INTRODUCTION

Natural rubber chemically consists essentially of cis-1,4-polyisoprene that is produced as a latex, primarily by the tropical tree Hevea brasiliensis. Natural rubber is of special interest in most developing countries where the climate is suitable for its cultivation, since it constitutes a valuable indigenous, renewable, resource. This natural polymer, and the analogous synthetic materials, can be crosslinked (vulcanized) with varying percentages of sulfur to produce materials ranging in physical properties from true elastomers to high modulus rigid materials (hard rubber). The use of high concentrations of sulfur raises the glass transition temperature ($T_g$) from well below 0°C to as high as 100°C. In practice, the hard rubbers will contain a minimum of 20-23 parts per hundred of rubber (phr) of sulfur and usually 30-50 phr. Flexible elastomers are made with lower 2-5 phr of sulfur.

The cis-1,4-polyisoprene has very low crystallinity, low $T_m$ (28°C) and $T_g$ (-73°C) values, and is an excellent elastomer over a temperature range including room temperature. More than two billion pounds per year of cis-1,4-polyisoprene are used in the U.S. for tires, coated fabrics, molded articles, adhesives, rubber bands, and other elastomeric applications. Trans-1,4-polyisoprene known in commerce as gutta percha is harder than natural rubber since it can crystallize to a greater degree due to symmetry and has relatively high $T_m$ (74°C) and $T_g$ (-58°C) values.
Bagasse is composed of the sheath and pith material from the sugar cane stalk, and is a byproduct of sugar cane processing. It is basically cellulose but contains hemicellulose, lignin, and extractives as well, with a high fiber content and a minor quantity of amorphous pith. Bagasse has a small percentage of inorganic silica that contributes to inherent fire retardant properties. Finally, bagasse also contains some residual sugars, pentosans, hexosans, and other reactive low molecular weight products.

In a separate report\textsuperscript{2}, we described materials made of bagasse (sugar cane processing residue) that were bonded with phenol/formaldehyde thermosetting resins to form strong low cost composites useful as building materials. This work describes similar rigid composite materials that also utilize bagasse as major component (filler), but are bonded with natural rubber and cured to the rigid hard rubber state (using relatively high concentrations of sulfur). The results of this development were successfully demonstrated in pilot plant manufacture of the material and installation on roofs of houses in the Philippines and Ghana. However, further optimization of the composition and formulation, process scale-up, and plant manufacturing studies are still needed before the material and process will be ready for commercial production.

BAGASSE-RUBBER COMPOSITE DEVELOPMENT

Composite Filler Selection

We examined a large number of agricultural and other low cost residues as fillers in composites with natural rubber as the binder. Typical fillers examined in raw form were bagasse, jute sticks, rice straw, rice hulls, coconut husks, palm fronds, water hyacinths, balsa wood, wood shavings, sawdust, and excelsior. The evaluation was done by determining the effects of the raw fillers, at high volume percent loading on the mechanical properties of the composite, initially and after 1,000 hours accelerated aging in a weatherometer.

The bagasse filled composites retained a higher percentage of their initial strength, after weatherometer accelerated aging tests than any other filler materials tested. Sawdust was second best in overall merit and therefore a good candidate filler in areas where bagasse is not available. Moreover, bagasse has other inherent features which make it especially attractive including:

- Renewable natural resource
- High fiber content
- Readily "powdered" and fibrillated