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DEVELOPMENT OF LOW-COST ROOFING FROM INDIGENOUS MATERIALS IN DEVELOPING NATIONS

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ABSTRACT

The United States Agency for International Development, sponsored a four-year research program to develop low cost roofing from indigenous materials in three developing nations (Philippines, Jamaica, and Ghana). In Phase I, resources were surveyed, and collaborating individuals and organizations defined. In Phase II, experimental roofing composite materials systems were developed and optimized. In Phase III, demonstrations of the roofing manufacture were conducted and experimental roofs installed.

Four composite panel roofing material systems were developed which utilize major percentages of indigenous bagasse filler, and minor amounts of phenolic or other resin binder. Three of the four processes use an intensive (Banbury) mixer. All four have compression molding as a final process step in panel fabrication. The products range in raw material cost from 6-14¢ per square foot of roofing panel, depending on composition, resin content, etc.

The program was implemented in the three participating countries through advisory committees and technical working groups. In-country, small-scale experimental work was initiated early, and continued throughout. Technology was transferred on both an organizational and person-to-person basis.

Local labor, materials, and facilities were utilized to demonstrate manufacture of roofing, by one or more processes, in the Philippines, Jamaica, and Ghana. Roofs were installed on houses in the Philippines, Jamaica, and Ghana.

FOREWORD

This report covers the work done by Monsanto Research Corporation, Dayton Laboratory, Dayton, Ohio, under Contract No. AID/CM/ta-C-73-12, from 18 May 1973 to 31 December 1977.

The program was administered under the direction of the Agency for International Development, Department of State, Washington, D.C. There were four AID project managers appointed consecutively throughout the duration of the program. The initial AID project manager was Mr. William H. Littlewood, then Associate Director, Office of Science and Technology (TA/OST), Agency for International Development. Interim project managers for OST were Mr. Merrill Conitz and Mr. Walter Parham. Mr. James J. Claps, DS/Engr., was project manager for the final year of the program. Support in monitoring the technical aspects of the program was provided by the Materials and Safety Division, Center for Building Technology, National Bureau of Standards, Department of Commerce, headed by Dr. Edward O. Pfrang, Chief, Structures.

The program manager for Monsanto Research Corporation was Mr. Ival O. Salyer, Manager, Solar Energy and Materials. Mr. George L. Ball III, Materials Applications Research Group Leader, was project leader. Technical assistance was provided by Mr. Robert A. Cass, Mr. Robert D. Myers, Dr. Arthur M. Usmani, and Mr. Dennis W. Werkmeister.

The Center for Development Technology, Washington University, St. Louis, Missouri, provided architectural, sociological, and economic input to the program under a subcontract. Professor J. P. R. Falconer, Associate Director, headed this effort in St. Louis and in the field. He was assisted by Mr. D. C.Royse and Mr. Stephen Kendall. Dr. Ben S. Bryant, Professor, Wood Utilization Technology, Wood and Paper Division, College of Forest Resources, University of Washington, Seattle, Washington, provided assistance in agricultural fiber utilization and contributed the basis for a fiber orientation process under subcontract. He was supported by Shan-Tung Hsu, Research Assistant, Joann Bopp, Administrative Assistant, Harry Christensen, Christoper Miller, and the contributed facilities of the American Plywood Association, Tacoma, Washington.

ACKNOWLEDGMENTS

The results of this program were achieved by the combined efforts of hundreds of individuals, institutions and organizations, in the United States, Jamaica, Ghana, and the Philippines. It would be impossible to name all of those intimately, or peripherally involved. However, an attempt will be made to list those organizations making more significant contributions. The participating individuals and their roles, are detailed in the text of the report when appropriate.

For the most part, those who participated did so at no cost to the contract. Contributed manpower and facilities within the participating countries of Jamaica, Ghana, and the Philippines amounted to at least $500,000.

Broad support was provided by a host of individuals in greater Monsanto Company, and its representatives in the United States, Ghana, and the Philippines. Acknowleged is the support of the Rubber Chemicals Division of Monsanto Industrial Chemicals Company, and the Plastic Division of Monsanto Polymers and Petrochemicals Company, who contributed their in-depth knowledge of rubber, plastics, and composites. Included also are Monsanto-Philippines and Reiss and Company (Monsanto representatives in Ghana) who facilitated the importing of materials and provided valuable communication links.

In Jamaica, the contributions of Standard Building Products, Scientific Research Council, Goodyear-Jamaica, Ltd., Berger Paints, Ltd., Ministry of Housing, World Bank, Jamaica Bureau of Standards, Thermoset, Ltd., Douet Brown Adams-Consultants, Ltd., Smada, Ltd., Physics Department of the University of West Indies-Mona Campus, A. F. Pattinson Company, and the U.S. AID Mission to Jamaica are acknowledged.

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In the Philippines, the contributions of the National Economic Development Authority, National Science Development Board, National Housing Corporation, National Housing Authority, Forest Products Research and Industries Development Commission, Goodyear-Philippines, Ltd., Jardine-Davies, Inc., Borden International-Philippines, Resins, Inc., Latex City, and the U.S. AID Mission to the Philippines are acknowledged.

The enthusiastic support and work of members of these institutions and organizations made the program what it was, and will provide the basis for its future with respect to the well-being and standard of living of citizens in Jamaica, Ghana, and the Philippines.

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NOTE

All cost information is given in equivalent United States dollars ($) or cents (¢) unless otherwise indicated.

All data was generated and is reported in English Scientific units.

Abbreviations are used throughout the report for the four developed materials systems. They are:

Bagasse Reinforced Phenolic	-BRP
Bagasse Reinforced Hard Rubber	-BRR
Bagasse Reinforced Thermoplastic	-BRT
Phenolic Bonded Oriented Bagasse	-BOB

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1. INTRODUCTION

The United States Agency for International Development, sponsored a four-year research program to develop low cost roofing from indigenous materials in three developing nations (Philippines, Jamaica, and Ghana). In Phase I, resources were surveyed, and collaborating individuals and organizations defined. In Phase II, experimental roofing composite materials systems were developed and optimized. In Phase III, demonstrations of the roofing manufacture were conducted and experimental roofs installed.

Adequate housing of citizens is essential in all countries. However, with the more limited economies in developing nations, it is necessary to reduce material and construction costs to provide shelter of adequate quality and quantity. This is especially true if the materials require foreign exchange. In housing, a roof is one of the key and most costly elements of construction. Consequently, the roof is a prime target for cost reduction and performance upgrading.

Following the floods in Bangladesh in 1972, which destroyed thousands of homes, the United Nations appealed for a program of research and development to provide improvements in the cost and performance of roofing. In response to the UN appeal, a special study of the roofing problem was conducted by the U.S. National Academies of Science and Engineering. The study group recommended the implementation of a specific roofing research project, with emphasis on composites consisting of low cost indigenous fillers and polymeric binders (Ref. 1).

In May 1973, the United States Agency for International Development, sponsored a four-year research and development effort with Monsanto Research Corporation. The objective was to provide a key ingredient for developing-country roofing that could maximize utilization of local natural resources, surplus manpower, and limited manufacturing capabilities in producing a better and

cheaper product than is now available. The research results were to be directed toward meeting low cost housing needs, improving the foreign exchange position of the countries involved, and developing products that might be the basis for a local industry.

In the roofing material, foreign currency requirements were to be minimized through the development of a composite material that required only a minor amount of imported binder and/or additives. The roofing was to be fabricated from largely indigenous materials and utilize abundant local manpower and locally available facilities. Performance and durability were to include resistance to static loading, impact, solar radiation, heat, rain, humidity, wind, fire, sound transmission, insects, pests, and fungus. Factors such as appearance, shape, form, and prestige were to be considered to assure acceptability. Manufacturing, ideally, was to be cost competitive in either small-scale (rural villages) or large-scale (urban) operations.

The ultimate goal of the research and development program was to make available, in at least three countries (Philippines, Ghana, Jamaica), an economically, technically, and socially acceptable alternative to current roofing systems. Achievement of the goals of the program was to be demonstrated within each of the three participating countries through: (a) the construction of at least four prototype roofs, and (b) transfer of the technology to qualified organizations and individuals. The program was divided into the following three phases:

Phase I (May 1973-May 1974) - Problem Definition, Country Survey and Country Selection.

Phase II (May 1974-May 1975) - Roof Definition, Ingredient Selection, Laboratory Composite Material and Process Development, and Collaborative Institution Definition.

Phase III (May 1975-December 1977) Material Optimization, Design, Fabrication, Testing and Evaluation of Prototype Roofing, Field Manufacture, Installation and Evaluation of Full-Scale Roofing

During Phase III, most of the work was carried out in the three participating countries, working through advisory committees and technical working groups of experts in each selected country.

Phases I and II were completed and summarized in the First and Second Annual Reports issued in July 1974 and December 1975, respectively (Ref. 2,3). Phase III objectives were also accomplished, the principal ones, including:

- Establishment of an experimental program early in Phase III, in each participating country, to provide familiarization with the technology.

- Transfer of technology, by visits to each of the participating countries, and by meetings with members of the advisory committees and technical working groups.

- Location of local facilities, or combinations of facilities, for later use in the large-scale manufacture of the roofing.

- Demonstration of pilot-scale or plant-scale production of at least one process and product in each of the three countries.

- Manufacture of sufficient roofing material to roof up to four houses in the three countries.

- Installation of roofing (made by three different processes) on up to four houses in the Philippines, Ghana, and Jamaica.

- Identification of private industry and quasi-governmental organizations in each of the three countries, which are interested in carrying the development further to commercial manufacture of the products.

This report summarizes the work accomplished in Phases I and II (May 1973-May 1975) and describes, in greater detail, the Phase III (May 1975-December 1977) experimental program, technology transfer, and demonstrations of the manufacture and installation of the developed roofing.

A future program to provide for product development and larger scale manufacture of the roofing, utilization of the materials in other structural and non-structural applications, and cost minimization is suggested and outlined.

2. PROGRAM SUMMARY

The roofing project functionally comprised materials development, methodology, manufacture and installation of roofing, and initial environmental impact examination.

This report describes the program for development of lower-cost roofing from indigenous materials for developing countries in four natural or functional categories: (1) roofing materials and process development, (2) methodology, (3) demonstrations of developed materials, and (4) evaluation of possible environmental effects.

The materials and process development work was started at Monsanto Research Corporation's Dayton Laboratory, and was expanded through experimental work conducted through qualified institutions in the participating countries. This "in-country" experimental work continued throughout, and merged into and became a part of the large-scale production demonstrations in Phase III.

The methodology selected at the beginning of the program, and followed throughout, was to locate (early) knowledgeable individuals, and qualified institutions having the necessary interest and facilities. The program was then implemented entirely through use of these in-country capabilities. Technical advisory committees provided overall direction of the effort, and technical working groups participated directly in carrying out the program.

The demonstrations of the large-scale manufacture and the installation of roofs were carried out in each of the three countries during the last half of 1976 and 1977.

Plant, or semiplant, production of the roofing was done, in each case, by organizations having the necessary facilities and potential interest in the future commercialization of the products (see Appendix A). In this way, the demonstrations can continue toward implementation of a commercial production of the materials.

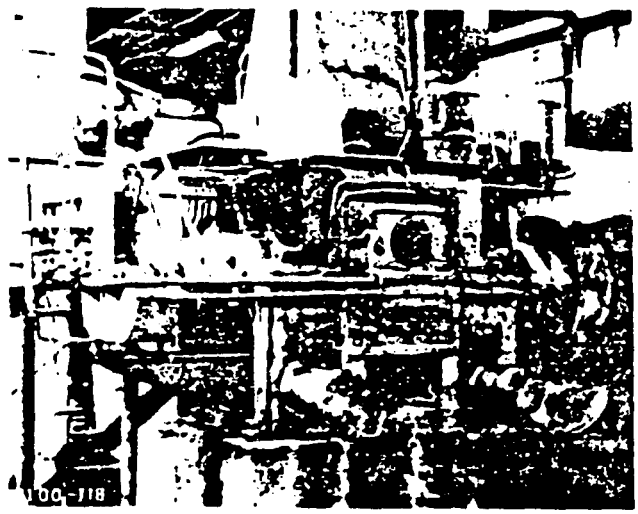
An initial Environmental Examination of the possible effects of the wide scale manufacture and use of the roofing developed in this program on land use, water quality, the atmosphere, natural resources, cultural and socio-economic factors, and health was made. It is concluded that the roofing project will not have a significant or negative effect, on the environment in the participating countries, at least in the demonstration stage.

2.1 ROOFING MATERIALS AND PROCESS DEVELOPMENT

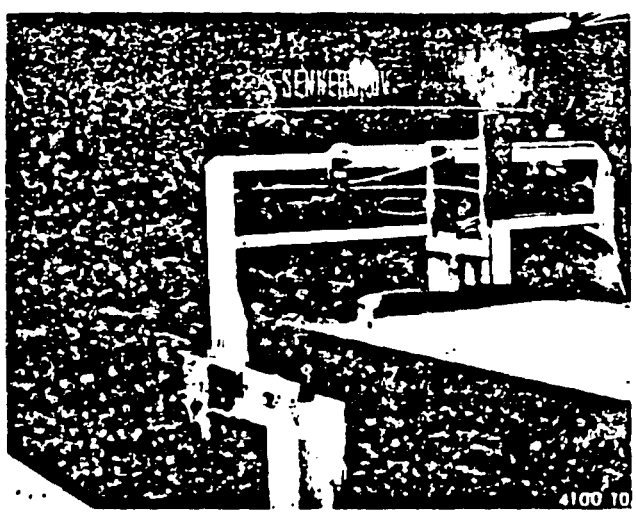
> Four composite panel roofing material systems were developed which utilize major percentages of indigenous bagasse filler, and minor amounts of phenolic or other resin binder. Three of the four processes use an intensive (Banbury) mixer. All four have compression molding as the final process step in panel fabrication. The products range in raw material cost from 6-14¢ per square foot of roofing panel, depending on composition, resin content, etc.

Four alternative roofing material systems were developed that maximize use of indigenous fillers in combination with minimum quantities of resin binders to form a strong composite roofing product. The four products differ in the type of resin binder, and/or manufacturing process, but have in common bagasse (sugar cane residue) filler and a process requiring an intensive mixer (Banbury), and a compression molding press as shown in Figure 1. All four composite materials can be produced as flat or corrugated panels useful for roofing and other structural and nonstructural applications.

(a) Sugar cane bagasse, indigenous to Jamaica, Ghana, and the Philippines is a key low cost filler used in high volume.



(b) The roofing compositions are compounded in a Banbury type intensive mixer that is unique in its ability to process the various ingredients together.



(c) Pressure and temperature, provided by common hydraulic molding presses, are required to form and rigidize the compounded material into roofing panels.

Figure 1. Common to the four developed alternative roofing materials are bagasse filler, an intensive mixing machine, and a hydraulic molding press.

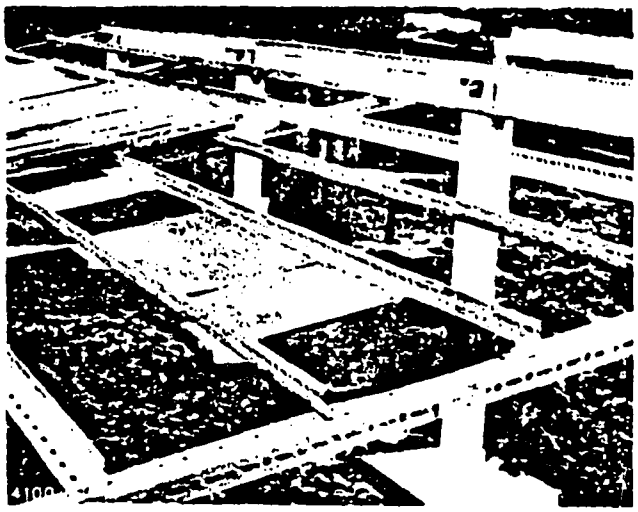
Product and process development was carried out initially in the United States. The materials and process development was continued and expanded through collaborating individuals and organization in the participating countries. In the materials and process development, emphasis was placed on the maximum use of available participating country facilities, manpower, and skills. The four composite material systems that were defined in the program, and demonstrated to varying degrees in the Philippines, Ghana, and Jamaica are illustrated in Figure 2 and summarized in the following subsections.

2.1.1 Bagasse-Reinforced Phenolic (BRP) Composite Roofing

> The bagasse-reinforced phenolic composite is a rigid, strong, durable, red pigmented panel product. The process involves only "fibrillating" of the bagasse, dry blending with resin binder, and molding-cure in 3-7 minutes at 275°F. The raw material cost is projected to be $\sim$12¢/ft^2 at 30% powdered phenolic resin.

The bagasse-reinforced phenolic composite is a strong, durable, heat and moisture resistant, colorful (pigmented red) panel product. It is rigid, insulating, of low thermal capacity, lightweight, and easily transportable. It can be sawed and nailed for easy installation. It is by far the simplest roofing material of those developed to process and requires only a few readily available ingredients. The composite formulation has been optimized to perform primarily in a roofing application.

The process for producing the bagasse-reinforced phenolic roofing composite is simple, requiring essentially only three steps. First, the bagasse is fibrillated and pigmented using available Banbury rubber compounding mixers. Second, this powder is dry blended with phenolic resin power in an end-over-end tumble blender such as a concrete mixer. Third, the blended powder is



(a) Test panels were installed at a 10° slope at BRRI in Ghana providing a severe water exposure for two years. Badly degraded control is at right and BRP and BRR panels are third and fifth from the right.

(b) Earliest panel exposure was at Berger Paints in Jamaica, 6 to 12 months before the other countries. Shown are flat and corrugated BOB and flat BRP panels.

(c) Data accumulated at Sherwin-Williams Paints in the Philippines over two years corresponded to other outdoor and accelerated weathering.

Figure 2. The four alternative roofing material systems were proven through outdoor exposure studies in Ghana, Jamaica, and the Philippines.

compression molded on a short cycle (3-7 minutes) at a relatively low temperature (275°F). Panel thickness is controlled at ~0.1 inch by the amount of powder blend charged to the compression molding area.

The raw material cost for the bagasse-reinforced phenolic composite roofing material is projected to be 12¢/sq ft. This estimate is based on 1/8 inch thick panels containing 30% by weight phenolic resin powder. Costs will be proportionately less for panels that are thinner.

If, as has been demonstrated in the Philippines, it is possible to use liquid phenolic resins, substantial raw material cost reductions can be realized since the liquid resins sell for approximately 50% less on a solids basis than the powdered resin.

The selling prices for roofing shingles or panels are projected from related industrial experience to be 3 to 4 times the raw material cost. The foreign exchange requirements would represent about 25% of the projected sales price.

Of the four processes developed in this project, the bagasse-reinforced phenolic requires the least capital equipment and has the lowest manufacturing cost.

2.1.2 Bagasse-Reinforced Hard Rubber (BRR) Composite Roofing

The bagasse-reinforced, natural-rubber-bonded composite is a medium modulus, strong, durable, red pigmented, flat or corrugated panel product. In the process, the bagasse filler, pigments, curing agents, etc. are compounded in a Banbury mixer. The rubber compound is formed into continuous sheets 52 in. wide by 1/8 in. thick. These flexible sheets are molded and cured for 30 minutes at 325°F to a rigid state. Raw material cost is 7-9¢ per square foot using the lowest cost grades of natural rubber.

The bagasse-reinforced hard rubber composite roofing has many of the desirable features of the bagasse-reinforced phenolic. The product is a durable, water resistant, tough, compliant, lightweight, low thermal capacity (specific heat x weight) panel that can be formed into a variety of shapes. It is amenable to normal carpentry techniques, and can be installed by nailing.

The bagasse-reinforced hard rubber composite is molded from a high sulfur content (15%) hard rubber formulation, similar to that used in battery cases, but containing an unusually high level of low-cost whole bagasse. The composition has been optimized in cost/performance for roofing applications. Two formulations with different degrees of fire resistance are available: a moderate cost material having a reasonable level of fire resistance and a lowest cost, less fire resistant alternative. The lowest cost formulation has elicited the greatest interest to date in the participating countries.

The process relies heavily on well-established technology and equipment used routinely in rubber manufacturing industries throughout the world. First, the bagasse is "fibrillated" and the rubber compounded into it in a Banbury intensive mixer. Second, the Banbury compound is sheeted on a mill roll, then

calendered to form a continuous flexible roll of the desired width and thickness. Third, the continuous sheets are cut to the desired length and compression molded for 30 minutes at 325°F. This molding temperature is about 35°F higher than is usual in commercial rubber processing and presents some difficulties, due to equipment limitations, in the participating countries. The higher molding temperature is attributed to the presence of the very large amount of bagasse filler.

Using the lowest cost grades of natural rubber, the unprocessed raw material costs for this product are projected to be 9¢/sq ft for the fire retardant composite, and 7¢/sq ft for the lowest cost product. Sales prices for roofing shingles or panels are projected to be 3 to 4 times these raw materials costs. The cost of the imported components for the fire retarded and lowest cost products are 17 and 15%, respectively, of the projected sales price.

2.1.3 Bagasse-Reinforced Thermoplastic (BRT) Composite Roofing

The bagasse-reinforced thermoplastic-resin-bonded composite is a rigid, strong, durable, red pigmented, flat or corrugated panel product. In the process the bagasse filler, pigments, etc. are compounded together in a Banbury mixer. The compound is formed into continuous sheets 52 in. wide x 1/8 in. thick. These sheets are molded and rigidized by cooling. Raw material costs are projected to be about 14¢ per square foot.

The bagasse-reinforced thermoplastic composite roofing material is also relatively simple with respect to the number and nature of the components, and it also uses established rubber compounding and molding processes. The panels have a pigmented red appearance, and both water resistance and outdoor

durability are good. The product is a lightweight, low thermal capacity panel system that can be formed into a variety of shapes.

The bagasse-reinforced thermoplastic composite consists of either styrene/acrylonitrile copolymer, or acrylonitrile/butadiene/styrene graft copolymer binder containing 60 volume percent of dried whole bagasse filler. The composite formulation was developed strictly for the intended roofing application. Less work has been devoted to this particular system, since the present economics of the process are less desirable. Accordingly, the formulations recommended may be somewhat less than optimum in terms of cost/performance.

The process used in preparing the bagasse-reinforced thermoplastic composite consists essentially of three steps, almost identical to those used for the bagasse-reinforced rubber. First, the bagasse is fibrillated and the thermoplastic resin compounded into it in a Banbury mixer. Second, the Banbury composition is sheeted on a mill roll, and then calendered to form a continuous roll of the desired width and thickness. Third, the calendered sheets are compression molded and "set" by cooling. The melt flow characteristics of the system are poor, due to the high filler loading. Therefore, thermoplastic molding techniques are limited to calendering and compression molding.

