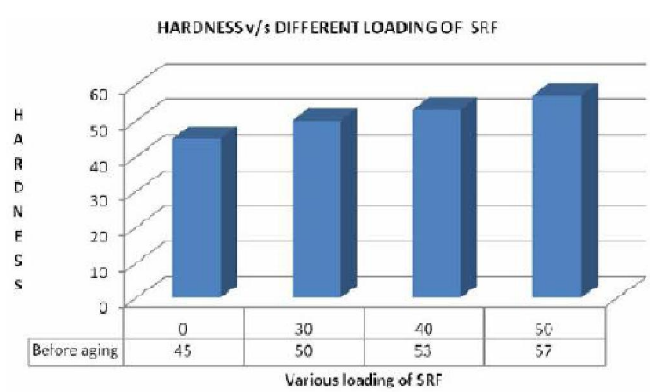

Figure 9b : Effect of SRF on hardness

TABLE 2 : Tensile strength for 30 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	26	24	24	24	18
SR	53	50	49	41	41
CP	32	27	25	24	22

TABLE 3 : Tensile strength for 40 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	26	24	24	24	18
SR	101	70	66	66	58
CP	33	29	28	28	27

TABLE 4 : Tensile strength for 50 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	26	24	24	24	18
SR	132	117	112	86	69
CP	44	42	37	37	36

TABLE 5 : Elongation at break for 30 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	300	300	340	360	370
SR	410	420	420	420	430
CP	400	400	410	420	430

TABLE 6 : Elongation at break for 40 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	300	300	340	360	370
SR	370	390	400	400	460
CP	300	340	370	400	410

TABLE 7 : Elongation at break for 50 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	300	300	340	360	370
SR	380	400	440	440	520
CP	520	520	520	530	600

to formation of physical crosslinks which can be very numerous because of the small size of the particles. These physical crosslinks further reinforce the rubber resulting in its increased hardness. Hardness increases in both cases, but the hardness increases to extent in coir pith based SBR compounds as compared to SRF based compounds due to the above mentioned reason.

Comparative data for 30, 40 and 50phr of Coir pith after specified days

Tensile strength

TABLE 8 : Hardness for 30 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	46	43	43	48	48
SR	49	48	48	49	50
CP	57	56	51	57	58

TABLE 9 : Hardness for 40 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	46	43	43	48	48
SR	53	51	52	55	52
CP	60	59	56	60	64

TABLE 10 : Hardness for 50 phr for specified days

	After 34 days	After 48 days	After 62 days	After 76 days	After 90 days
B	46	43	43	48	48
SR	55	55	55	56	55
CP	60	56	54	60	60

As we see the tensile values, it is observed that the tensile strength goes on increasing as the loading of coir pith increases, but simultaneously as the number of days increases from 34 days to 90 days the tensile strength values decreases for any of the filler system used, hence in our future work carbon blank replacement with coir pith will be carried out and the optimum loading of carbon black with coir pith will be determined.

Elongation at break

The increase in the elongation at break values is the measure of the decrease in the tensile strength values which indicates that fillers are able to degrade themselves along with the rubber matrix to some extent.

Hardness

Hardness value increases as the number of days increases in most of the cases where coir pith is used a filler. The reason for increase in the hardness value is mentioned in the above paragraph for Hardness 3.2.

CONCLUSION

Coir pith decreases the mechanical properties to extent and hence coir pith alone should not be used as a filler, it shall be used a non reinforcing filler and shall be considered as a replacement for carbon black. Coir pith being natural filler could be considered as filler for enhancing bio degradation in rubber products. Coir pith is light weight and cheap, also a byproduct of agriculture sector may augment life of farmers cultivating coconut, using coir pith as filler may promote their secondary business and earn more livelihoods. In our further work partial replacement of carbon black with coir pith will be carried out and optimized for better physio mechanical properties.

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