The raw materials costs for the bagasse-reinforced thermoplastic, including no processing, are projected to be about 14¢/sq ft. The price for roofing shingles or panels are projected to be three to four times these raw material costs. The foreign exchange requirement thus represents 33% of the projected sales price.

2.1.4 Phenolic-Bonded, Oriented Bagasse Fiber (BOB) Composite Roofing

The phenolic-bonded, oriented bagasse fiber composite roofing is a durable, buff-colored, flat or corrugated panel having directional strength properties. As currently formulated, this product has the most bagasse filler and least resin binder. The process requires different equipment and more steps than the others. The bagasse is "wet" depithed, and phenolic resin is precipitated onto it. The fibers are oriented in a centrifugal water extractor, and the fiber mat is compression molded and cured. Raw material costs range from 6-11¢ per square foot for 0.1 in. thick corrugated panels.

As currently formulated, the phenolic-bonded, oriented bagasse fiber composite roofing incorporates the most indigenous filler, and consequently the least phenolic resin binder, of any of the four developed roofing systems. In the process, a very low cost structural material is first made and secondary treatments are used to provide the desired water and/or fire resistance. The BOB composition is unique in that the orientation of the fibers makes it possible to put the highest strength of the product in the desired direction (i.e., longitudinally for long spans). The composition differs also from the other three developed products in that a high percentage of the pith material is removed in the process. Liquid phenolic resin is used as the bonding agent, in contrast to the phenolic powders used with the whole bagasse reinforced phenolic. These liquid resins are identical to those used in the particle board and plywood industries.

The oriented, bagasse-fiber reinforced composite formulation was optimized to have the necessary water resistance (wet strength), a minimal level of fire resistance, and lowest cost (minimum resin concentration). The composition can be modified, however, to achieve further reductions in costs with some compromise of water and/or fire resistance.

The process for the BOB composite material is the most complex of the four developed alternative roofing products. It is a wet process, which uses relatively large quantities of water during removal of pith and separation of the bagasse fiber bundles into individual fibers (fibrillation). Pith and acid residues are produced that must be disposed of using appropriate, established methods. A high degree of orientation of the fibers in one direction is obtained during a centrifugation and water extraction step. The final step in the formation of the panel is compression molding and curing of the fiber-resin composite. The panel is then treated to provide the necessary durability, including resistance to water and outdoor aging and fire resistance.

The unprocessed material costs for the oriented bagasse-fiber reinforced composite are projected to be about 12¢/sq ft for the fire retarded product, and 6¢/sq ft for the lowest cost material. The selling price for corrugated roofing panels are projected to be four to five times these raw material costs. The imported materials (resin binder) represents 19 and 15% of the selling price of the fire retarded, and lowest cost formulation, respectively. Significantly, the foreign exchange requirement for resin for the structural panel alone is less than 2¢/sq ft.

2.1.5 Non-Roofing Building Materials Applications for the Developed Products

Several of the products developed show promise for use as structural and non-structural materials. Other applications include floor tile, exterior and interior walls, ceilings and building blocks.

Roofing applications require higher strength and outdoor durability of materials than do non-roofing and non-structural applications. Thus, it can be assumed that materials which are adequate for roofing can be used in other applications of a building, depending on their costs. In these less demanding applications, it is also likely that further reductions in cost can be achieved, such as in reductions in resin content, while retaining adequate performance. All of the materials developed have some tailorability to make them suitable for other structural and non-structural applications.

The bagasse-reinforced rubber-bonded composite (BRR) can be formulated to obtain a flexible product that should be suitable for floor tiles, counter tops, etc.

The bagasse-reinforced phenolic (BRP) can be diluted with wood chips to form thicker structural panels having a very low (e.g., 5%) resin content and adequate strength and water resistance for interior applications.

The bonded oriented bagasse fiber composite (BOB) composition can also be used as is for exterior walls. The composition can be reduced in cost and resin content and still have adequate strength and water resistance for interior applications.

It is also possible that one system investigated and rejected in the earlier work for roofing (a clay-reinforced phenolic) may, with further development, provide adequate cost performance for use as building blocks and exterior walls.

2.2 METHODOLOGY - HOW THE PROGRAM WAS IMPLEMENTED

The program was implemented in the three participating countries through advisory committees and technical working groups. In-country, small-scale experimental work was initiated early, and continued throughout. Technology was transferred on both an organizational and a person-to-person basis.

One of the key goals of the program was to assure that the technology developed was made available to, and left with the participating countries. The approach to achieving this technology transfer goal was through getting participating country personnel and organizations actively involved early in the program in both the decision making and the actual work. Financial and in-kind commitments were encouraged in order to insure direct involvement and follow-up of the program. In detail, the approach differed slightly in the three countries but was, in general, identical.

The collaborative effort, and transfer of technology was initiated at the start of the program and continued throughout. Most of the contacts were on a direct person-to-person basis, with key individuals in government organizations, universities and private industry. These early and continued personal contacts between the MRC team members and collaborating personnel in the participating countries was one of the most important aspects in the transfer of technology.

A wide variety of skills and expertise in the areas of agricultural residues, materials, processing, roofing architecture, building materials, etc. were called upon. The skills and expertise were necessary in order to insure that the systems being developed were compatible with the specific needs and prevailing situations in the individual participating countries. This

approach also had the advantage that as better systems were defined, skilled individuals would be available to pursue the effort. This part of the materials development, and technology transfer was implemented by the formation of "Advisory Committees" with broad experience, and high level of authority in the government, academic institutions, and private industry, as illustrated in Figure 3.

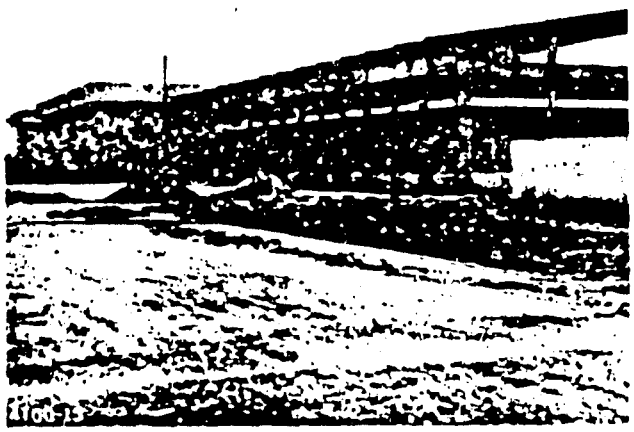
In addition to the Advisory (decision-making) Committees, it was also necessary to have Working Groups responsible for the experimental work, actual manufacture of the materials, installation of the roofs, etc. These "Technical Working Groups" consisted of key individuals who were to be directly involved in the experimental effort, and thus would have detailed knowledge of the materials, processes, and applications being considered. It was through these key individuals that the detailed technology was to be transferred to others.

The development of materials and processes for the manufacture of roofing panels was conducted in a systematic manner. There was initially an extensive screening program carried out in MRC's laboratories. This was followed by an intensive laboratory experimental program, both in MRC laboratories and in those of the participating countries. Finally, demonstrations involving larger scale (pilot plant) manufacture of materials and construction of roofs were done in each of the three collaborating countries.

From the joint program, in MRC laboratories and in the participating countries, four candidate roofing material systems were developed. These systems took advantage of advanced materials composite technology developed in the United States in Defense and Aerospace programs. The systems developed rely on plentiful

(a) The Scientific Research Council, Kingston provided technical expertise in behalf of the government of Jamaica.

(b) Ghana Rubber Products, Ltd. in Accra made available their industrial, technical , and business knowhow, manpower and facilities.



(c) The National Housing Corporation, Caloocan City, made available their quasi-industrial plant, manpower, knowhow, and houses.

Figure 3. Implementation of the program was achieved by the contributed participation of government, academic institutions and industries in Jamaica, Ghana, and the Philippines.

quantities of low-cost bagasse as a reinforcing filler in the composite. The bagasse is or can be made available in each of the three participating countries, and is also available in other tropical countries throughout the world where sugar cane is produced. The products developed in the four processes have utility as roofing and appear as well to have use as structural and non-structural materials for other parts of the house.

Technology transfer constituted the knowledge of the specific materials and processes and their applications as roofing and materials of construction. The transfer of the technology was achieved and demonstrated by laboratory experimentation, plant manufacture, and actual construction of roofs in the participating countries using local manpower and facilities.

The entire program was carried out without the necessity of formal, written agreements in any of the three countries. Key people in the participating countries agreed that the programs would be beneficial and therefore worth their support and cooperation. Thus, an informal, verbal, "gentlemans' agreement" was all that was necessary. Attempts to negotiate a formal "Memorandum of Agreement or Understanding" proved to be exceedingly difficult and time-consuming in the only two countries where it was tried (Philippines and Zambia). Drafting, negotiating, approval, and signing of such an agreement would have required two years or even longer to complete.

2.3 DEMONSTRATIONS OF ROOFING MANUFACTURE AND ROOF INSTALLATION IN THE PHILIPPINES, JAMAICA, AND GHANA

Local labor, materials, and facilities were utilized to demonstrate manufacture of roofing, by one or more processes, in the Philippines, Jamaica, and Ghana. Roofs were installed on houses in the Philippines, Jamaica, and Ghana.

The goal of the demonstration of the program was to utilize local materials, labor and facilities to manufacture at least one of the candidate roofing materials in small production quantities, and to install roofs on four houses in each of the three countries. The bagasse-reinforced rubber (BRR) composite system was demonstrated in the Philippines and Ghana. The bagasse-reinforced phenolic (BRP) composite was demonstrated in Jamaica, Ghana, and the Philippines. A bonded oriented bagasse (BOB) roof was constructed in Jamaica. These demonstrations of larger scale manufacture and roofing installations, as shown in Figure 4, helped to insure transfer of the technology. Secondary systems, and alternative uses for the products as structural materials, were also explored.

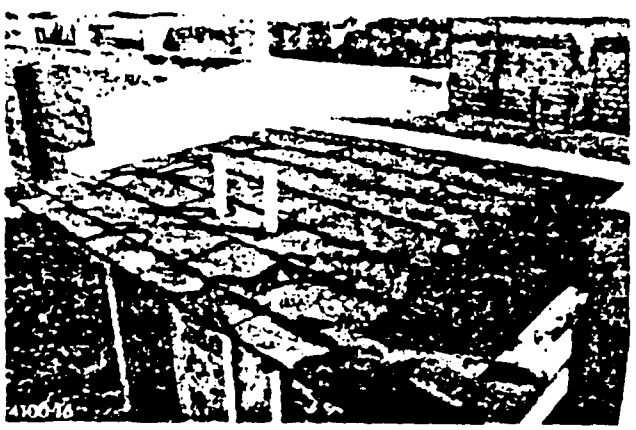
2.3.1 Philippines

In the Philippines, the facilities of the Goodyear Rubber Company and the National Housing Corporation were used to manufacture large quantities of roofing shingles from both bagasse-reinforced rubber and bagasse-reinforced phenolic. Four employee houses at NHC were roofed with the bagasse-reinforced rubber shingles. It was also demonstrated that the BRP roofing composition could be diluted with large quantities of ground wood chips to make low-resin composites of interest as structural (non-roofing) materials. NHC employees are now living in the four roofed houses.

In the Philippines a wide range of capabilities and facilities were available. Because of the wider range of capabilities

(a) Four NHC employee houses roofed with BRR flat shingles at Caloocan City.

(b) One of the units of four house cores roofed with BRP shingles at Hunts Bay Site and Service project, Kingston, after one year exposure.



(c) Security building at CSIR secretariet, Accra, roofed with BRP flat shingles.

Figure 4. Transfer of the roofing material technology was demonstrated by the installation of roofs in the Philippines, Jamaica, and Ghana using panels manufactured there.

and the direct commitment and interest of the National Housing Corporation, it was possible to demonstrate production scale manufacture of two of the four basic processes, as well as modifications of one of them for non-roofing applications. Extensive rubber compounding facilities exist in the Manila area, and natural rubber is grown in the Philippines. Thus the manufacture of the bagasse-reinforced natural rubber composite was demonstrated first. Secondly, the production of the bagasse reinforced phenolic on a plant scale was demonstrated along with production of a "wood chip dilution" product for structural (non-roofing) uses. Smaller scale (laboratory production) of the phenolic-bonded oriented bagasse fiber system was also demonstrated in the Philippines.

The experimental program in the Philippines was designed to bring together the expertise to define, manufacture, and evaluate two viable roofing alternatives, based on the earlier experimental work done by Monsanto Research Corporation in conjunction with the Philippines Roofing Advisory Committee. The experimental effort was conducted mainly in the laboratories of the National Housing Corporation, and those of the Forest Products Research Industries Development Commission (FORPRIDECOM). Assistance with the compounding of the rubber was provided by Goodyear Tire and Rubber Company (primarily), Latex City Rubber Company, and Manila Rubber Company. Mabuhay Vinyl also permitted the use of their laboratory molding facilities at no cost to the program for small scale experiments. Jardine-Davies, through their partially-owned Sherwin-Williams subsidiary, provided a site for outdoor aging of panels of the various candidate materials.

The actual technical working group came almost entirely from the National Housing Corporation. However, interest and participation throughout the program was also maintained by personnel

from the National Economic Development Authority, the National Science Development Board, and FORPRIDECOM.

In the demonstration of the bagasse-reinforced natural rubber composite, 15,000 pounds of composite roofing panels were prepared using the combination of Goodyear Rubber facilities for compounding the rubber, and National Housing Corporation particle board press for compression molding and curing the panels. Large 4 ft x 16 ft x 1/8 in. thick panels were prepared and sawed into 4 ft x 2 ft shingles. These shingles were then used to roof four employee houses having a roof area of 850 sq ft each. Flat shingles were used instead of the more cost-effective corrugated panels because of lack of corrugated molds.

NHC employees are living in each of the four houses and performance is being monitored by them, and by NHC technical personnel assigned to the project. No major problems have been encountred to date.

There was also a demonstration of the plant production of the bagasse-reinforced phenolic composite material. Approximately 5000 pounds of 4 ft x 16 ft x 1.8 in. panels and 50 tons of "wood chip dilution" construction materials were produced. Entire model houses, not just roofs, were scheduled to be put up in 1977 from the combination of materials produced.

2.3.2 Jamaica

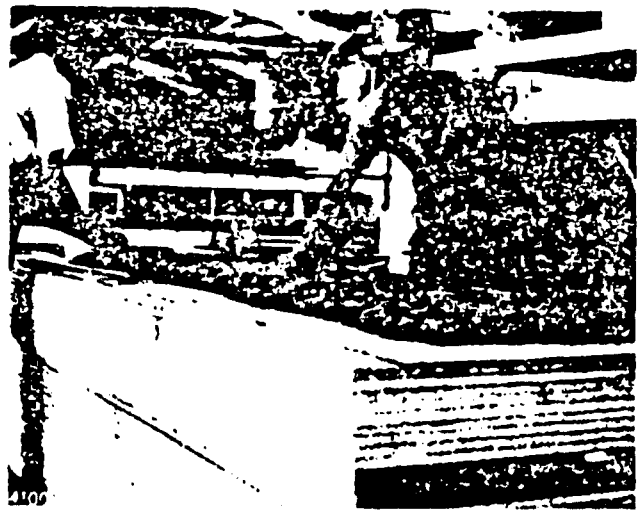
In Jamaica, bagasse-reinforced phenolic flat roofing shingles were manufactured using the facilities of the Goodyear Rubber Company and the Standard Building Products Company. Roofs were installed on parts of eight houses at the Hunts Bay low-cost housing project, and an additional house is scheduled to be roofed. A fourth roof consisting of painted BOB corrugated panels was constructed.

The combination of facilities required for the manufacture of bagasse-reinforced phenolic roofing existed in Jamaica. Thus, bagasse-reinforced phenolic flat roofing shingles were manufactured in the Kingston area using a combination of facilities of the Goodyear Rubber Company, the Scientific Research Council, and Standard Building Products Company. This is illustrated in Figure 5.

For the bagasse-reinforced phenolic composite roofing material demonstration, only the resin binder, pigment and stabilizer were imported. Otherwise, local materials, facilities and manpower were used to manufacture the roofing panels. Approximately 3400 sq ft of flat roofing shingles, sufficient to cover four roofs, were manufactured.

Using the 2 ft x 4 ft bagasse-reinforced phenolic shingles, roofs were installed over the cores of eight houses at the Hunts Bay low cost housing project on November 11, 1976. The remaining shingles are to be installed on a house scheduled to be constructed before the end of 1977. Flat 2 ft x 4 ft shingles were manufactured and used, in lieu of more cost-effective corrugated panels due to molds not being available.

(a) Processing of bagasse in a Banbury type mixer at Goodyear-Jamaica, Ltd.



(b) Leveling of BRP compound into 2 1/2 ft x 9 ft mold at Standard Building Products (SBP).

(c) Molded BRP panel being removed from press and mold at SBP.

Figure 5. Manufacture of bagasse-reinforced phenolic roofing panels at Goodyear and Standard Building Products in Jamaica typifies the availability of the developed technologies in the three participating countries.

There was strong interest in Jamaica in the oriented bagasse fiber reinforced composite material, and a considerable amount of small-scale experimental work performed on this system. Thus, this material and process was also considered for use in the demonstration phase, but not manufactured due to the lack of appropriate facilities to produce the required quantity of material on the desired time schedule. However, panels manufactured at our U. of Washington pilot plant were used to roof a building in the Kingston area in order to initiate a practical durability experiment.

The experimmental program in Jamaica was designed to bring together personnel with the necessary expertise to define, manufacture, and evaluate viable alternative roofing systems based on work done by Monsanto Research Corporation in conunction with the Roofing Advisory Committee. The effort included experimental work at the Scientific Research Council, analysis of roofing criteria by members of the Advisory Committees, selection of candidate roofing sites by the Ministry of Housing, and outdoor exposure studies at Berger Paints. The result was the basis for a roofing product demonstration. The actual demonstration was carried out by the Technical Working Group which had become thoroughly familiar with the systems through the small-scale experimental program while planning for the demonstration.

Long-term performance of the roofing installation will be monitored by the Advisory Committee, specifically personnel at Berger Paints Ltd., Kingston.

2.3.3 Ghana

> In Ghana, both the bagasse-reinforced phenolic (BRP) and rubber (BRR) roofing systems were demonstrated. BRP roofing shingles were manufactured by Ghana Rubber Products, Ltd. and installed on a building in November 1977 through the assistance of the Building and Roads Research Institute. A quantity of the BRR roofing material was also manufactured but could not be made into rigid shingles due to a minor, but significant, equipment problem. Ghana Rubber Products has purchased and is installing equipment that will allow them to manufacture the BRR roofing early in 1978, which is planned.

The existence of excellent rubber compounding facilities and rubber technology in Ghana provided for a perfect fit with the developed roofing systems. Interest existed in both the bagasse-reinforced rubber (BRR) and bagasse-reinforced phenolic (BRP) systems that utilize rubber processing equipment. Particular interest existed for the BRR system since natural rubber is grown in Ghana and thus a high percentage of indigenous material could be utilized.

The main emphasis in the Ghana program was on the BRR system and in October 1976 a quantity of roofing compound was manufactured. Produced were flexible bagasse reinforced rubber sheets ready to be rigidized by heating under pressure. Unfortunately, the temperature available to the molding press at Ghana Rubber Products was less than the 325°F required to cure the rubber. Accordingly, rigid panels could not be made and thus a roof could not be installed.

Ghana Rubber Products realizes the problem, is correcting it by installing a new high temperature boiler, and will on their own proceed to manufacture a pilot quantity of the BRR roofing early in 1978.

There is also an interest in the BRP system at Ghana Rubber Ltd. and in November 1977 a quantity of 10 in. x 20 in. roofing shingles were manufactured at their Accra plant. A small production line was utilized and the molding cycle was optimized to reduce cure time down to less than 1.5 minutes. These roofing shingles were supplied to the Building and Roads Research Institute (BRRI) who made available a structure at their C.S.I.R. Secretariet in Accra. A ∿100 sq ft shingle roof was thus installed which initiated a realistic outdoor exposure of the BRP system in Ghana.

As in the other countries, the experimental program in Ghana was designed to bring together the expertise to define, manufacture and evaluate one or more of the candidate roofing systems developed by Monsanto Research Corporation, in conjunction with the Ghana Roofing Advisory Committee. The total effort included small-scale experimental work on three of the four candidate processes, analysis of roofing criteria, outdoor exposure studies, and selecting sites for the roofing demonstration houses. The ground work for performing the manufacturing demonstration at Ghana Rubber Products Ltd. was conducted by personnel of the Building and Roads Research Institute, Kumasi.

2.4 SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACT

An initial environmental examination was made in which the possible effects of the wide scale application of the results of the AID-sponsored roofing program on land, water quality, atmosphere, natural resources, and cultural, socio-economic, and health aspects were considered. It was concluded that no negative environmental effects could be foreseen as a result of this project as viewed from its initial and interim stages.

The policy of the Agency for International Development (AID) is to carefully consider the environmental implications of all AID-supported projects. Accordingly, all projects must include an "initial environmental examination" in which the possible effects of the wide scale application of the results (positive or negative) are considered. Major areas to be addressed include the effects on: land use, water quality, atmosphere, natural resources, and cultural, socio-economic, and health aspects, etc.

The possible effects of the wide scale manufacture and use of the developed roofing on the specified major areas was addressed. Of the eight areas listed for evaluation, three (water quality, natural resources, and health) were identified as possibly being effected significantly. In these there is only limited or slight environmental effect (see Section 3.4).

3. TECHNICAL DISCUSSION

This section summarizes the nature of the roofing material systems developed, the approach taken in developing the materials and transferring the technology to the three participating countries, and the work done in each to illustrate the practical transfer of the technology and its utilization.

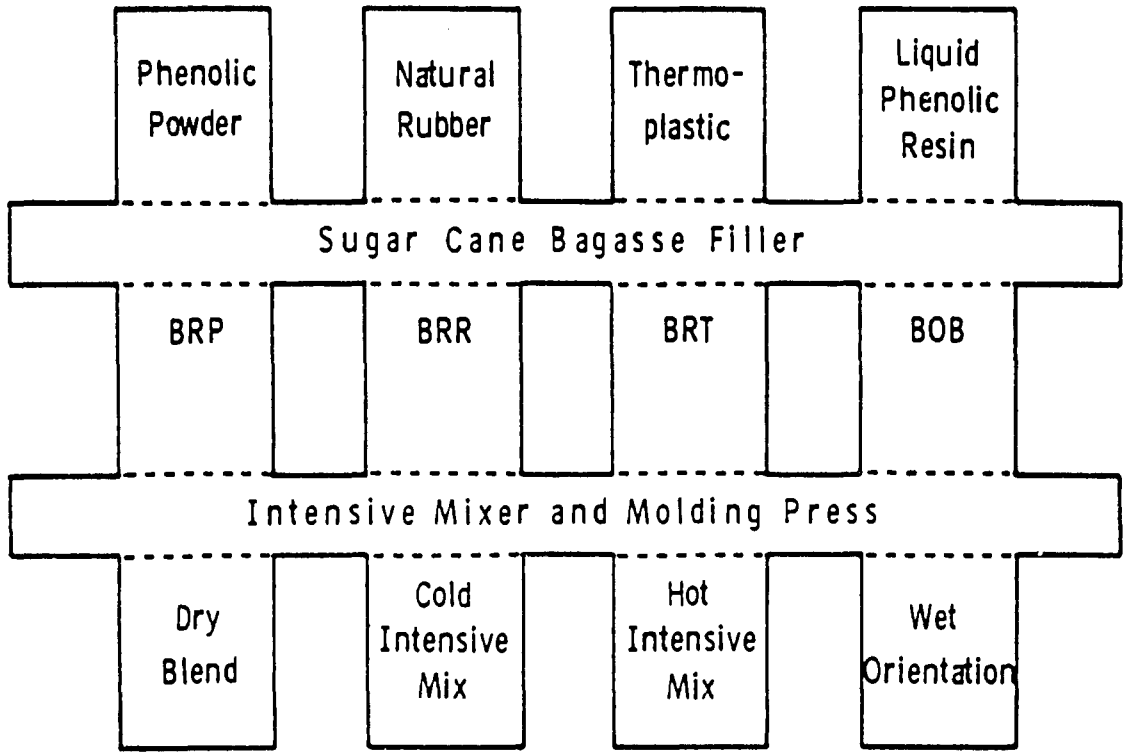
3.1 ROOFING MATERIAL AND PROCESS DEVELOPMENT

Four alternative roofing material systems that maximize use of indigenous components were developed. The four products differ in the type of resin binder and/or manufacturing process, but have in common bagasse (sugar cane residue) filler and a process requiring both an intensive mixer (Banbury) and a compression molding press. Product and process development was carried out initially in the United States with support from the three participating countries where the effort was continued and expanded. The potential use of available participating country materials, facilities, manpower, and skills was emphasized.

Four different roofing products, and the processes to manufacture them, were developed in a joint research and development effort involving Monsanto Research Corporation, The University of Washington, Washington University, and participants in the Philippines, Jamaica and Ghana. The four roofing systems are: bagasse-reinforced phenolic (BRP), bagasse-reinforced hard rubber (BRR), bagasse-reinforced durable thermoplastic (BRT), and phenolic-bonded, oriented bagasse fiber (BOB).

These systems are illustrated in Figure 6.

The first three systems (BRP, BRR, and BRT) all involve the extension of a strong, durable resin with very low cost reinforcing bagasse. The last system (BOB) is unique among these



- Bagasse Reinforced Phenolic - BRP
- Bagasse Reinforced Hard Rubber - BRR
- Bagasse Reinforced Thermoplastic - BRT
- Phenolic Bonded Oriented Bagasse - BOB

Figure 6. Four material and process alternatives were developed that have in common the fibrous filler and the type of mixing and molding operations, but that differ with respect to the resin binders used and the process details.

four in that the mechanical characteristics are dominated by refined bagasse fibers joined together, but not surrounded by, a phenolic resin.

These four roofing systems are not the same as the four described in the second annual report on this program. They differ in the separation of the durable thermoplastic binder system from the hard rubber (because of the significantly different nature of the process) and the omission of clay systems bonded with polyelectrolytes or phenolic resin. The clay system received no further treatment since neither its economics nor its physical properties appeared equal to those of the other roofing alternatives.

In addition to the use in roofing, other non-roofing applications using variations of the four candidate material systems were envisioned and in some cases illustrated. The modified products could be used as structural or non-structural materials for other parts of the house, such as ceilings, exterior and interior walls counter tops, furniture, etc. Some of these products are discussed in section 3.3, together with experience in their manufacture, particularly in the Philippines.

Experimental work in the United States was conducted at the Dayton Laboratory of Monsanto Research Corporation with the support of sub-contract personnel at the University of Washington in Seattle, and Washington University in St. Louis. Dr. Ben S. Bryant and his colleagues at the University of Washington introduced the concept of the oriented bagasse fiber system and advanced the state-of-the-art with respect to materials and processes throughout the program. Importantly, they scaled up the process with pilot facilities to actually manufacture a quantity of 2 ft x 7 ft corrugated panels that

were installed as a roof in Jamaica. Professor J. P. Rudd Falconer and his coworkers at Washington University contributed to the architectural, design, and socio-economic aspects of the program. They assisted in determining the most desirable type of roofing and in providing roof designs compatible with panels that could be manufactured in a demonstration phase.

Discussion of these materials herein will include their physical characteristics as a panel material, the nature and quantity of the ingredients, the latitude available in varying the formulations, a detailed description of the manufacturing process as conducted in the laboratory, and finally an analysis of cost. The cost information was determined and is reported in 1976 dollars. Costs were relatively firm with respect to materials. Processing and other costs could only be estimated until experience is generated in a plant manufacturing operation.

3.1.1 Bagasse-Reinforced Phenolic (BRP) Composite Roofing Material

The bagasse-reinforced phenolic (BRP) composite roofing consists of a durable, heat- and moisture-resistant material that can be produced in various colors and which is rigid, insulating, of low thermal capacity, lightweight, and easily transportable. It can be sawed and nailed for easy installation.

The BRP roofing product is a rigid, dark red panel that can be visually distinguished from the other roofing alternatives only through its slightly darker color. It can be made in the form of flat, corrugated, or other roofing shapes that can be nailed, drilled, cut, sawed, etc. for installation.

The outdoor durability of this roofing product has been very good, as determined both by accelerated weatherometer exposure and outdoor exposure in Jamaica, Ghana, and the Philippines. The only degradation of the product was noted early in its exposure. In about the first 60 days a very thin top surface layer that is rich in resin binder was degraded and eroded away, changing the surface from a glossy to a dull finish. This change was expected and is generally considered desirable for the appearance of the roof.

Durability was judged qualitatively on the panels exposed in the weatherometer for up to 5000 hours (4000 hours of intense sun mingled with 1000 wet/dry cycles) and with one square foot panels mounted on exposure racks in Jamaica since May 1975 and in Ghana and the Philippines since September 1975.

The mechanical characteristics of the roofing product are shown in Table I. Results are for the material tested dry and then wet after 48 hour immersion in water. The wet strength and modulus

Table I

MECHANICAL PROPERTIES OF BAGASSE-REINFORCED PHENOLIC COMPOSITE ROOFING MATERIAL[a,b]

	Initial	Wet[c]	Dry
Flexural Strength (psi)	7200	5500	7000
Flexural Modulus (psi, 10^3)	710	510	700
Tensile Strength (psi)	4130	3600	4100
Tensile Modulus (psi, 10^3)	830	680	820
Water Pick up (%)	-	1.9	0

[a] Dry blended, phenolic-resin-bonded, bagasse fiber reinforced, dense composite. Process: bagasse fibrillated with oil in Banbury (no separation of pith), dry blend of ingredients, compression molding at ∿500 psi.

[b] ASTM D790 - flexural, D638 - tensile, rate 0.05 in./min. Specimens 0.1 inch thick.

[c] Immersion in water for 48 hours. Tested wet.

were approximately 80% of the dry values and were recovered completely upon drying. The 15 and 25% decrease in these properties upon direct immersion in water was anticipated. This decrease was attributed to the high surface area at the cut edges of the test specimens. The mechanical property decrease was found not to be a problem with respect to performance in a roofing situation because the roof designs took this into account and most of the strength and toughness was required for shipping, handling and installation, rather than for installed roof performance.

This roofing material also has desirable fire resistance characteristics. It is not easily ignited, forms a protective char, burns slowly, and gives off little smoke. A cigarette left to burn on it caused only charring with no ignition.

3.1.1.1 Composition

The bagasse-reinforced phenolic (BRP) composite is by far the simplest roofing material with respect to the ingredients, which are few and readily available.

Table II shows the formulation for the BRP roofing composite material on both a volume and weight basis. The volume data indicates the relative effect of the ingredients on the total mechanical characteristics of the composite. The weight data are used for formulating and in calculating costs in manufacturing.

The phenolic binder shown in Figure 7 ends up as a continuous phase in the system, giving it its strength, rigidity, water and fire resistance. The bagasse represents the largest weight and volume of the system and, in this particular formulation, acts as an extender (i.e., a compatible, low-modulus reinforcing filler). Important to the economics of the product is that whole bagasse is used, although in the process it is shredded and defibrillated.

Table II

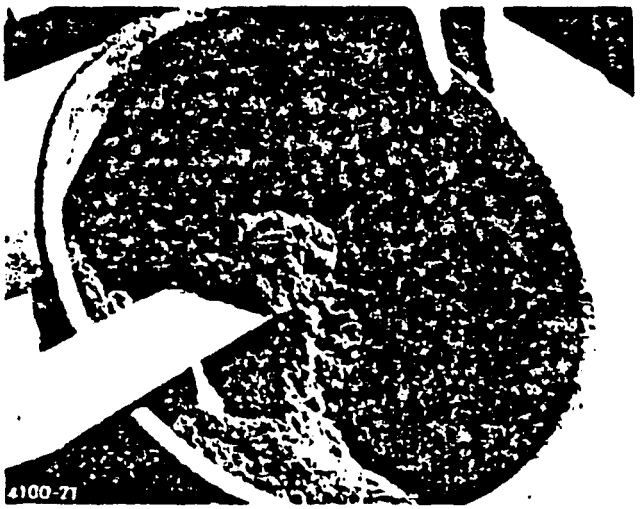
BAGASSE-REINFORCED PHENOLIC COMPOSITE MATERIAL FORMULATION[a]

Ingredient[b]	Volume[c] (%)	Weight (%)
Phenolic binder	31	30
Whole bagasse	61	61
Iron oxide pigment	1.4	5
Oil	6.2	4
Preservative	0.05	0.05

[a] Dry blended, thermoset-resin-bonded, bagasse fiber reinforced, dense composite. Process: bagasse fibrillated with oil in Banbury (no separation of pith), dry blend of ingredients, compression molded at ∿500 psi.

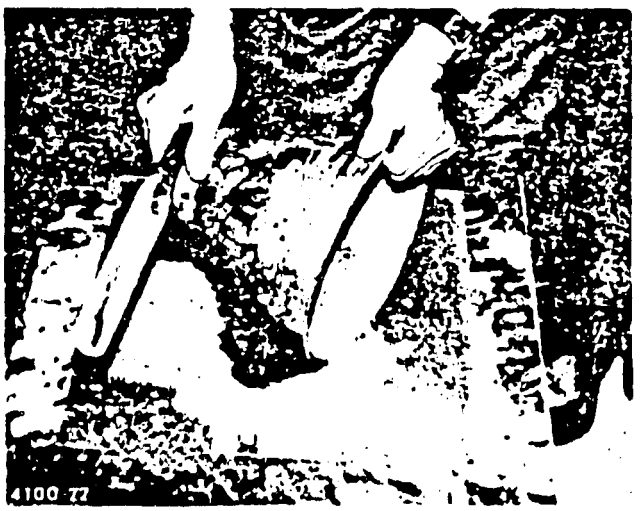
[b] Phenolic - phenol formaldehyde resin, Monsanto PR 736 dry powder; whole bagasse - dried to ∿1% moisture, but weights based on dry material. Extender oil - Sundex 790 or equivalent. Preservative - pentachlorophenol. Iron oxide pigment - Mapico No. 477, Cities Service Co.

[c] Determined experimentally from specific gravities: phenolic - 1.35, bagasse ∿1.4, oil ∿0.9, iron oxide ∿5.



(a) Oil treated, pigmented, defibrillated whole bagasse.

(b) Phenolic binder stable at room temperature that cures to a hard, dense solid at 275°F.



(c) Molding compound containing defibrillated whole bagasse, phenolic powder, oil, pigment and stabilizer are being poured into a test mold.

Figure 7. The primary ingredients in the BRP material are processed whole bagasse and phenolic powder resin that are blended to form a dry molding compound.

Approximately 0.1% of a preservative, pentachlorophenol, based on the bagasse was added to prevent biological degradation of the bagasse and residual sugars. This preservative was intentionally omitted from the outdoor exposure test specimens, and no mold growth or other problems were observed until the second year of exposure. It is recommended that the preservative be retained to inhibit growth in certain high humidity/ low sunlight areas.

The process oil (any rubber extending type oil) assists in water-proofing the bagasse, but its main function is to enhance processability which is discussed later. The pigment, treated iron oxide, gives the roofing product its red color, acts as a screen to shield the ultraviolet rays of the sun from the phenolic resin, and improves the flow of the material in the molding process.

3.1.1.2 Composition Latitude

The bagasse-reinforced phenolic composite formulation was optimized to perform in a roofing application. Little latitude exists in altering the ratio of its components.

Little latitude in modifying the BRP formulation exists for the roofing application. If the phenolic resin content is lowered, the product will be porous, have lower strength, and lose its water resistance. If the amount of phenolic resin is increased, the product will be very hard and brittle and thus difficult to nail or cut. In effect, the bagasse acts to considerably toughen the phenolic resin.

The preservative is at a minimal level. The level could be increased if desired but this would add cost and introduce an excess of ingredient that might have detrimental environmental

effects such as on water quality. Omitting it entirely would introduce the high probability of mold growth in non-sun exposed portions of a roof.

The process oil is added at a level sufficient for complete wetting of all the bagasse surface. Additional oil would only reduce the strength of the overall product, and less than 3.5% would introduce difficulties into the manufacturing process.

The pigments can be of any type that have good hiding power and provide the desired color. Their level could be reduced to as low as 3% without any detrimental effect to the roofing material except for color density and durability.

There is the possibility that lower cost liquid phenolic resins could be used in this material system. The water portion, of the phenolic resin however, would have to be completely removed adding to processing costs.

Modifications to this formulation for interior building materials that are subject to less severe environmental conditions can be projected and are discussed separately. Wood residues can be partially substituted for bagasse, if desirable.

3.1.1.3 Process

The process requiring only a few relatively simple and established steps is unique in that it makes use of a generally available piece of rubber compounding equipment to process whole bagasse into a usable form. The Banbury refined bagasse, plus pigments, is dry blended with phenolic resin powder and molded into dense panels.

The process for making the dense, bagasse-reinforced phenolic comprises the five primary steps shown in Figure 8. The first step, intensive mixing, is the most critical, and technically the most complex, but uses existing facilities and technology.

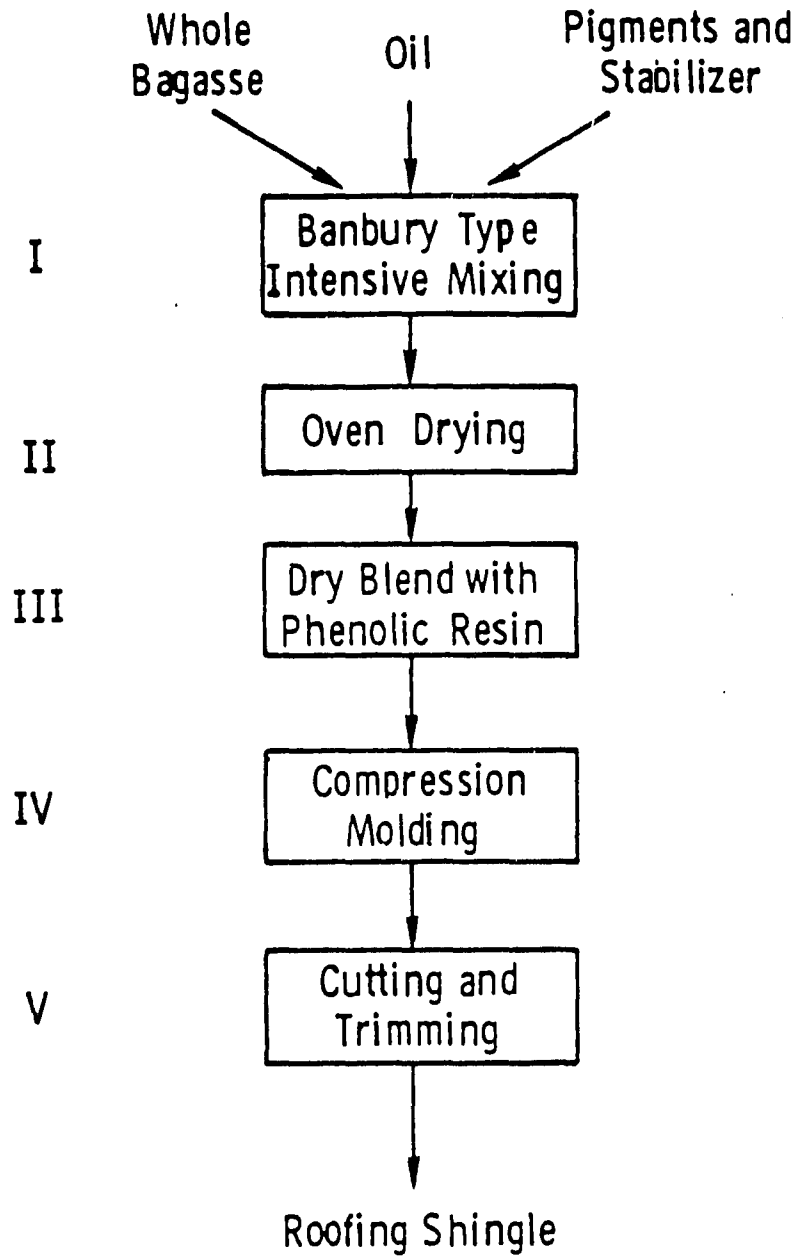


Figure 8. The process for preparing the bagasse-reinforced phenolic composite roofing material requires only a few, well-established steps.

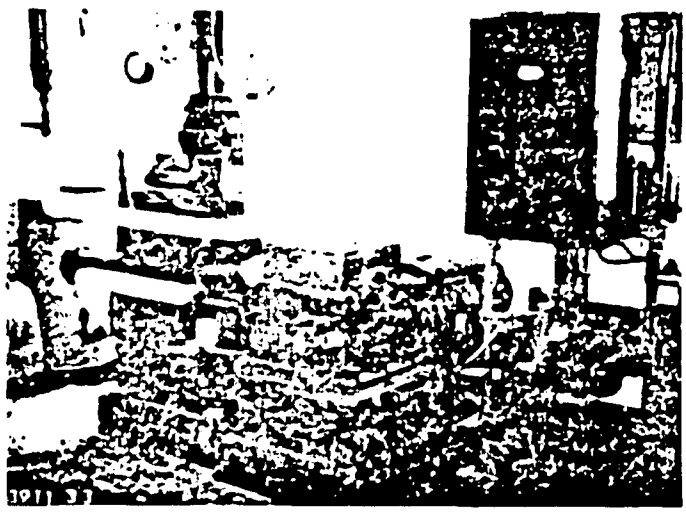
The second and third steps are simple drying and blending, wherein processed material is dried in an oven to remove all but 1% of the moisture and is then blended with the dry phenolic powder. Blending is continued until a uniform distribution of the phenolic onto the dry processed bagasse is achieved. In the fourth step a mold is filled uniformly with the dry molding compound and pressure and heat are applied to activate the resin and form a rigid panel or part.

In the first step, processing in a Banbury-type intensive mixer (shown in Figure 9), the rather coarse, whole bagasse is ground to a very fine particle size and the fibers are separated from the pith. Oil is then uniformly distributed over the surface of the fibers and pith by the mixing and shearing action of the machine.

The oil coating eventually helps keep moisture out of the system but, most important for the process, acts as a surface tackifier to which the pigments, stabilizer, and the phenolic resin physically attach themselves to the bagasse fiber. The oil thus assures an even and wide distribution of phenolic throughout the molding compound. The pigments and stabilizer are added in the intensive mixer where they are similarly distributed onto the bagasse. When the bagasse comes out of the intensive mixer it is red in color.

The Banbury-type intensive mixer can perform the various processing functions simultaneously due to the very high shearing forces that are generated. Water boils out of the system, resulting in some pre-drying, due to the heat thus generated. The system is under pressure generated by a hydraulic ram. However, because the resin could possibly set up and fuse at the high temperatures generated, the phenolic powder is not added at this stage (reaction with water is also possible and undesirable).

(a) View of bagasse being loaded into hopper that is then forced down into the mix chamber.



(b) General view of mix chamber (left), gear box, motor and controls for a 5 pound capacity unit.

Figure 9. Views of a laboratory Banbury type intensive shear mixer for processing bagasse into usable form for the various roofing products illustrate the nature of the required equipment.

The oiled, pigmented, and stabilized bagasse is dumped from the Banbury either directly into containers, or onto the floor and then shoveled into containers such as plastic or burlap bags, etc. At this point the bulk density of the bagasse is approximately 16 times higher than when it entered the Banbury. The higher density is important for the compression molding step where the lower volume is an advantage in filling a simple mold.

The processed bagasse is dried in an air circulating oven at 100°C (usually overnight) to reduce the moisture content to below 1%. Upon removal of the bagasse from the oven, it must be placed into containers (plastic bags) which will keep it dry. If the bagasse is not kept dry, the water will boil out in the compression molding step, causing blistering and blowing up of the panel upon release of pressure. Alternately, the bagasse can be dried prior to Banbury grinding provided the dry powder is then placed in closed moisture-proof plastic bags.

The third process step comprises measured addition and blending the powdered phenolic powdered resin with the processed bagasse. This can be done in a simple tumble blender, with a spatula and bucket, or in a concrete mixer. The better the mixing, the more uniform and dense the product will be. It is at this stage that the powdered phenolic resin sticks to the processing oil at the bagasse surface. This dry molding compound must also be kept sealed to prevent the pick up of moisture prior to molding.

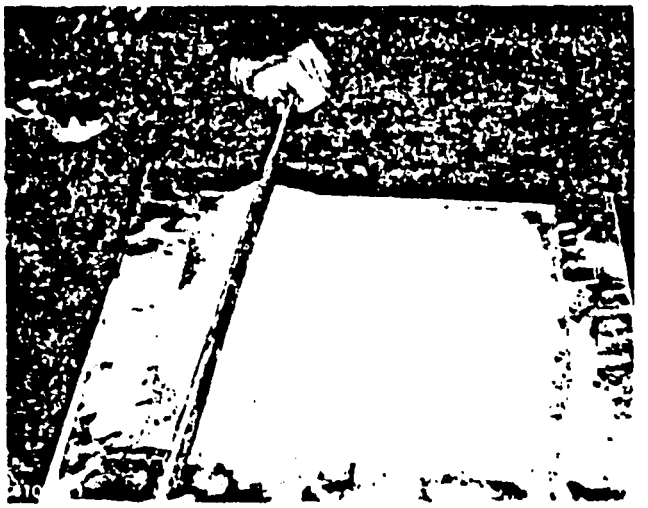
The final processing step involves compression molding of the loose molding compound. Because of the high resistance to flow characteristics of this particular molding compound, confining type compression molds are not required. Only a top and bottom caul plate (preferably aluminum) which have been treated with a specific mold release agent, Moldwiz EQ-6, are used.

Achieving the proper charge and distribution of ingredients to the mold is facilitated by the use of a simple removable ∿1/4 inch thick frame that is slightly larger than the part to be molded.

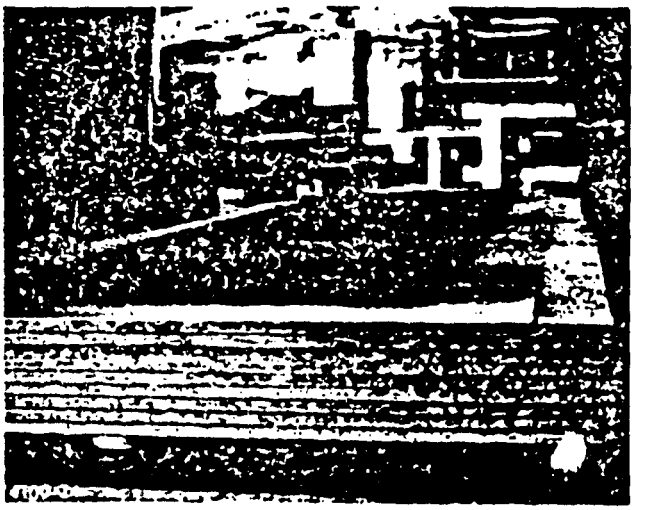
The mold is filled by dumping the molding compound uniformly inside the frame onto the bottom caul sheet as shown in Figure 10. It is then distributed within the mold frame by hand using the sharp edges of spatulas and a vibrating motion. Uniform distribution of this material is highly important for making a good part and preferably would be done in a more mechanized manner in any scaled-up process. After leveling the molding compound, the frame is removed and the top caul sheet is placed over the material.

The molding compound, sandwiched between the caul plates, is inserted into a press preheated at 290°F and at least 300 psi pressure is applied. The actual cure time for the phenolic resin, once it is heated to 290°F, is less than 60 seconds. However, heating of the panel usually takes longer, especially since the heat must travel through the bagasse, which is a relatively good insulator. Accordingly, cure cycles of 15 minutes are routinely utilized. It is expected that in mechanized plant operations cycle times as short as 2 minutes would be practical.

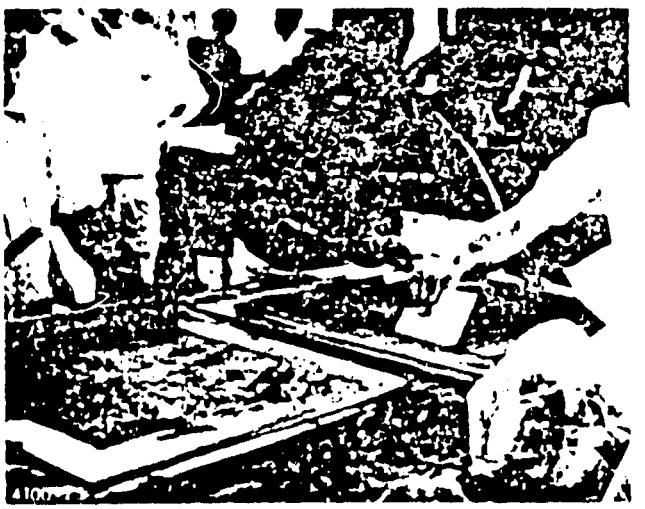
Routinely, a bumping process consisting of releasing the pressure and opening the press slightly after about one minute of heating, and immediately reclosing the press and applying the 300 psi pressure, was used to accommodate the expulsion of moisture and/or condensation products that may be present in the molding compound. This moisture and/or gases, if not expelled, could result in blistering of the panel upon release of pressure once the cure



(a) Layup of the compound in a laboratory mold.



(b) Compound layed up in a 2.5 ft x 9 ft mold at Standard Building Products.



(c) Layup of the compound into double shingle molds at Ghana Rubber Products.

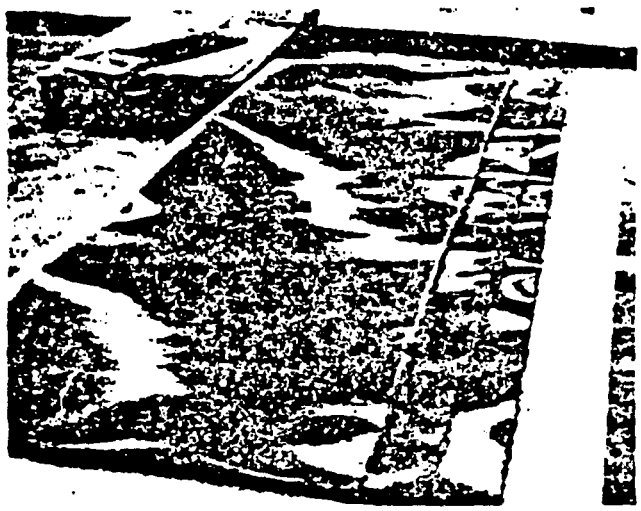
Figure 10. The process steps for the BRP composite material can be done on a small laboratory scale, or using larger high volume production facilities.

is complete, because paths for expelling these gases would not exist in the properly densified panel.

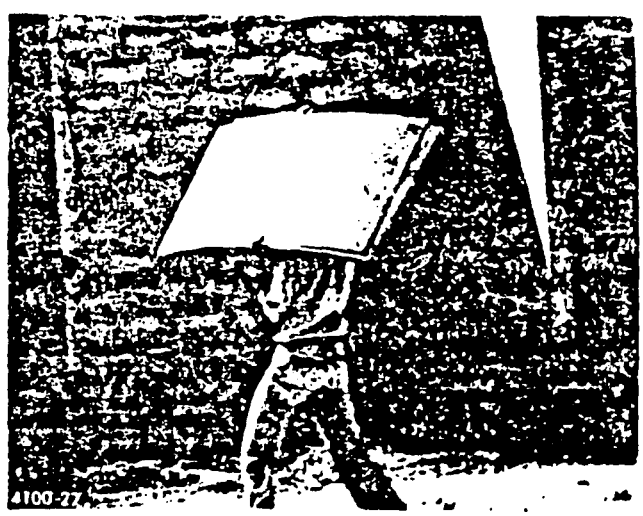
After the cure cycle the part and the caul sheets are removed from the press and separated by lifting them apart. The roofing panel is separated from the caul sheet by the combination of the specific mold release agent, Moldwiz EQ-6, and the rapid cooling and shrinkage of the aluminum caul plates, which forces mechanical debonding. Note: Phenolic resins are excellent adhesives. Accordingly, no deviation from the use of the Moldwiz release agent, in combination with the aluminum caul plates, should be introduced without intensive study to assure a similar reliability. Deviations could result in cementing the press platens together.

This process results in dense, durable panels very similar in appearance to a Formica high pressure laminate. They can be cut to appropriate size for forming into a roof. Shingles can be made from the larger panels simply by cutting with hand, band, or circular saws. The blades of these saws should be quite sharp and be operated at relatively slow speeds to prevent spalling or breaking away of surfaces at the cut edge.

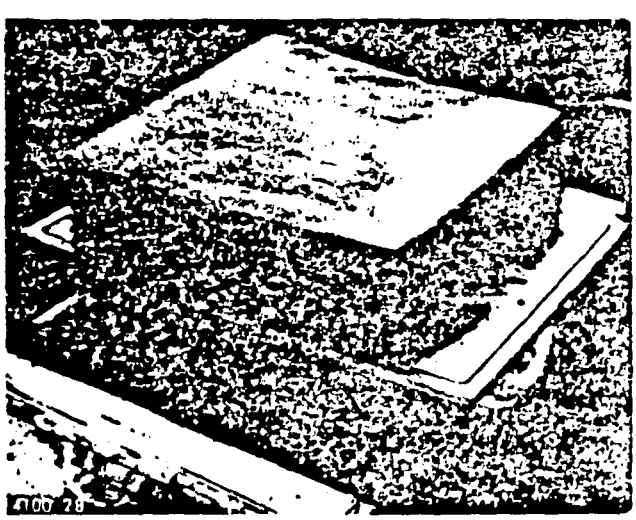
This process was used to make flat roofing panels like those shown in Figure 11, which were used as shingles to make a built up roof. Corrugated panels or panels of other shapes could also be fabricated similarly. However, this was not done since corrugated caul sheets, or flexible caul sheets which could be laid into a corrugated mold would be necessary and could not be made available within the time and dollar restraints of the program. Process details would also have to be worked out in a plant scale. Molds are discussed in Appendix J.



(a) 2.5 ft x 9 ft panels as they came from the press at Standard Building Products (SBP).



(b) 26 in. x 52 in. shingles cut from larger panels at SBP.



(c) 21 in. x 21 in. panels which were manufactured and cut into 10 in. x 20 in. shingles by Ghana Rubber Products.

Figure 11. Flat BRP roofing panels were manufactured and cut into shingles using the developed process.

3.1.1.4 Cost Projection for Ingredients

The cost for materials alone are projected as 12 cents per square foot. Selling prices for roofing shingles or panels are projected to be 3 to 4 times these material costs.

The breakdown in cost for the various ingredients is shown in Table III for the fire-retarded, lowest cost BRP formulation (based on 1976 dollars and costs). The material considered to indigenous to Jamaica, Ghana, and the Philippines is the whole bagasse, the cost of which is taken as the cost of an equivalent amount of fuel oil. However, where bagasse is presently available in excess, it is being sold at a fraction of that cost and, in fact, in many cases, has a negative cost in the sense that it is considered a waste product which must be disposed of. The price shown would need to prevail to justify use of bagasse in a roofing product in competition to alternative applications such as fuel, cattle feed, bagasse board, etc.

Liquid and solid phenolic resins are manufactured locally in the Philippines by two companies from indigenous formaldehyde and imported phenol.

Some of the other ingredients also exist in commerce in Jamaica, Ghana and the Philippines. These include the process oil, pigments, and phenolic powder. However, for the most part, they require some foreign exchange and therefore were not considered indigenous in this analysis.

Prime objectives of this R&D program were to reduce both the absolute cost and the foreign exchange component of the entire roofing system in the participating countries. These, in combination with the fact that roofing must be competitive with alternatives on a cost-per-square-foot basis, were controlling factors in the effort.

Table III

PROJECTED MATERIALS COST FOR BAGASSE-REINFORCED PHENOLIC (BRP) COMPOSITION[a]

Ingredient	Ingredient Cost (US$/lb)	Formula (Wt)	Component Cost (US$/lb)
Milled whole bagasse	0.014	61.0	0.0092
Phenolic power	0.38	30.0	0.1140
Preservative	0.42	0.05	0.0002
Process Oil	0.15	4.0	0.0060
Pigments	0.35	5.0	0.0175
		Total	0.1469

Equivalent Panel Thickness[b]: 0.12 in.

Panel Weight: 0.84 lb/ft^2

Material Cost[c] - 12 US¢/ft^2

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[a] 1976 data

[b] Corrugated 0.10 inch panel

[c] Selling price projected at 3 to 4 times this cost.

The percentage of imported raw materials costs, including phenol/formaldehyde imported at "world prices", for the BRP System is 78%. Since the imported materials represent only 40% by weight of the system, the high 78 percent is a result of the counter balancing by the very low cost of the indigenous bagasse.

The selling price for the roofing should be in the range of 3 to 4 times that of the basic materials costs. This factor includes the processing (which industrial experience shows would be expected to be about equal in cost to the raw materials), sales and administrative expenses, and profit. Using an average 3.5 multiplier to achieve the sales price for the BRP roofing, the foreign exchange requirements represent 27% of the selling price. The remaining 73% value in the roofing material would be added in the country manufacturing it. Overcapacity in the required equipment for the process exists in all three participating countries. This provides for immediate implementation of such manufacturing, with little added capital. Only molds of to be determined size and shape compatible with existing presses are needed.

The major expense in the BRP system is the phenolic molding powder. It is expected that with proper process development much lower cost liquid phenolic resins could be utilized. The cost of the molding compound could be reduced by as much 4¢/lb, which would reduce the materials costs from 12¢/sq ft to 9¢/sq ft (based on 25¢/lb liquid phenolic resin). Such a refinement could possibly take place in a future development program working with specific manufacturers. The costs discussed do not include importation duties and restrictions of the various governments. It is assumed that these can be minimized and/or eliminated for government sponsored housing applications, if deemed advisable by the participating countries.

While all of the costs will inflate with time, and have been especially dynamic for the past five years, no costs contained in the formulation are expected to escalate disproportionately with projected inflationary factors or have any projected availability problems over the next few decades of time.

3.1.2 Bagasse Reinforced Hard Rubber (BRR) Composite Roofing Material

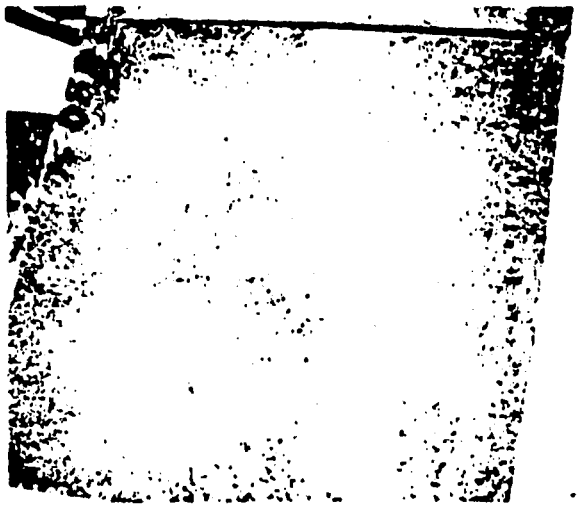
The bagasse-reinforced hard rubber (BRR) composite roofing is a durable, water resistant, tough, lightweight, low thermal capacity, panel system that can be formed into a variety of shapes. It is amenable to normal carpentry techniques and can be installed by nailing.

The BRR roofing product is a rigid, tough, dark red panel that can be molded into flat, corrugated, or other roofing element shapes. It can be nailed, drilled, cut, sawed, etc. for installation of a roof.

The outdoor durability of this roofing product has been very good, as determined both by accelerated weatherometer exposure and outdoor exposure in Jamaica, Ghana, and the Philippines. In about the first 60 days a very thin top surface layer that is rich in the natural rubber resin binder degrades and erodes away changing the surface from a glossy to a dull finish and exposing some fiber surfaces. This degradation of the fully exposed resin binder was both expected and considered desirable because it imparted a dull finish to the roof, consistent with usual acceptable alternative roofing.

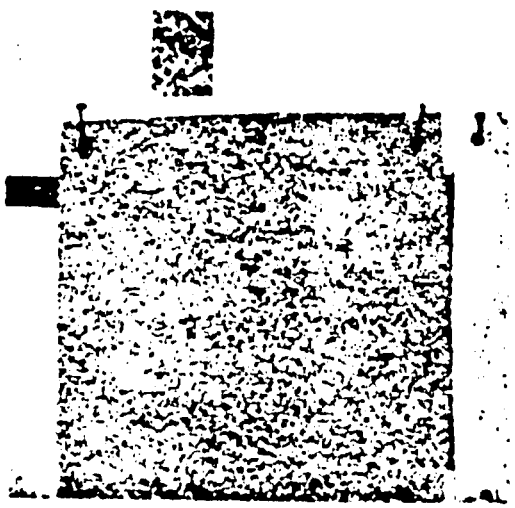
Durability was judged qualitatively on the panels exposed in the weatherometer for up to 5000 hours (4000 hours of intense sun, mingled with 1000 wet/dry cycles) and with one square foot panels mounted on exposure racks in Jamaica since May 1975 and in Ghana and the Philippines since September 1975. This exposure is illustrated in Figure 12.

The mechanical characteristics of the BRR roofing product are shown in Table IV. Results are for the initial conditioned



(a) Panel under exposure at Berger Paints, Kingston, Jamaica.

(b) Panel under exposure at the Building and Roads Research Institute, Kumasi, Ghana.



(c) Panel under exposure at Sherwin-Williams, Manila, Philippines.

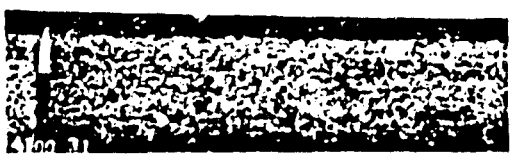


Figure 12. BIF panels were exposed to the elements for over two years in Jamaica, Ghana, and the Philippines.

Table IV

PHYSICAL PROPERTIES OF BAGASSE-REINFORCED HARD RUBBER[a,b]

	Initial	Following Exposure[c]
Flexural Properties		
Strength, psi	4,500	-
Modulus, psi	400,000	-
Tensile Properties		
Strength, psi	3,000	2,900
Durability		
Weatherometer - 5000 hours		
Outdoor - Jamaica since May 1975 Philippines since Sept. 1975 Ghana since Sept. 1975		
Density, lb/ft^3	60	

[a] Process: Banbury melt blending, sheeted on mill roll, compression molded at ~500 psi and 325°F.

[b] Flexural - ASTM 790; tensile - 638; rate - 0.05 in./min.

[c] Tensile strength following 1000 hours of weatherometer exposure with cyclic UV (carbon arc), water spray, temperature, and humidity.

material and following 1000 hours of weatherometer exposure with cyclic UV (carbon arc), water spray, temperature and humidity. The tensile strength retention of 97% was considered excellent.

Test specimens of the BRR composite completely immersed in water for periods of up to 7 days gained less than 0.1% moisture by weight and lost this water after a few days of drying. The material has a relatively low specific gravity of ~1.1, a low thermal capacity (ability to retain heat) and an insulating quality superior to that of metal roofing. In panel form, with a thickness adequate for a roofing shingle (approximately 0.1 inch), it has a weight of approximately 0.6 pound per square foot. Thus, 4 ft x 8 ft panels can be handled readily by one person.

The roofing material is tough and therefore can be nailed without cracking. Using commercially available roofing nails with large heads, panels can withstand the tensile and shear forces introduced from wind loading and thermal expansion and contraction, as illustrated by results generated in roof demonstrations discussed later.

Two formulations exist for the BRR roofing product, one of which is fire retarded. The non-fire-retarded composition offers the advantage of lower cost. The fire-retarded composition was shown to be slow burning in lab tests where it was ignited with an external source. Thus, when properly installed, flame spread across the roofing would be generally acceptable.

Burning characteristics will be highly dependent upon the nature of the roofing panel, roof design, installation, etc. and therefore would need to be quantified under specific projected conditions. Generalizations should not be made. However, char would be formed upon burning, and dripping of hot plastic would not be expected, as illustrated in the laboratory burning tests.

The roofing panels have a degree of compliancy when hot (~150°F) and therefore can be bent around large radius simple curves. This feature allows the material to fit to specific roofing substructures, minimizing sealing problems.

3.1.2.1 Composition

The bagasse-reinforced hard rubber (BRR) composite consists of a well known and established, durable hard rubber formulation historically used in battery cases, but with an unexpectedly high level of low-cost whole bagasse. Additives are used to obtain a desired degree of fire retardation.

Shown in Table V is the formulation for the BRR roofing composite material on both a percent by weight basis and parts by weight (based on 100 parts of natural rubber, a format typically used in the rubber industry).

The system is made up of three basic parts: (1) components of a hard rubber matrix material, (2) constituents needed to introduce a level of fire resistance, and (3) the fillers (both to reduce costs and increase durability and toughness).

The hard rubber component includes natural rubber (shown in Figure 13), which is indigenous in the Philippines and Ghana, sulfur, stearic acid, zinc oxide, stabilizer, and accelerator. Sulfur is used to crosslink the natural rubber into a rigid state. The sulfur reaction is promoted by the accelerator, which specifically was Monsanto's A100 accelerator. Stabilizers are used to prevent degradation during thermal curing of the rubber and also to prevent oxidation during long-term outdoor exposure. The stabilizers used were Monsanto stabilizer Flectol H, zinc oxide, and stearic acid.

Table V

BAGASSE-REINFORCED HARD RUBBER ROOFING FORMULATION

Ingredient	Weight (Parts)	Weight (Percent)
Natural rubber	100	20.5
Sulfur	46	9.4
Chlorinated paraffin	42	8.6
Stearic acid	1	0.2
Zinc oxide	1	0.2
Dry whole bagasse	265	54.2
Iron oxide pigment	15	3.0
Magnesium oxide	15	3.0
Stabilizer	0.25	0.05
Accelerator	1.5	0.31
Pentachlorophenol	0.1	0.02
Antimony oxide	2.5	0.51

Chlorinated paraffin - Chlorowax 80, Diamond Shamrock Company

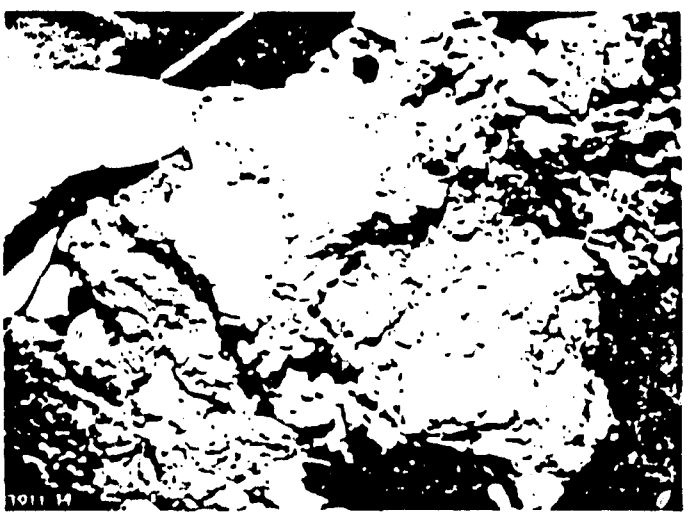
Iron oxide pigment - Mapico #477, Cities Service Co.

Stabilizer - Monsanto's Flectol H rubber stabilizer or equivalent

Accelerator - Monsanto's A-100 rubber accelerator or equivalent

Antimony Oxide - fire retardant grade

(a) Natural rubber that is grown and processed in Ghana and the Philippines.



(b) Molding compound containing the natural rubber binder, curing and stabilizing additives and 55% whole bagasse.

Figure 13. The BRF roofing has a high indigenous content in Ghana and the Philippines based on its natural rubber binder and bagasse filler.

Rubber systems normally include a processing oil which provides a variety of benefits. Among them is reduced cost. In the fir retarded formulation the oil is a low cost chlorinated paraffin (40% chlorine). The oil also aids in making the rubber flexible, tough, and compatible with the filler.

Antimony oxide (Sb_2O_3) is an additive known for its quality of improving the fire resistance of plastics and rubbers. It performs a variety of functions. One is assisting in the forming of a char layer to the surface of the material once burning is initiated. The char reduces further propagation of the fire. It is for this purpose that the antimony oxide was included in the formula, but its effect in this system is considered to be marginal, depending on the exact conditions of ignition, heat flux, etc.

The fillers consist of dry (less than 1% moisture), clean, whole bagasse as received from a cane sugar mill, pigments, and a fungicide. Red was deemed to be a highly satisfactory color for roofing, and therefore an iron oxide pigment, Mapico Red No. 477, produced by Cities Service Company was used. In this fire-retarded formulation containing the chlorinated paraffin oil, magnesium oxide was substituted for a portion of the iron oxide. The magnesium oxide acts as a pigment but more importantly, prevents degradation of the system during high temperature processing since it acts as a neutralizer for the HCl generated from the chlorinated oil.

The pentachlorophenol is incorporated to prevent biological action on the bagasse, natural rubber, or residual sugars. The toxic pentachlorophenol is not water-soluble and therefore would not be extracted from the molded material when wet, thus not be present in any rainwater run off.

3.1.2.2 Composition Latitude

The bagasse-reinforced hard rubber composite formulation was optimized to perform in a roofing application and have a reasonable level of fire resistance at low cost. It, however, can be tailored to some extent, offering an even lower-cost but less fire-resistant alternative.

In contrast to the bagasse-reinforced phenolic composite, considerable latitude is available for modification of the BRR formulation. The optimization of the BRR involved maximizing the utilization of bagasse and minimizing the cost of the system. Even though the bagasse, acting as a fibrous reinforcement, toughens the composite, the amount could be reduced to 130 parts based on 100 parts of natural rubber, while still maintaining mechanical rigidity. The penalty would be cost rather than mechanical performance. The nailability of the panel might also be reduced slightly, which would result in spalling around nail holes during installation.

The lowest cost formulation possible is illustrated in Table VI. This recipe, however, has poorer fire resistance because of the use of a high fuel content processing oil. The degree of fire resistance required for roofing depends on the specific application. All roofs will burn, or lose their integrity, under some set of fire conditions. The non-fire-retarded BRR roofing formulation would provide mechanical performance and durability equal to that of the fire retarded formulation. Its use, however, is left up to the discretion of the manufacturers, builders, and housing code formulators.

The low-cost BRR composite roofing formulation ingredients are identical to those of the fire-retarded formulation, except that a rubber processing oil is substituted for the chlorinated

Table VI

LOWEST COST BAGASSE-REINFORCED HARD RUBBER ROOFING COMPOUND FORMULATION

Ingredient	Weight (Parts)	Weight (Percent)
Natural rubber	100	21.1
Sulfur	41	8.6
Processing Oil	36	7.6
Whole bagasse	265	55.9
Pigment	27	5.6
Stearic acid	1	0.2
Zinc oxide	1	0.2
Stabilizer	0.25	0.05
Accelerator	1.5	0.3
Pentachlorophenol	0.1	0.02

Processing Oil - Any processing oil used in tire manufacture. Sundex 790, Sun Oil desirable.

Pigment - Mapico #477 red iron oxide, Cities Service Company

Stabilizer - Flectol H, Monsanto Company

Accelerator - A-100, Monsanto Company or equivalent.

paraffin oil, no antimony oxide is included, and magnesium oxide is not necessary. Additionally, a slightly lower amount of sulfur is required to cure the natural rubber.

Additional latitude exists in formulating of the BRR formulation in the following respects. First, the natural rubber can be of any grade usually available in commerce, and need not be of the quality normally required for automobile tires. Second, a variety of chlorinated paraffins can be used in the system Those having chlorine contents greater than 40%, however, caused severe difficulties in processing at 325°F. Finally, the stabilizer, Flectol H, could probably be reduced in quantity as time and experience in the processing and long-term outdoor durability are better quantified. At this time it is recommended that the stabilizer not be changed.

A curative accelerator, Monsanto's A-100 type, was found to be the only one of a number of accelerators or combinations tried that provided the desired degree of cure at any temperature. Future work in this area could be productive, especially in reducing process temperatures and times, which presently are the major negative factor in this system.

The fungicide should be of the water insoluble type such as pentachlorophenol, and will perform at concentrations as low as 0.05 part per hundred based on manufacturers data. Higher levels could be used with added cost to the system but with no major benefits except possibly very long-term retention of efficacy. Similarly, the level of antimony oxide could be reduced by 50% or doubled, but the savings, or benefits would probably not be cost effective. After more extensive fire testing, especially under realistic roof simulating conditions, it may be found that the antimony oxide could be eliminated. However, tests should be performed before any action to reduce the concentration is taken.

The above technology is based on common processes used in rubber formulating, which are well established around the world. Accordingly, those skilled in the art may reformulate to better satisfy locally existing conditions and material availability. This may be done as long as the rationale for use of the various ingredients is well understood and substitutions introduce no primary or secondary processing or performance problems.

Importantly, it is possible, by reducing the sulfur content, to produce a flexible rubber sheet that can be cured at lower temperatures and/or shorter molding cycles. The flexible rubber sheets, would require larger amplitude corrugations to permit covering reasonable spans, and more extensive supporting substructure. However, the economic advantage of a 50% reduction in press cure time might make this alternative attractive. This option should be evaluated.

3.1.2.3 Process

The BRR process requires only a few relatively simple and well-established steps routinely used in rubber manufacturing industries throughout the world. An intensive mixing step is unique in the result that is achieved, but not how it is done. Molding temperatures are about 35°F higher than are usual in commercial rubber processing. This difference is attributed to the presence of the bagasse filler.

The process for making the dense, bagasse-reinforced hard rubber material comprises the four primary steps shown in Figure 14. The second step is the most critical, and technically the most complex. The second, third and fourth steps require significant capital equipment which, however, is routinely available in the rubber manufacturing industry. The first step requires only oven drying of whole bagasse to remove moisture and packaging it so that moisture is not reabsorbed prior to process step II. The calendering step (III) converts the material from large chunks into a continuous sheet which is then cut, laid into molds, and run through a pressure/ temperature cycle to irreversibly cure it into a hard form (step IV).

The first step, that of oven drying the whole bagasse, is most important to rid the material of all moisture prior to compounding. Even though compounding is conducted in step II at temperatures well above the boiling point of water, it is very difficult and expensive to remove water at that point. The consequences of not removing the water are that in the molding stage, also done above the boiling point of water, steam will be generated which will cause blistering and/or blow up the panel on release of pressure.

Oven drying should be conducted on the whole bagasse until moisture contents are reduced below 0.1%, based on the dry

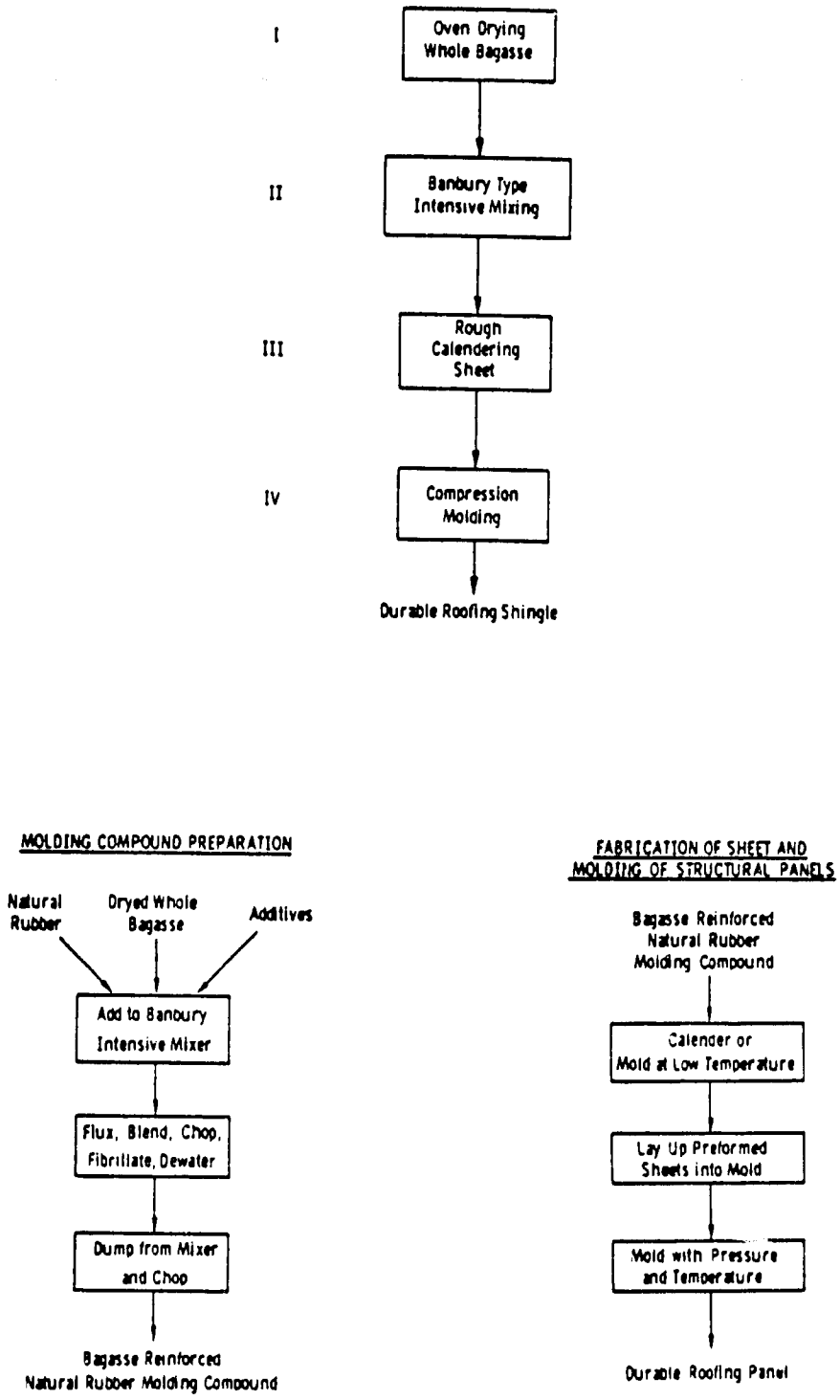


Figure 14. Process outline for making dense, bagasse-reinforced hard rubber (BRR) material shows four primary steps.

weight of the whole bagasse. The equilibrium moisture content of bagasse is about 20%, while bagasse as it comes from the sugar mill process contains equal parts of water and bagasse. Accordingly, it is advisable to reduce the moisture content from the 50% down to 20% by storing it under ambient outdoor conditions. After the bagasse is dried, it will have less tendency to pick up water. However, it can recapture water to the 20% level and therefore must be packaged in waterproof bags and/or used immediately upon removal from the oven. The other ingredients should also be dry, but this is usually not a problem if the materials are kept in their original containers.

The second step, processing in an intensive mixer, accomplishes a variety of functions, both expected and unexpected. Expected are the excellent, intimate blending of all of the materials together into a homogeneous mass, some reduction in size of the bagasse, and removal of water. Temperatures as high as 250-300°F are generated purely by the mechanical action of the intensive mixing, even though cold water is run through jackets in the Banbury mixer.

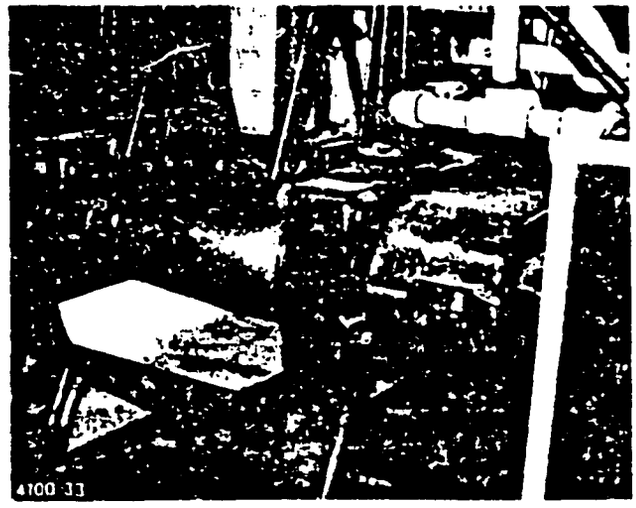
Temperatures as high as 325°F were achieved when mixing large batches in manufacturing scale Banbury mixers. In such cases it was advisable to not add the sulfur and/or the accelerator to the product in the Banbury mixer until it cooled, or to delay their addition to the calendering stage.

The unexpected function of the Banbury type intensive mixer was its ability to reduce the bagasse to very small bundles of fibers and to separate the pith from the fibers. These components were simulatneously compounded into the natural rubber matrix. This intimate compounding provided much greater reinforcement capability by the bagasse and allowed the incorporation

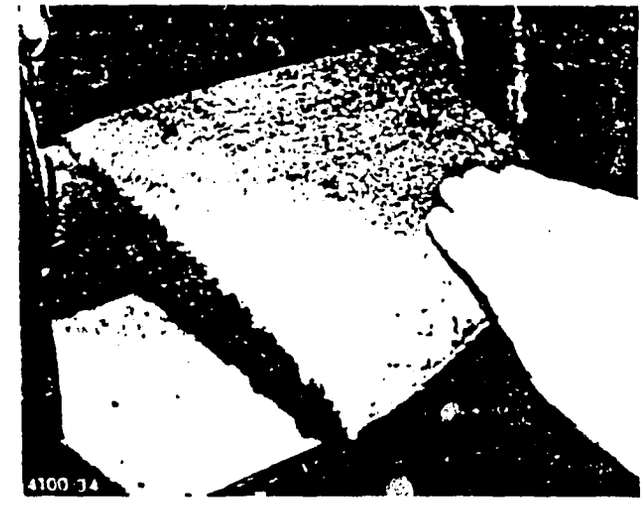
of much more bagasse on a volume basis, than is usually allowed for cellulosic fillers in rubber.

The processing oil or chlorinated paraffin oil is well distributed over the bagasse as a result of the mixing, and it also assists in making the bagasse compatible with the natural rubber, thus allowing the very intimate mixing. The product from the Banbury-type intensive mixing (step II) is homogeneous, red blobs of material, with very little visible fiber. Advantageously, a mill roll is usually located directly beneath the Banbury mixer and is used to convert the hot "chunks" from the Banbury into manageable sheets for handling and cooling. Otherwise, massive guillotine-type rubber cutting equipment is required to cut the rubber chunks into smaller pieces.

The third step, calendering, shown in Figure 15, converts the irregular, large lumps of roofing compound into a uniformly thick, wide, continuous sheet that has almost the final desired thickness and width for a roofing panel. Calendering consists of placing the large chunks or sheets of compounded material onto mill rolls (sets of from 2 to 4) which grab onto the material, heat it some through mechanical action, and convert it into a sheet configuration. Such sheets when formed at moderate speeds have little residual stresses. This prevents them from returning to their original shape. The product of this process step is a roll of thin (0.13 in.), flexible rubber sheet that can be trimmed with scissors or knives to fit into any desired mold. The sheet is stable in this form until heated to high temperatures, and it can be rolled up and stored almost indefinitely and/or shipped to another site until it is cured into its final form.



(a) Calendering with a laboratory two roll mill at near room temperature.



(b) Stripping of the flexible formed sheet from the laboratory calender.

(c) Calendering with a production two roll mill at Ghana Rubber Products.

Figure 15. Lumps of compounded BRR material are converted to a flexible, dense, uniformly thick sheet by calendering.

This third step, milling, is not entirely necessary, but for large scale processing it usually reduces handling problems and eventually minimizes molded-in residual stresses in a roofing panel which, if relieved non-uniformly, could cause warping. This third step is therefore highly recommended for the preparation of material, even in the laboratory stage. A limited amount of additional material can also be compounded in at this stage (such as the sulfur and accelerator). This controlled addition of curing ingredients may offer advantages to the manufacturer, such as increased storage stability for the intermediate product.

The final process step also shown in Figure 15 is compression molding at elevated temperatures and pressures. In this final step, the flexible calendered sheet is laid into a mold, that can be flat, corrugated, or any other desired shape. Pressures in the range of 300 to 500 psi are applied, and the materials are heated to at least 325°F. This temperature must be maintained for approximately 30 minutes to cure the rubber into a relatively hard state. Temperacures of less than 325°F and times of less than 30 minutes are not acceptable. Higher temperatures and longer times were also not allowable or advantageous. Higher temperatures were a disadvantage for the fire-retarded formulation, because decomposition of the chlorinated paraffin oil could take place.

It may not be necessary to cure the rubber to the rigid, hard rubber stage. Either flat rubber shingles or larger amplitude corrugations may permit a flexible formulation to be used. This would require revision of the formulation (e.g., use of less sulfur) but would permit shorter, more economical curing cycles.

3.1.2.4 Cost Projection for Ingredients

Costs for materials alone, including no processing, are projected to be 9 cents per square foot for the fire-retarded BRR composite and 7 cents per square foot for the lowest cost system. Sales prices for the roofing shingles or panels are projected to be three to four times these material costs.

A breakdown in costs for the various ingredients is shown in Table VII for the fire-retarded and in Table VIII for the lowest cost BRR formulations (based on 1976 dollars and costs). The situation for the Philippines where natural rubber is available at about 20¢/lb (even as low as 18¢/lb), is illustrated. In Ghana the world market price of about 40¢/lb prevails due to existing, but artificial, controls. Costs for material produced there would differ accordingly.

Materials considered to be indigenous to both the Philippines and Ghana are the natural rubber and the whole bagasse. The cost of the bagasse is taken at its fuel oil equivalent, since it can be used as a fuel. However, where bagasse is presently available in excess, it is being sold at a fraction of that cost and, in many cases, has a negative cost in the sense it is considered a waste product that must be disposed of. In the long term, however, the higher price would need to prevail to justify its use in the roofing product in contrast to alternative applications such as fuel, cattle feed, bagasse board, etc.

Some of the other ingredients already exist in commerce in the Philippines and Ghana, especially the Philippines. However, for the most part they require some foreign exchange and therefore were not considered indigenous in this analysis. The original objective of the overall program was to reduce costs compared to alternate roofing materials (e.g., corrugated galvanized iron).

Table VII

MATERIALS COST FOR BAGASSE-REINFORCED HARD RUBBER ROOFING

Ingredient	Ingredient US$/lb	Formula Wt %	Component Cost US$/lb
Natural Rubber	0.20	20.5	0.0410
Sulfur	0.05	9.4	0.0047
FR Process Oil	0.30	8.6	0.0258
Whole Bagasse	0.01	54.2	0.0054
Pigments	0.35	6.0	0.0210
Additives	0.96	1.29	0.0214
		Total	0.1103

Eq. Panel Thickness: 0.12 in.

Panel Weight: 0.84 lb/ft^2

Material Cost: 9 US¢/ft^2

Table VIII

MATERIALS COST FOR LOWEST COST BAGASSE REINFORCED HARD RUBBER

Ingredient	Ingredient US$/lb	Formula Wt %	Component Cost US$/lb
Natural Rubber	0.20	21.1	0.042
Sulfur	0.02	8.6	0.002
Processing Oil	0.15	7.6	0.012
Whole bagasse	0.014	55.9	0.008
Pigment	0.5	5.6	0.028
Additives	0.8	1.2	0.010
		Total	0.102

Eq. Panel Thickness: 0.12 in.

Panel Weight: 0.6 lb/ft^2

Material Cost: 7 US¢/ft^2

Minimizing the foreign exchange costs also was of interest, while retaining a competitive absolute cost per square foot. The percentages of cost of imported materials alone, based on only total materials cost, are respectively 58%, and 51% for the fire-retarded and the lowest cost compositions. These percentages are remarkably low considering the indigenous materials are so very low in cost and represent 75% by weight of the formulations.

The sales cost for the roofing is projected to be in the range of 3 to 4 times that of the basic materials cost. This factor includes the processing cost (normally expected to be about equal to the cost of raw materials) plus sales and administrative expenses and profit. Using an average 3.5 multiplier to achieve the sales prices for the two types of roofing, the imported materials cost then represents 17% and 15% of the sales prices, respectively. The remaining 80 to 85% value in the roofing material would be added in the country manufacturing it.

Over-capacity in the required equipment for the process exists in the Philippines and Ghana providing for the immediate implementation of such manufacturing, with little added capital.

Because of the formulating latitude allowable, as discussed in Section 3.1.2.2, it can also be anticipated that substitutions for various ingredients could help in reducing costs even further. That can only be achieved with time as experience is gained by the manufacturers, the demands of the market place, and the controls set by the governments. These costs do not include importation duties and restrictions of the various governments. It is assumed they can be minimized and/or eliminated for government-sponsored housing applications, if deemed advisable by the participating countries. While all of the prices will inflate with time and have been especially

dynamic for the past five years, none of the materials in the formulation is expected to escalate in cost disproportionately with projected inflationary factors, and none has any projected availability problems over the next few decades of time.

3.1.3 Bagasse-Reinforced, Durable Thermoplastic (BRT) Composite Roofing Material

The bagasse-reinforced, durable thermoplastic (BRT) composite roofing material is a relatively simple system with respect to the number and nature of the components. It uses established plastic compounding and forming processes. Its appearance and outdoor durability are very good. It is similar to the bagasse-reinforced hard rubber composite roofing material with respect to processing. It is a highly water resistant, lightweight, low thermal capacity panel system that can be formed into a variety of roofing shapes.

This roofing product is a rigid, tough, dark red panel that can be molded into flat, corrugated, or other roofing element shapes. It can be drilled, cut, sawed, etc. for installation of a panel-type or shingle roof. It is both moisture resistant and water resistant. Nailability, however, is marginal and will depend on the type of nails and the thickness of the panel since the product is hard and tough. Small diameter steel nails might work with 0.1 inch thick panels.

The outdoor durability of this roofing product was very good as determined both by accelerated Weatherometer exposure and outdoor exposure in Jamaica, Ghana, and the Philippines. Either of two alternate thermoplastic matrix or binder materials can be used in this product, ABS or SAN (see Table IX) with near equal results. The outdoor aging properties of these panels are slightly better than those of the alternative BRR material. The thin top surface layer, which is rich in resin binder, was degraded and eroded away in the first 90 days. This resulted only in changing the surface from a glossy to a dull finish, which was expected and considered generally desirable with respect to appearance. In spite of this minor amount of controlled erosion, the fibers did not become exposed.

Durability was judged qualitatively on the panels exposed in the Weatherometer up to 5000 hours (4000 hours in intense sun, mingled with 1000 wet/dry cycles) and with 1 square foot panels

Table IX

MECHANICAL CHARACTERISTICS AND DURABILITY OF BAGASSE REINFORCED DURABLE THERMOPLASTIC COMPOSITE ROOFING MATERIALS WITH ALTERNATIVE BINDERS [a]

	Initial				Following Exposure [d]			
	Flexural [c]		Tensile [d]		Tensile/1000 hr		Tensile/430 hr	
Binder [b]	Str. (psi)	Modulus (10^3 psi)	Str. (psi)	Modulus (10^3 psi)	Str. (psi)	Modulus (10^3 psi)	Str. (psi)	Modulus (10^3 psi)
SAN	6400	1230	4000	960	3900	942	3900	930
ABS	5400	1110	4200	970	4200	940	4600	960
PS	5650	1265	3400	1067	1650	500	3100	1000

[a] Melt-compounded, resin-bonded, bagasse-reinforced composite.
Process: Banbury melt blending, grinding to molding compound, compression molding at ~500 psi. Molding temperature 400°F for SAN and 375°F for ABS.

[b] SAN - styrene acrylonitrile.
ABS - acrylonitrile butadiene styrene.
PS - polystyrene, shown as reference.

[c] ASTM D790 - flexural, D638 - tensile, rate 0.0.5 in./min.

[d] Tensile strength following either 430 hours of intense UV or 1000 hours of weatherometer exposure with cyclic UV (carbon arc), water spray, temperature and humidity.

mounted on exposure racks in Jamaica since May 1975 and in Ghana and the Philippines since September 1975.

The mechanical characteristics of the BRT roofing product are shown in Table IX for the two alternative SAN and ABS binders. Also, for comparison purposes, data are given for the product made with just polystyrene as a binder. Results are for the initial conditioned materials and following either 1000 hours of Weatherometer exposure with cyclic UV (carbon arc), water spray, temperature and humidity, or 430 hours of intensive UV at 74°F and 50% relative humidity.

Rention of tensile and flexural strength and modulus was greater than 97%. What could happen if a less desirable matrix were used in this system is illustrated by the data for the polystyrene (PS) binder. In this case, over half of the tensile strength and modulus were lost following the Weatherometer exposure. The fact that this degradation was much more severe than that shown for the intense UV was due both to the longer exposure time and to the presence of water and moisture. The water wicked into the bagasse fibers, which then swelled and thus accelerated the degradation of the composite. That this did not occur with the SAN or ABS binders was highly significant and could be partly attributed to the great affinity of the SAN and ABS for the bagasse fiber.

Test specimens of the BRT composite completely immersed in water for periods of up to 7 days picked up less than 1.0% moisture by weight and lost this water after a few days of drying. In this respect it was very similar to the BRR material. The material has a specific gravity of approximately 1.1, a low thermal capacity, and an insulating quality superior to metal roofing

when formed in a thickness adequate for a roofing shingle (approximately 0.1 in.). It has a weight of less than 1 pound per square foot and standard panels readily can be handled by one person.

A composite with one of the high rubber grade ABS binders has a potential for nailability which does not exist with the SAN matrix. However, the slightly shorter expected life, and higher cost, could make ABS less attractive than SAN as a binder.

The fire resistance of this type material was not determined. It is not, however, expected to be outstanding. As with the natural rubber system, additives could be used to obtain a fire-retarded material.

3.1.3.1 Composition

The bagasse-reinforced durable thermoplastic (BRT) composite is basically a simple, filled thermoplastic. It is unique, however among filled thermoplastics in containing 60 volume percent of a filler. With respect to the number of ingredients, it is indeed the simplest of all developed materials. Two alternative binders are available and dried whole bagasse is the preferred filler.

The formulation for the BRT roofing composite material is shown in Table X, on both a volume and weight basis. Volume because this indicates the relative effect of the ingredients on the mechanical characteristics of the composite. Weight because this is the basis for formulating and determining costs in manufacturing. The BRT formula is almost identical to that of the BRP material except that a thermoplastic binder takes the place of the combination of a thermosetting phenolic binder and a processing oil. The density of the thermoplastic resin is approximately 20% less than that of the thermosetting resin.

Table X

COMPOSITION OF BAGASSE-REINFORCED DURABLE PLASTIC MATERIAL[a]

Ingredient[b]	Percent	
	Volume[c]	Weight
SAN or ABS binder	35	26.7
Whole bagasse	60	63.2
Dry ground clay	3	4.9
Iron oxide pigment	2	5.2
Pentachlorophenol	0.05	0.06

[a] Melt-compounded, resin-bonded, bagasse fiber-reinforced composite.

Process: Banbury melt blending, grinding to molding compound, compression molding at ∿500 psi. Molding temperature 400°F for SAN and 375°F for ABS.

[b] SAN - Monsanto LNA 21 or equivalent.
ABS - Monsanto LNI 780 or equivalent.
Whole bagasse - dried to ∿20% moisture, but weights based on dry material.
Clay - brick grade ground to ≤20 mesh.
Extender oil - Mapico red #477, Cities Service Company.

[c] Determined experimentally from specific gravities of:
SAN - 1.02 bagasse ∿1.4, clay ∿2, iron oxide ∿5.

The thermoplastic binder can be either SAN (styrene/acrylonitrile) or ABS (acrylonitrile/butadiene/styrene) and is the matrix which is the continuous phase in the system providing the strength, toughness, durability, rigidity, surface appearance, and water resistance. The primary difference between composites made with ABS or SAN is in nailability. The ABS binder is a rubber-modified rigid thermoplastic. It is tougher and more readily nailable. The SAN binder is more rigid and hard. Therefore, driving a nail through it without causing brittle fracture is very difficult. If it were used, nail holes would have to be "molded in" or drilled.

The advantages of SAN over ABS are that lower temperatures are required for processing, it has an expected longer outdoor life, and it was recently slightly lower in cost. If this type of system were to be exploited, it is suggested that research be conducted and the various benefits weighted to select the most appropriate thermoplastic binder. This was not done in this program because the alternative composite systems were considered more appropriate for demonstration due to available plant facilities and projected better long range cost benefits.

It originally had been anticipated that lower cost polystyrene could be used as a binder in this system when combined with minor amounts of relatively expensive stabilizers. The poorer aging and rapidly escalating price of polystyrene, however, ruled out this material in favor of the SAN and ABS thermoplastic binders. SAN and ABS inherently have superior outdoor aging properties and are commercially available in grades that contain the necessary stabilizers to protect against exterior environments.

The whole bagasse is multifunctional in the composition. First, it replaces 60 volume percent of the binder, thus increasing the relative amount of both indigenous and low cost materials.

Second, and important to the economics of the system, is the fact that whole bagasse, as it comes from the sugar mill, is used. A large portion (60-80%) of the bagasse is fiber. Thus, it acts both as a filler and as a reinforcing element. This reinforcement is reflected in retention of rigidity, improvement in impact resistance, and minimal loss of strength, in tension or flexure. The remaining portion (20-40%) is pith. The pith contributes by improving melt flow during processing and by filling the spaces between the fibers that otherwise would require binder.

The incorporation of clay in the composite is an extension of the beneficial function of the pith in processing. The clay also assists in filling in the space between the oriented fibers and provides an internal "mechanical lubricant" that aids in the processability of the composite.

The iron oxide pigment shields the binder from the external environment, especially the ultraviolet component of sunlight. It also provides color. It functions because it is highly compatible with the thermoplastic binders. The clay and pith also contribute to this "hiding" effect.

A preservative (pentachlorophenol) is present at a level of approximately 0.1% (based on the bagasse) to prevent biological degradation of the bagasse and residual sugars. The existing outdoor exposure test specimens intentionally did not include a preservative, in order to accelerate the aging effect. Even so, no mold growth or other problems were observed. It is recommended, however, as with the other systems, that the preservative be retained to inhibit growth in certain high humidity/ low sunlight areas.

3.1.3.2 Composition Latitude

The bagasse-reinforced durable thermoplastic composite formulation was developed to perform in a roofing application, but was not optimized to a given set of criteria. Accordingly, the latitude must be narrowed to provide an optimized system. Options should then be made available based on this specific tailored formulation.

The advantages of two alternative binders, SAN and ABS, are explained in the previous section. Others might also be considered by those skilled in the art taking into account the results generated and reported in the first two years of this program. The binders should be limited, however, to thermoplastics that are processable at less than 425°F (thus preventing degradation of the bagasse) and that have established outdoor durability (either alone or stabilized with additives).

The amount of whole bagasse could be reduced to improve the thermoplastic processability of the system, but with obvious penalties to the economics and some loss of toughening, especially with the SAN binder, which is relatively rigid and brittle. There is also a possibility that bagasse pith, the residue from a bagasse board operation, could be substituted for the whole bagasse. The pith actually contains a quantity of small fiber bundles that might provide sufficient mechanical performance, but some loss in tensile, flexural and impact properties would be expected. Such a substitution would be more advantageous where this pith presently exists as a waste product.

Latitude exists in the use of the clay and iron oxide pigments. One of these could be completely substituted for the other, if compatability were maintained to allow wide and uniform distribution throughout the thermoplastic matrix. Additional experimental work would be needed to verify a correspondence, however.

The risk of altering the amount of preservative has already been discussed. The type of preservative could be altered, if judged advisable if based on actual performance, cost, and availability. Even though this system has a high degree of water resistance, it is recommended that water soluble preservatives not be considered due to possible environmental hazards (especially where rainwater is collected from roofs for human consumption). The incorporation of fire retardants might be advisable from a performance viewpoint. Both would require a separate study and would most probably impact the absolute and foreign exchange cost negatively.

3.1.3.3 Process

The process requires only a few relatively simple and well-established steps routinely used in thermoplastic compounding and manufacturing industries throughout the world. An intensive mixing step similar to that for the BRR material is unique only in the result that is achieved and not how it is done. The melt flow characteristics of the system are poor, due to the high filler loading. Therefore, thermoplastic forming techniques are limited to calendering and compression molding.

The process for making the dense, bagasse-reinforced durable plastic comprises the four primary steps shown in Figure 16. They are identical, except for details, to that for the bagasse-reinforced hard rubber. One practical difference in manufacturing is that whereas Banbury type intensive mixers are nearly always used in rubber compounding, they have been found to be used less in thermoplastic compounding in the manufacturing facilities in participating countries.

As with the BRR system, the second step, Banbury-type intensive mixing, is the most critical and technically the most complex. The second, third, and fourth steps require the availability of significant capital equipment, but are routine to the plastic

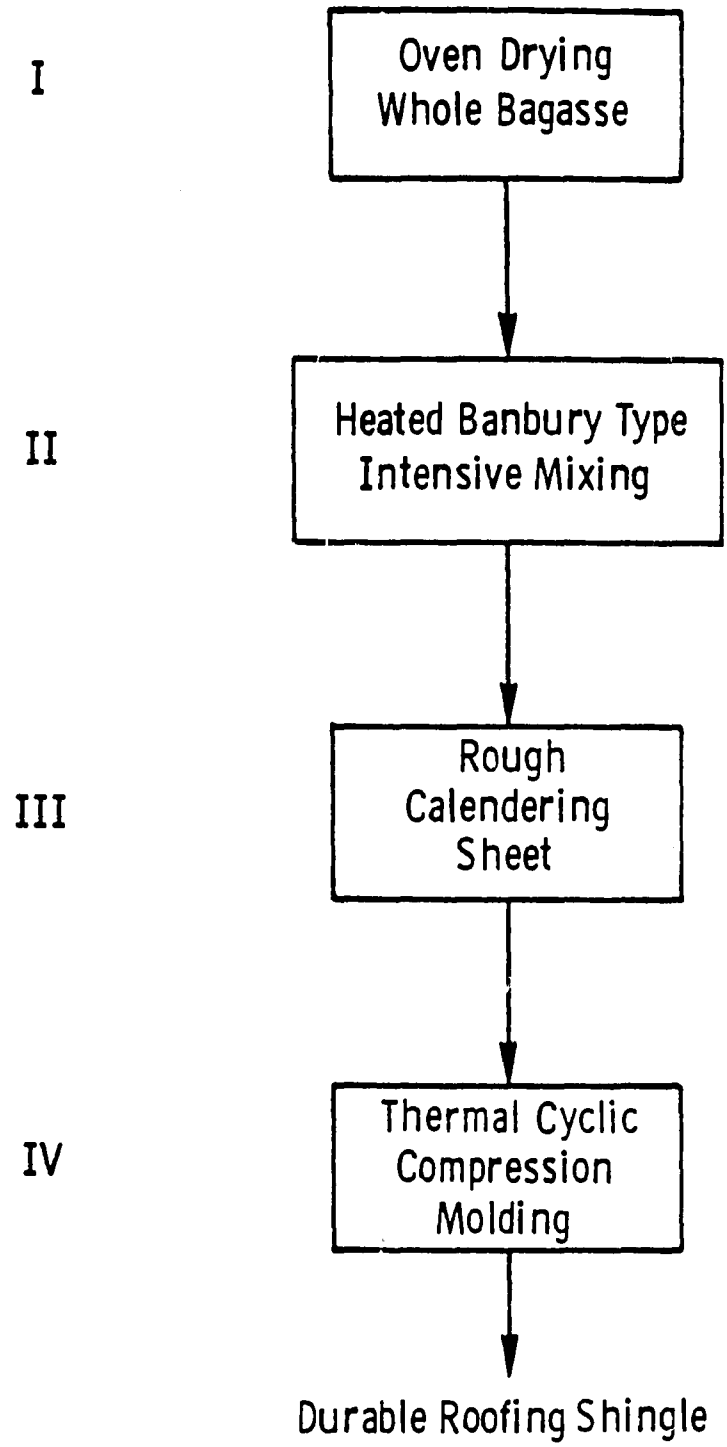


Figure 16. Four primary steps are shown in the process outline for making the bagasse-reinforced durable thermoplastic (BRT) material.

manufacturing industry. The first step requires only oven drying of whole bagasse to remove moisture, and packaging it so that moisture is not reabsorbed prior to process step II. The calendering step (III) converts the material from large chunks into a continuous sheet. In step IV the sheet is then cut, laid into molds, and run through a pressure-heating/cooling cycle to form and rigidize it. As a thermoplastic, however, it can reversibly be reformed upon the application of heat and pressure.

The first step, drying the whole bagasse, is important to rid the material of all moisture prior to compounding. In contrast to the BRR system, however, some water can be boiled out in the second step and/or some water can remain in the system without introducing the consequent blistering and/or blow up of panels in the molding stage. As will be shown, with the thermoplastic it is necessary to cool the formed panel well below the boiling point of water before release of mold pressure. Any water would be condensed and thus would be less of a problem. In spite of these advantages of the process, it is recommended that moisture contents be reduced to below 0.1% in an initial oven drying since any water encapsulated in the roofing panel could have long-term detrimental effects, especially when roofs reach the readily attainable temperatures of 150°F or higher. Wet bagasse is also less compatible with thermoplastic binders, introducing mixing problems.

The second step, Banbury-type intensive mixing, is again the key to the production of this roofing material. The process taking place is called melt compounding. A number of processes occur simultaneously. These include: (a) fluxing, (b) blending, (c) chopping, (d) fibrillating, and (e) dewatering.

Fluxing involves raising the temperature of the binder to above its glass transition temperature to render it a viscous fluid.

Blending involves separating, distributing and dispersing the ingredients. Chopping involves reducing the size of the bagasse filler. Fibrillation involves further separation of the bagasse into smaller fiber bundles by physical breakdown of the pith that holds these fibers and fiber bundles together. Dewatering involves the boiling out of residual moisture by the application of relatively high temperatures to continuously re-exposed melted surfaces.

The importance of the melt compounding is that one piece of equipment is used to process all of the ingredients of a formulation. The result is a material, known as a molding compound, that can be melt-formed by a variety of standard plastic processing techniques. It can be granulated and fed into a variety of plastic processing equipment, or it can be left in large chunks, direct from the Banbury intensive mixer and dropped to heated rolls.

The third step involves the conversion of the irregularly shaped molding compound into a roughly dimensioned continuous sheet. This can be done using a calender (3 or 4 rolls), or a two roll mill. Heat is required on both the calender and the mill. This is usually achieved with high pressure steam, but some thermal energy is generated due to the work going on in the system. As long as temperatures are maintained below the degradation point of the bagasse (450°F), heating is not a problem. This is in contrast to a similar stage for the BRR material where elevated temperatures could induce premature curing of the system.

Conversion of the molding compound into a sheet by extrusion, i.e., by forcing the melt through a die, is not practical due to the very high filler loading and the relatively poor flow characteristics of this formulation. To achieve an extrudable

compound the resin content would have to be increased to the level of 60-70 volume % which of course, in this specific application, negates the value of the system.

The fourth and last of the primary process steps is compression molding. This step differs from a similar step in the BRR alternative system, with respect to the necessity for thermal cycling. This is due to the nature of the matrix material, a thermoplastic that softens upon heating and rigidizes upon cooling. This is in contrast to a thermosetting binder, which becomes irreversibly rigid at elevated temperature by chemical reaction.

The compression molding step consists of placing the calendered sheet, or even irregular shapes of the compound, onto a caul sheet (a thin mold plate), inserting a simple forming frame, and enclosing with a second caul sheet. All of the metal mold surfaces should be coated with a good thermoplastic release agent, such as a silicone. This mold is then placed into a hydraulic press, where contact pressure is first applied, then heat, and finally an elevated pressure.

In the case of molding the ABS binder, temperatures of 350°F are adequate, but for the SAN binder, temperatures of at least 400°F must be reached. Pressures are usually on the order of 300 psi, but 500 psi is preferable. The final step in forming the part is to cool it in a mold to a handable temperature, usually less than 100°F.

The compression mold can be flat, corrugated, or any other desired shape. Since the flow of this type of molding compound is poor, it must be distributed evenly throughout any given mold. This low flow, however, is advantageous because it allows

simplification of the molds. Corrugated molds would not need to have confining sides.

After the part is removed from the mold it can be used as is or trimmed to the desired size. When the SAN binder is used, it would be necessary to drill holes for placement of nails due to the very high strength and rigidity of the product. Panels made with the ABS binder can be nailed.

3.1.3.4 Cost Projection for Ingredients

Costs for materials alone, not including processing, are projected at 14 cents per square foot. The price for roofing shingles or panels are projected to be 3 to 4 times these materials costs.

A breakdown of costs for the various ingredients is shown in Table XI, for the BRT formulations (based on 1976 dollars and cost). Ingredients considered to be indigenous to all three participating countries are the bagasse and clay.

The cost of the bagasse is taken at its fuel oil equivalent, even though it is presently, and probably will for sometime, be available at a fraction of that cost. In the long term, however, the higher price would need to prevail to justify its use in the roofing product in contrast to other alternative uses. The thermoplastic binders and pigments exist in commerce in the three participating countries, however, for the most part, they require some foreign exchange and therefore were not considered indigenous in this analysis.

The sales cost for the roofing would be about 3 to 4 times the basic materials cost. This factor includes the processing cost (normally expected to be about equal to the cost of raw materials), plus sales and administrative expenses and profit.

Table XI

PROJECTED MATERIALS COST FOR BAGASSE-REINFORCED DURABLE PLASTIC (BRP) COMPOSITION[a]

Ingredient	Ingredient Cost (US$/lb)	Formula (Wt %)	Component Cost (US$/lb)
SAN binder	0.50	27	0.135
Whole bagasse	0.014	63	0.009
Iron oxide pigment	0.50	5	0.025
Ground clay	0.01	5	0.001
		Total	0.170

Eq. Panel Thickness[b]: 0.12 in.

Panel Weight: 0.85 lb/ft^2

Projected Material Cost[c]: 14US¢/ft^2

(a) 1976 Data

(b) Corrugated 0.1 inch thick panel

(c) Selling price projected at 3 to 4 times this cost.

Using an average 3.5 multiplier to achieve the sales price for the roofing, the foreign exchange requirements then represent 29% of the sales price. The remaining 71% value in the roofing material would be added in the country manufacturing it.

Because of these percentages, this system is less attractive than the other three systems. Only the excellent durability and water resistance salvage this system as a potential alternative.

These remaining costs would not be free from foreign exchange requirements, which would need to include capital, equipment, and fuel. However, it is expected that this foreign exchange requirement would represent, at most, an additional 20% of the sales price. Facilities, when modified to operate at higher temperatures, are available to handle such materials in the Philippines and Ghana.

Not much latitude is available in reformulating that would allow any significant reductions in costs of the system. While all of the prices will inflate with time, and have been especially dynamic for the past five years, none contained in the formulation are expected to escalate disproportionately with projected inflationary factors, and none have any foreseeable availability problems over the next few decades of time.

It is possible that the entire sheet forming process could be achieved in the calendering step alone. Trimmed hot sheets from the calender would be cut to length and rigidized by cooling on a flat (or corrugated) surface. This type of process could effect considerable cost reduction (if successfully demonstrated) by eliminating the expensive compression molding step.

3.1.4 Phenolic Bonded, Oriented Bagasse Fiber (BOB) Composite Roofing Material

The phenolic-bonded, oriented bagasse fiber (BOB) composite roofing material incorporates the most indigenous material of any of the four developed roofing systems. It has great long-range potential as roofing and as a general, very low cost material of construction. This product differs advantageously from the other alternative materials in that a very low cost structural panel is first made and then secondary treatments are added to make the system more water and fire resistant.

This roofing product is a rigid, textured, light-colored panel that is visibly quite different from the other three alternatives. It has been made in the form of both flat and corrugated panels that can be nailed, drilled, cut, sawed, etc. as needed for simple installation.

The outdoor durability of this roofing product has been very good, as determined both by accelerated Weatherometer exposure and outdoor exposure in Jamaica, Ghana, and the Philippines. The panel consists basically of a thin, porous structural element that is impregnated with waterproofing agents, and preservatives, and coated with a reflective paint film.

In the outdoor exposure studies, conducted on both the treated and the plain structural elements, excellent retention of properties was indicated. The only change in performance of the treated panels was a slight loss of gloss, resulting in a dull aluminum finish that occurred in about six months. The unexpected good outdoor performance of untreated panels continued with the only indication of any shortcoming being initiation of mold growth after about one year of outdoor exposure.

Durability was judged qualitatively on the panels exposed in the Weatherometer for up to 1000 hours (800 hour intense sun mingled

with 200 wet/dry cycles) and with square foot panels, both flat and corrugated, treated and untreated, mounted on exposure racks in Jamaica since May 1975 and in Ghana and the Philippines since September 1975, as shown in Figure 17.

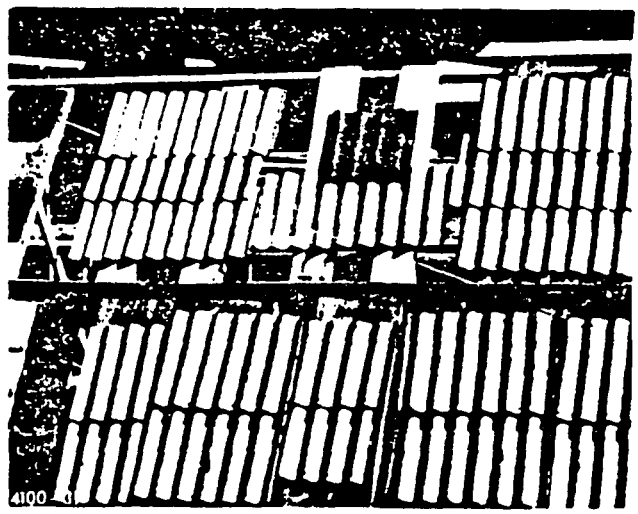
This product is very different from the other three alternatives. The key difference, which is a major contributor to the cost effectiveness of the system, is that the structural strength and rigidity is generated by a continuous matrix of oriented bagasse fibers. In the other three systems the bulk of the mechanical performance is the result of the binder material which is a continuous phase surrounding the bagasse that is used to extend or dilute the resin.

While the roofing panel consists essentially of bagasse, it is obviously distinctive from available and known commercial bagasse boards, that have a poor reputation for exterior use, in four major ways.

The first difference is density. When examined on a volume basis, ordinary bagasse board will have up to 50 volume percent of air, implying that it is very porous. The roofing composite on the other hand, has less than 10% free space and that is filled with waterproofing ingredients. The density of bagasse board is approximately 35 lb/cu ft, while the density of this material is ∿70 lb/cu ft.

The second factor distinguishing the roofing panels from bagasse board is the absence of pith, which assures bonding of individual bagasse fibers or bundles together. Pith is a very low strength, non-fibrous material that contributes nothing to the mechanical performance of a board. It also attracts and soaks up binders, thus causing the binder to be concentrated on the low strength pith, rather than on high strength fibers.

(a) Painted flat panel after one year exposure in Ghana showing no changes.



(b) Treated corrugated and flat panels after at least one year exposure in Jamaica indicating only some deterioration of painted surfaces.

(c) Commercial bagasse board, that has urea/formaldehyde resin binder and low density, which has a generally poor reputation for unintended outdoor use.

Figure 17. BOB panels were exposed as both flat and corrugated panels in Jamaica, Ghana, and the Philippines for more than two years.

The third factor distinguishing the two materials is the orientation of the bagasse fibers. This significantly increases the strength and modulus in a given direction. It also allows better packing of fibers, providing the basis for the higher density indicated above. This close packing minimizes free space within the composite, reducing porosity and the amount of resin required to completely bind all the fibers together.

The fourth factor distinguishing the roofing panel from commercial bagasse board is after-treatment. This includes adding waterproofing, preservatives and surface treatments that render the product usable in an outdoor environment. The roofing panel is relatively thin (0.1 inch) thus the weight and cost of the treatment per square foot is kept low. At least 10 times as much treatment material would be required for typical 0.5 inch thick bagasse board because of both its greater thickness and free space resulting in prohibitive costs. The untreated roofing panel also has a high degree of water resistance; it will maintain the necessary portion of its strength when wet, and will recover its strength when redried. In contrast, when commercial bagasse board becomes wet it is usually irreversibly swollen and destroyed. This is due to the type resin binder used.

The mechanical properties of the bonded, oriented bagasse fiber composite without waterproofing, preservative, and surface treatments are shown in Table XII compared to a similar thin panel made with randomly oriented bagasse fibers. Flexural and tensile strength properties, initially, following immersion in water for 48 hours (tested wet), and after redrying, are shown.

That the fibers are oriented, and that improved strength and modulus are actually achieved is illustrated best by the tensile

Table XII

MECHANICAL PROPERTIES OF THE UNPROTECTED BONDED, ORIENTED BAGASSE FIBER COMPOSITE MATERIAL[a,b,c]

	*(d)	=(d)	⊥(d)
Flexural Strength (psi)			
Original	3100	4700	1740
Wet	1500	1900	520
Dry	3000	4700	1700
Flexural Modulus (psi, 10^3)			
Original	480	600	250
Wet	200	330	95
Dry			
Tensile Strength (psi)			
Original	1780	5410	1130
Wet	600	1700	510
Dry	1700	5400	1100
Tensile Modulus (psi, 10^3)			
Original	650	910	365
Wet	240	290	100
Dry	650	900	360
Water Pickup (%)	40	33	34

(a) Wet process, phenolic resin bonded, depithed fibrillated oriented bagasse fiber-reinforced composite. Process: bagasse fibers prepared with wet caustic treatment to depith and beating to fibrillate, fibers oriented in centrifuge, wet resin precipitated to fibers, compression molding in pressure cycle at 300°F.

(b) Immersion in water for 48 hours. Tested wet.

(c) ASTM D790 - flexural, D638 - tensile, rate 0.05 in./min.

(d) *Unoriented bagasse fiber for reference.
=properties measured with load parallel to fiber direction
⊥properties measured with load perpendicular to fiber direction.

properties measured both parallel and perpendicular to the fiber direction and compared to the panel made from randomly oriented fibers. The strength is improved nearly five-fold and the modulus 2.5-fold. These properties are respectively 3 and 1.5 times those of the randomly oriented panel. The flexural properties are affected by the orientation significantly, but to a slightly lesser degree.

It is most important for the roofing application to observe that following the exposure to total immersion in water and then drying the flexural strengths and moduli where fully recoverable. This indicated that no irreversible degradation occurred, such as breaking of the bonds between the bagasse fibers and the adhesive binder. As expected, the added performance provided by orientation was retained even when the samples were quite wet.

The water pick up is for the unwaterproofed panels and following direct immersion (normally not encountered in a roofing situation) in water for 48 hours. The pick up appears relatively high but is significantly reduced by the waterproofing treatment which introduces a time delay. Panels of the oriented boards were actually boiled in water for periods up to 24 hours. These panels remained dimensionally stable, visually showed no degradation, and lost no more than 5% of their mechanical strength upon redrying. This loss is acceptable for roofing since the level of strength available is needed for handling and shipping of panels rather than performance on the installed roof.

The fire resistance of the untreated oriented bagasse fiber panels is "good". The material burns slower than most wood panels of equal thickness and gives off little smoke or fumes. When waterproofed by low cost asphalt impregnation, the fire resistance is substantially less, however.

Fire retardant additives can be incorporated, along with the asphalt waterproofing to improve fire resistance. However these add to the cost. Whether or not this is satisfactory will need to be determined by local decision makers, and naturally will depend on the specific application. It is expected that a tradeoff between fire and water resistance will need to be made as this product is further developed.

Another option, not investigated, would be to apply a thin, dense coating of phenolic-bonded bagasse to the surface of the oriented fiber panels. This would be a combination of the raw materials from the BRP and BOB systems.

3.1.4.1 Composition

> The phenolic-bonded, oriented bagasse fiber (BOB) composite composition is new and unique and fits between bagasse-type particle board and bagasse-based paper with respect to degree of refinement. Different is the nature of the bagasse from which a large percentage of the pith has been separated with only small fiber bundles remaining. Phenolic resin technology that is well-known by the particle board and plywood industries is utilized.

Shown in Table XIII is the formulation for the phenolic-bonded, oriented-bagasse fiber roofing composite on a weight basis. It is made up of four basic parts. The first are the components that provide a strong, rigid structural board, The second are the ingredients to waterproof and preserve it. Third are the ingredients that provide outdoor durability. Fourth are the ingredients that are necessary for use in the process but that do not necessarily remain as part of the system.

The components that provide strength and rigidity are the processed bagasse and phenolic resin. Obvious are the high level of bagasse (near 80%), and the very low level of phenolic resin

Table XIII

BONDED, ORIENTED BAGASSE FIBER COMPOSITE FORMULATION

Ingredient		Weight (%)
Group 1		
Processed bagasse fibers		78.66
Liquid phenolic resin		4.14
Group 2		
Preservative		0.55
FR waterproofer		
Asphalt		2.04
Cl paraffin oil		5.77
Organo phosphorus liquid		4.21
Group 3		
Aluminum surfaces		
Paint solids		4.53
Sb_2O_3		0.10
Group 4		
Alum	(0.4)	
Sulfuric acid	(0.2)	
Solvents	(2.5)	

Phenolic Resin - Borden International Cascophen PA-2 liquid resin

Preservative - pentachlorophenol

Cl paraffin oil - Chlorowax C-70, Diamond Shamrock Co.

Organo phosphorus liquid - Phosgard C22R, Monsanto Co.

(near 4%), relative to the alternative systems, which utilize 60% and 30% of these components, respectively. This is the primary factor in the cost effectiveness of the system on both an absolute and foreign exchange basis. It is significant, however, that processed bagasse is required, so the advantage of using whole bagasse is lost and the residual pith can not be used for other applications without prohibitively costly treatments.

The second group of ingredients retards the imbibing of water and biological growth and/or decay in the bonded structural panel. This group includes asphalt, chlorinated paraffin wax, an organo phosphorus liquid compound, and pentachlorophenol. The waterproofing agent must wet the bagasse fiber and the cured phenolic resin so that the resin will deposit on the fibers and spread uniformly to provide a water barrier. Additionally, the waterproofer should fill all the free space within the structural panel to prevent the entrapment or absorption of water. The best (i.e., lower cost) single ingredient to perform this function is asphalt. It, however, is easily ignited and contains a high quantity of fuel, thus contributing poor fire resistance to the panel.

Two other materials, a chlorinated paraffin wax and an organo phosphorus compound, are also used. Both compounds add to the fire-retarding effect,

The preservative, as with the other systems, is pentchlorophenol, the level of which is based on the amount of bagasse. It is used at a slightly higher concentration here, however, because a larger surface area of bagasse is exposed and the average moisture content of this system is expected to be higher.

The outdoor durability and attractive surface appearance of the panel are provided by a flake aluminum (or other colored) filler in a durable acrylic paint. Antimony oxide is added to this paint to produce a level of fire retardancy, both to the paint itself and to the paint as a barrier between an open flame and the waterproofed structural panel.

The last group of ingredients include reagents and solvents used in the processing which do not end up in the final product. The alum and sulfuric acid are used to precipitate the phenolic resin from a water soluble state (where it exists as a salt) to an insoluble state. Sulfuric acid alone may be used but precipitation, in combination with alum, adds a minor degree of water resistance. The alum also causes some swelling of the bagasse fibers in water which then allows better and more uniform distribution of the phenolic resin in the bagasse.

The solvent in the formulation, toluene, was included to lower the viscosity of the fire-retarded waterproofing ingredients so that they could be applied by dipping. This solvent was then evaporated and collected for reuse.

A final, very necessary part of the system, not shown in the formula, is water. For every pound of product obtained, at least 40-80 pounds of water are required in the process. While this water was not recovered in the experimental work, it is possible that in a continuous manufacturing process the water could be recovered and a portion of it reused following a purification step. This water would contain the pith from the bagasse and would be slightly acidic. Thus it would have to be treated and pith removed before discharge into a stream or before reuse.

3.1.4.2 Composition Latitude

The phenolic-bonded, oriented bagasse fiber composite formulation was optimized to perform in a roofing application and have at least a minimal level of fire resistance while retaining its low foreign exchange costs. A high degree of tailorability is available, however, which, with some compromise of water and/or fire resistance, would provide significant reduction of costs of ingredients and processing.

In considering the latitude available in the recommended formula toward retaining the bulk of its desired properties, the following is recommended. No less than 4% phenolic resin based on its dry weight relative to the dry weight of the processed bagasse, can be used without jeopardizing the outdoor mechanical performance and durability of the system. Higher levels may be used but would contribute little to compensate for the additional costs. Any liquid phenolic resin with satisfactory shelf life may be used. A urea/formaldehyde resin should not be used under any conditions. Urea/formaldehyde resins will not provide the water-resistant bonding that is absolutely necessary for the roofing product.

The amount of processed bagasse should be at least 75% by weight of the composition. Less bagasse would be indicative of a lower-density, less-structurally-sound panel. The processed bagasse should contain no more than 2% free pith.

The pentachlorophenol preservative should be at a level of no less than 0.5% nor greater than 1%, (preferably 0.7%) by weight based on the weight of the processed bagasse. It must be a water insoluble type.

Latitude is available in the fire retarded waterproofer with respect to decrease in the amount of asphalt. However, any

decrease must be made up by added amounts of the chlorinated paraffin or organo phosphorus compound, which would add a cost penalty. Similar fire-retarded compositions could be made from other ingredients. They could be used if proven to provide the same level of water and fire resistance.

The surface film providing the outdoor durability should be based on acrylic and have a relatively low viscosity so that it can be sprayed as a very thin film. Less material than that shown would not cover the surface adequately and additional material would add more non-fire retarded fuel. The level of antimony oxide in the paint could be increased, but with little added benefit, and decreasing it should be done based only on evidence achieved from burning tests.

Four alternatives to the formula may be considered. The two shown in Table XIV have a major benefit of very significantly reducing the cost per square foot of the roofing system. These alternatives should be considered, however, only after due regard is given to their negative aspects, namely, reduced fire and/or water resistance.

In the first of these alternatives simple substitutions are made for the fire retarded waterproofing agent and paint film. In its place, plain asphalt is used as a waterproofing agent, and a typical aluminized asphalt roofing paint is used as the durable surface finish. A panel derived from such a formulation will have equivalent water resistance to the recommended formulation but would burn vigorously once ignited. A roof made from such panels, if protected by a fire-resistant ceiling from the inside of the house, might be considered. Otherwise the relatively high surface area of available fuel (asphalt) would make such a system inadvisable. Outdoor performance of this system has been very good to excellent in Jamaica.

Table XIV

TWO VIABLE LOWER COST ALTERNATIVES EXIST FOR AFTER-TREATING THE BONDED, ORIENTED-BAGASSE STRUCTURAL PANEL. THESE ALTERNATIVES MAY BE CONSIDERED INDEPENDENT OF THE BASIC STRUCTURAL ROOFING PANEL THAT IS THE SAME IN ALL CASES

ALTERNATIVE A

Waterproofed, Non-Fire Retarded Bonded Oriented-Bagasse Composite Formulation

Ingredient	Weight
Processed bagasse	79.3
Liquid phenolic resin	4.2
Preservative	0.5
Asphalt waterproofer	12.0
Aluminized asphalt paint	4.0
Alum	(0.4)
Sulfuric acid	(0.2)

ALTERNATIVE B

Minimal Cost Bonded-Oriented-Bagasse Composite Formulation

Ingredient	Weight
Processed bagasse	86
Liquid phenolic resin	4.5
Preservative	0.5
Roofing paint	9
Alum	(0.4)
Sulfuric acid	(0.2)

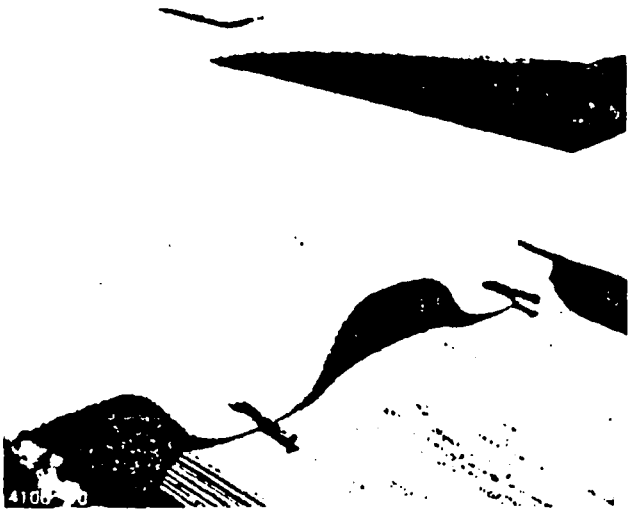
A second viable alternative for slightly less permanent roofing exists in the second formulation shown in Table XIV. In this case the waterproofing is eliminated entirely and the burden of preventing water penetration is provided by a thick, durable roofing paint that seals the top side of the structural panel and sheds the water. Since the structural panel itself burns no more readily than wood, additional fire retardants would not be required.

A key to this alternative is using a cost effective roofing paint that will seal the top surface of the structural panel and be durable with time. One such paint already exists commercially. It is known as Roofmaker (Plastifiber Formulations, Inc., Miami Beach, Florida, or Mercedita, Peurto Rico), and is being marketed in the Carribean and as well the United States. This is an acrylic paint that is reinforced with bagasse fibers. It is cream colored and shown in Figure 18.

While an extensive study on this paint was not made it has been independently evaluated by Battelle-Columbus Laboratories. Accelerated weathering tests in a Weatherometer of this paint on the bonded oriented-bagasse composite has demonstrated it to be an excellent performer. In any future investigation, this particular formulation should be evaluated in more detail.

A third, lowest cost, alternative is to use the molded panels "as is" without added waterproofing. A slightly higher resin content might be used to further improve water resistance and wet strength. Fire resistance of this product would be good and it would burn slowly, with little smoke or fumes, if ignited. The main negative aspect of this otherwise attractive alternative is the less generally acceptable unpainted tan appearance of the exposed bagasse fibers. Durability up to 5 years may be expected, as illustrated in Figure 18.

(a) Corrugated panels painted with a thick bagasse reinforced acrylic coating before installation at the Scientific Research Council in Jamaica.



(b) Completely unprotected corrugated panel after two year outdoor exposure in Jamaica. Only moderate mold growth observed without any physical changes.

(c) Unprotected and paint striped flat panels after almost three years exposure in Jamaica. Severe black mold growth shown on unprotected surface and no mold on painted surface.

Figure 18. There are several potential alternative treatments for the BOB roofing material which can reduce its cost with some compromise in durability.

A fourth alternative would be to combine the materials for the BRP system by applying a thin dense coating of a phenolic-bonded powdered bagasse to the surface of the oriented bagasse fibers during molding.

3.1.4.3 Process

The process for the phenolic-bonded, oriented bagasse fiber composite material is the most complex of the various developed alternative material systems. This complexity could be handled by a large manufacturing process or used to advantage in a labor intensive process in almost any scale operation. The process is similar to others in finally requiring compression molding in a press, but differs in that an oriented bagasse panel is first formed, which provides the structural characteristics of the system. This is then treated to provide the necessary durability.

A BOB composite roofing panel is manufactured in three primary stages, as shown in Figure 19. The first step is the preparation of bagasse fiber, starting with whole sugar cane bagasse, in a wet process. The second stage, also a wet process, involves depositing a phenolic resin binder onto the bagasse fiber, orienting and forming these fibers into mats, laying up these mats, and finally compression molding them into a structure roofing panel. At this stage, the final mechanical performance and the shape of the panels are fixed.

The third stage is the stabilization of the structural roofing panels by the application of treatments to provide waterproofing, outdoor durability, and resistance to biological attack. It is at this stage that alternative formulations can be applied. This provides more product versatility than exists with the other candidate roofing systems.

Before proceeding with a discussion of the process details, it is important to consider that the process was tailored around

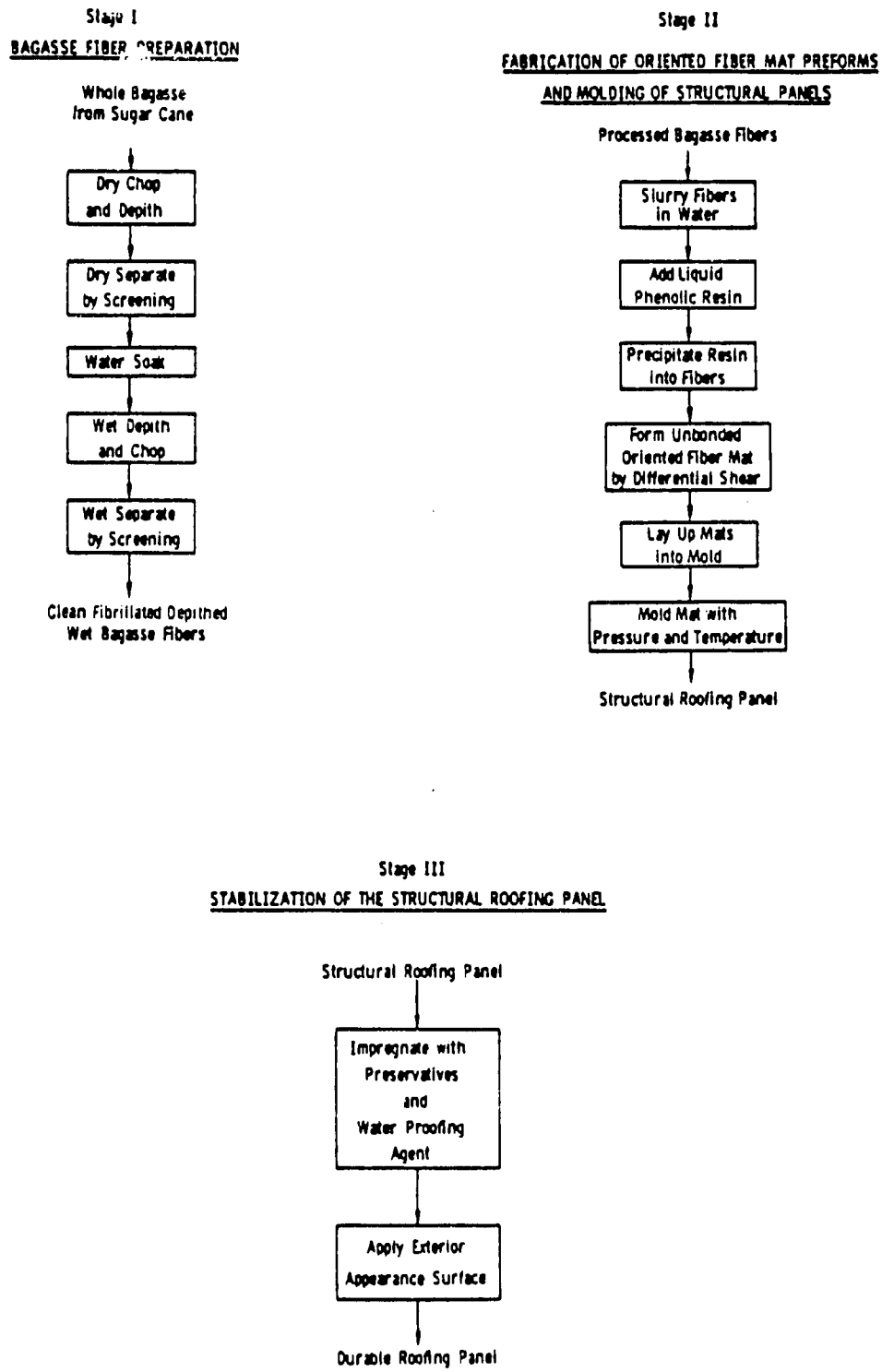


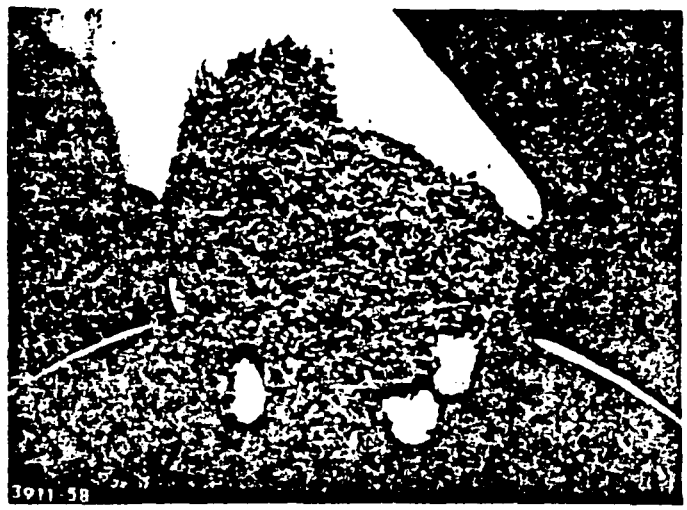
Figure 19. Three primary stages are shown in the process outline for making bonded, oriented bagasse (BOB) fiber roofing panels.

existing, easily obtainable, or projected available facilities in the MRC laboratory and the participating countries. Accordingly, the most efficient techniques probably were not used for manufacture of the experimental samples. Where possible, better alternative processing steps will be mentioned for those considering scale-up of the operation. In any case, further developmental work should be conducted to validate those projections.

The first major stage, that of bagasse fiber preparation, comprises five steps illustrated in Figure 20. In the first two steps the whole sugar cane bagasse is chopped and a portion of the pith is broken away from the small fiber bundles. The desirable fiber bundles are then separated from both the pith and large bagasse pieces by screening. These first two steps could be eliminated in the process. However, it is more efficient to conduct this initial pith separation on a dry basis, because it reduces requirements for process water and its further treatment.

The third step of the first stage is the soaking of the small bagasse fiber bundles (approximately 1 inch long and 1/16 inch diameter) to weaken the adhesive bonds between the pith and the bagasse fibers. It takes time for the water to soak into the bagasse and weaken the pith. However, an overnight soak without agitation was found to be adequate. Agitation or minor addition of caustic could be used to accelerate the breakdown where bulk storage of the bagasse is not convenient.

The wet mass of bagasse is then exposed to severe beating and shear in a vertical cutter mixer (various wet depithers could also be used for this purpose). This step is very similar to the first step except it is done in a wet state, and therefore causes much greater separation of fibers and pith. The last step in this stage is wet screening and washing of the bagasse



(a) Wet whole bagasse containing fibers bonded with pith.

(b) Fibrillated fibers with pith removed.

Figure 20. Whole bagasse must be defibrillated, separated and washed to end up with the desired bagasse fibers.

pith from the fibers so that only clean, defibrillated, depithed small bagasse fiber bundles reamin.

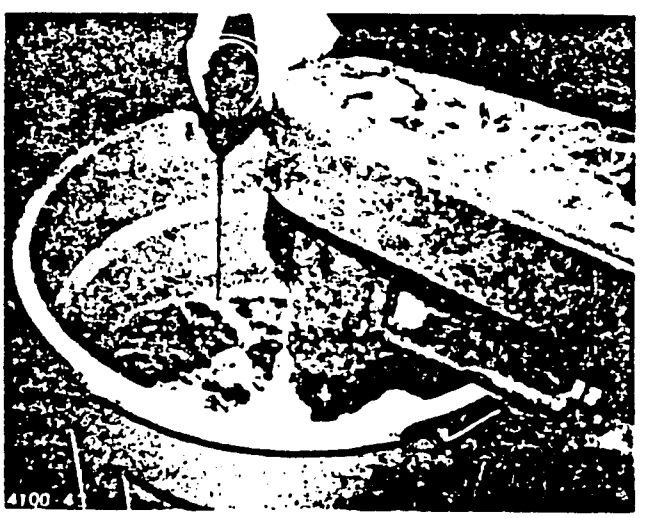
The second major stage comprises six processing steps in which the clean processed fibers are converted into a structural roofing panel which may be corrugated, flat, etc., as desired.

The second stage starts with slurrying the wet fibers into water (about 20 pounds of water per pound of dry fibers). The small individual fiber bundles in this slurry are separated by stirring slowly. Then, a liquid phenolic resin is added and distributed with a minor amount of gentle stirring.

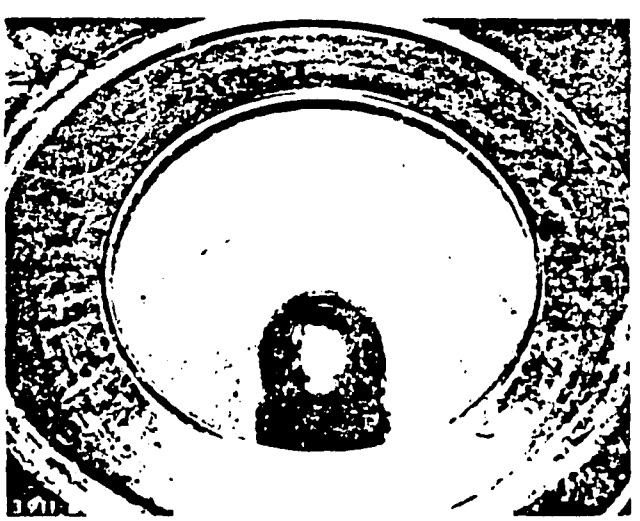
The phenolic resin is then precipitated onto and into the fibers by acidification of the solution. Acidification is achieved by addition of the sulfuric acid and alum slowly to the stirred slurry. The individual small fiber bundles, then each contain a quantity of unreacted phenolic resin. Up to this point, the process is not much different from wet hard-board manufacturing and is illustrated in Figure 21.

The next process step is the key to the performance of the panel. It requires that the fiber be properly prepared as described. The resin-impregnated fibers are aligned in one direction and densified into a mat that can be handled. At the same time most of the water is removed. All of these functions are performed at once by dumping the slurry into a centrifugal extractor (a commercial spin dryer) containing a very fine screen. The fine screen strains out the water at a controlled, relatively slow rate, while retaining the fibers. The centrifugal action causes a column of water to form in which the fibers are suspended. These suspended fibers line themselves up in the direction of the spinning action due to

(a) Clean fibrillated fibers are reslurried before addition of the resin.



(b) The liquid phenolic resin in the form of a salt is added to the fiber slurry and then precipitated onto the fibers by acidification of the solution.



(c) For orientation of the fibers a dense screen which retards the water flow is placed inside of a commercial water extractor (spin dryer).

Figure 21. Liquid phenolic resin is added to the wet processed bagasse fibers before the orienting step to achieve wide and uniform distribution.

differential shear. When the column of water containing the aligned fibers has been formed, the water is then forced out through the screen by the centrifugal action. The screen is a very important part of the system because it holds the water column long enough for the fibers to align. Screening which will provide the necessary retardation of water flow is readily available. It is a very tightly woven, hard fabric used in the manufacture of paper and is referred to as a Fourdrinier fabric.

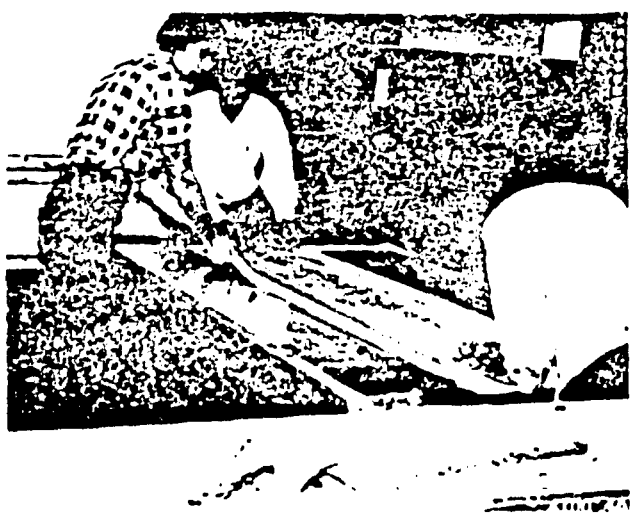
The mat forming step provides what is commonly referred to as a "wet prepreg". The prepreg contains bagasse fibers with a high degree of orientation, an unreacted resin, and a "solvent" (water). These prepregs, which will be referred to herein as mats, are too weak to be carried by themselves but can be carried around on a supporting fabric or on the thin metal screen used in the orientation step shown in Figure 22.

A number of these mats, prepared as described above, are then laid up into molds of the desired configuration (flat, corrugated, etc.). The molds must be designed for heating and pressure to the extent discussed below.

During the experimental effort mats as wide or as long as the size of the panels desired could not be made (except for small exposure plaques). The mats however, can be laid up together to form panels much larger than their individual size, but then there is no structural support between the mat edges since fibers do not fill this boundary layer. Accordingly, a procedure was developed to bridge these gaps. The procedure consisted of first forming mats that contain only enough material for half the thickness of a panel. These half-thickness mats were then laid down in a staggered fashion so that a continuous portion of the mat always covered any butt joints. Although this procedure worked quite well, it would be better

(a) The slurry is dumped into a spinning water extractor where a standing column is formed and the fibers line up in the direction of rotation.

(b) Water is removed from the mat by the centrifugal action of the extractor.



(c) The moist mats are supported by a fabric which is used to remove it from the extractor.

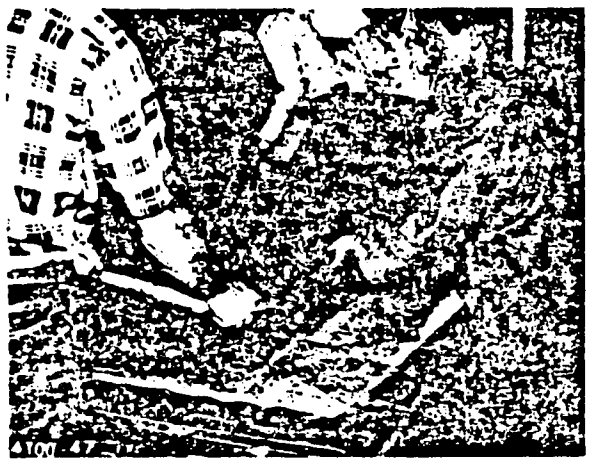
Figure 22. A key step in the BOB process is the orientation and simultaneous dewatering of the resin containing bagasse fibers into a handleable mat preform.

to form mats that are at least as large as the final desired panel, because hand layup work and chances for imperfections would be reduced.

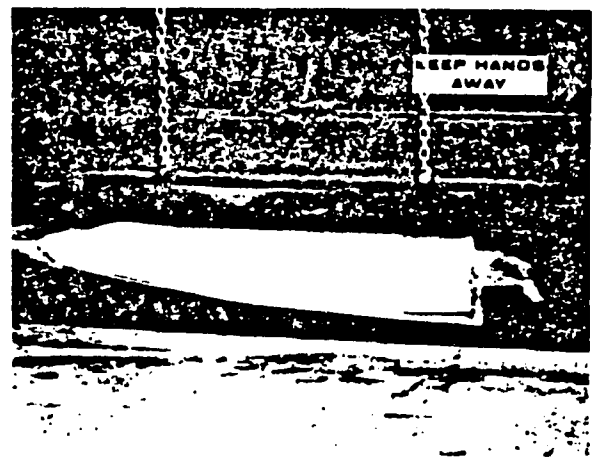
The final step in the second stage is the molding of the mats in compression using pressure and temperature. In contrast to the processes for the alternative materials, the mat is very wet at this point, which is a benefit. Usually the molds are part of the press and therefore can be preheated and remain heated during the entire operation. In such a case, the mats, rather than being laid-up in the mold, are laid onto a flexible caul sheet and carried in the mold. An ideal caul sheet for this purpose is the Fourdrinier fabric previously mentioned. When making corrugated panels this caul sheet must be flexible so it can bend into the corrugations. It must also be strong enough so that when pinched at the peaks of the corrugations it can be stretched down into the corrugation without breaking. Accordingly, simple, lightweight apparel fabrics would not be adequate.

After charging the mold (which is at 270 to 290°F) with the properly laidout mats, pressures of at least 300 psi are applied. Upon the first application of pressure, as might be expected, a considerable amount of steam is generated and ejected from the sides of the press. To assist in venting this steam the pressure is relieved from the press, held off for about 30 seconds, and then reapplied. This process stage is shown in Figure 23. A discussion on molds is contained in Appendix J.

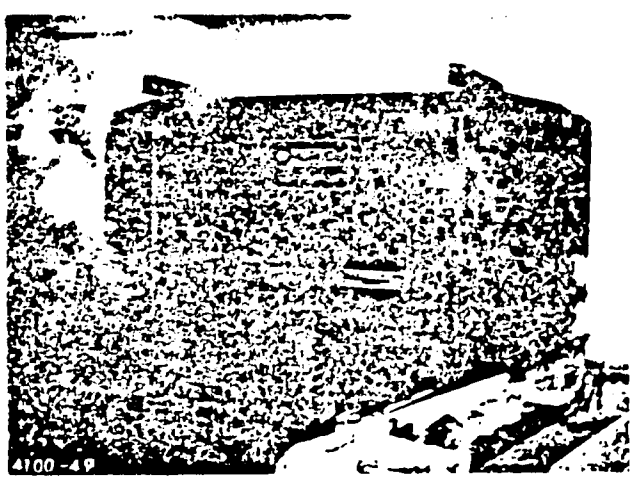
During the generation of steam no curing of the resin occurs since the steam itself will control the temperature at about 210°F. When the pressure is reapplied, however, and the mat is heated to about 275°F, the resin cures and the bagasse fibers are compressed into a dense mass. The total heating cycle ranges from 10 to 15 minutes depending upon the mass of the



(a) Where the mats are not large or thick enough they are plyed together to fill a mold cavity using laps over any butt joints.



(b) The laid up mats are contained between a strong, porous fabric that allows expulsion of water or steam and prevents lateral separation.



(c) Pressure and temperature is applied in a hydraulic press of the type used to make plywood to densify the mat and cure the resin.

(d) After a short cycle time the rigidized hot part is removed from the press and the fabric peeled away.

Figure 23. Resin containing oriented bagasse fiber mats are laid up to fill a mold and pressed to form a dense panel and cure the resin to a hard, rigid state.

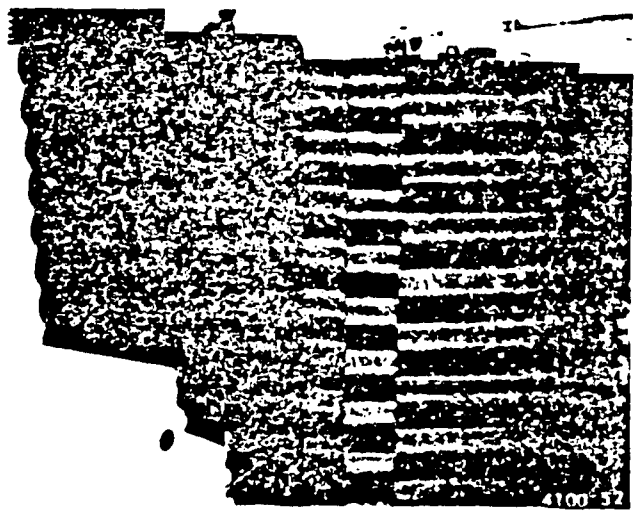
press, the mold and the amount of heat dissipated in converting the water to steam. This cycle time can be reduced by some predrying of the panels, but the bagasse should contain at least an equal weight of water because this allows its compression under pressure and results in better packing and higher densities.

Once the curing cycle is complete, the press is opened (while still hot) and the structural panel removed. It then only needs to be trimmed (with any type saw) to remove low-density, nonuniform edges. The result is a structural roofing panel that has all of the mechanical strength and rigidity that it will ever attain. It may contain moisture which rapidly evaporates. Such a panel can easily be handled by one person, stacked, shipped, and subjected to any of a variety of forces without injury.

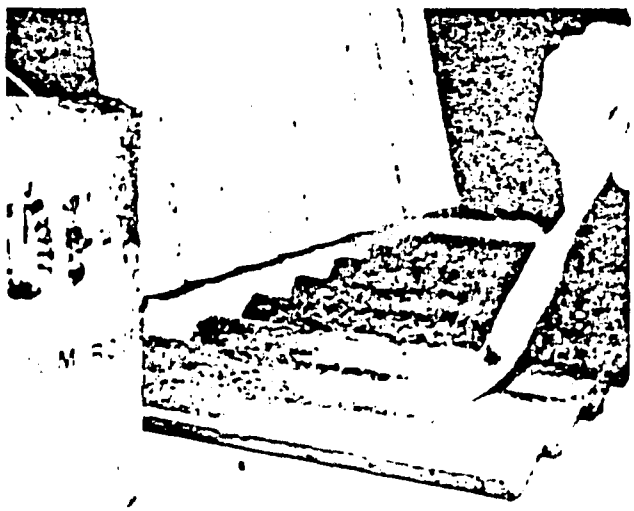
The third and final stage of the process for the BOB composite roofing panel involves stabilization with additional materials. These retard water from entering the bagasse, prevents biological degradation, and provides outdoor durability and an appropriate appearance. In the preferred composition, a fire-retarded waterproofer and preservative are added at the same time from solution. These materials are asphalt, chlorinated paraffin wax, the organo phosphorus liquid, and pentachlorophenol.

The additive materials are dissolved in toluene. The panels are dipped into and readily soak-up the solution. When the panels are removed from the dip, the solvent evaporates, leaving behind the active ingredients. The concentration of the ingredients in the solvent and the number of dippings can be controlled to apply the optimum amount of material (which is designated in the formulation described in a previous section). However, usually only one dip is required, as illustrated in Figure 24.

(a) Waterproofing is best introduced by dipping into a fire-retarded asphalt solution.



(b) Solvents used to facilitate dipping are removed by air drying.



(c) A durable aluminized asphalt based paint is applied for exterior appearance and durability.

Figure 24. Water, fire and weathering resistance is provided to the BOB structural panel by dipping and/or painting.

At this point a waterproofed, stabilized, structural roofing panel has been made. All that remains is to apply an outer surface that is durable to the weather and provides the desired appearance. Suggested is a fire-retarded flake aluminum filled alkyl or acrylic paint. Spraying is necessary in order to minimize the amount used while achieving uniform coverage. The addition of too much paint would adversely affect the fire-resistance of the panel since the paint itself is a fuel. Fire-retarded paints are commercially available, but they are normally too expensive and lack sufficient outdoor stability to be considered for this application.

The panels need only be painted on the side and edges to be exposed to the weather. However, the bottom side can also be painted if so desired, especially where this side will be the interior ceiling of a structure. The last step of the process is the drying of the paint. The panel can then be handled in much the same way as corrugated iron or aluminum panels, It will be much lighter in weight and much tougher than these or equivalent asbestos cement roofing panels.

3.1.4.4 Cost Projection for Ingredients

The cost of materials alone, not including processing, are projected to be 12 cents per square foot for the fire-retarded BOB composite and 6 cents per square foot for the lowest cost system. Sales prices for corrugated roofing panels are projected to be 4 to 5 times these materials costs. The foreign exchange requirement for resin for the structural panel alone is less than 2 cents per square foot.

A breakdown of costs for the various ingredients are shown in Table XV for the fire-retarded and lowest cost BOB formulations (based on 1976 dollars and costs). The third alternative BOB formulation, which is just waterproofed with a surface paint, would cost about the same as the lowest cost asphalt waterproofed and painted system (6¢ per square foot).

The material indigenous to Jamaica, Ghana, and the Philippines is bagasse. The cost of the bagasse is taken at its fuel-oil equivalent, since it can be used as a fuel. The cost for the bagasse shown here is higher than for the alternative roofing systems because only a portion of the bagasse is used and it is assumed that the residue has no value. Again, where bagasse is available in excess, it is being sold at a fraction of that cost or is considered a waste product. In the long term, however, this higher price must prevail. Phenolic resin is presently manufactured in the Philippines and has been manufactured in Jamaica, but still a significant portion of its cost is in foreign exchange.

The selling price of the roofing is projected from industrial experience to be in the range of 4 to 5 times that of the basic materials cost. This factor includes the processing (normally expected to be about equal in cost to the raw materials, but for this system is anticipated to be about double the cost of the raw materials), sales, administrative expenses and profit.

Table XV

MATERIALS COST FOR FIRE RETARDED, WATERPROOFED, BONDED-ORIENTED-BAGASSE FIBER COMPOSITE

Ingredient	Ingredient (US$/lb)	Formula (Wt. %)	Component Cost (US$/lb)
Processed bagasse	0.03	78.7	0.024
Liquid phenolic resin	0.35	4.1	0.014
Preservative	0.42	0.6	0.002
FR waterproofer	0.51	12.0	0.061
Al surface	1.22	4.6	0.056
		Total	0.157

Eq. Panel Thickness: 0.12 in.
Eq. Panel Weight: 0.77 lb/ft^2

Material Cost - 12 US¢/ft^2

MATERIALS COST FOR LOWEST COST WATERPROOFED, BONDED-ORIENTED-BAGASSE FIBER COMPOSITE

Ingredient	Ingredient (US$/lb)	Formula (Wt. %)	Component Cost (US$/lb)
Processed bagasse	0.03	79.6	0.024
Liquid phenolic resin	0.35	4.0	0.014
Preservative	0.30	0.4	0.001
Asphalt	0.20	12.0	0.024
Al/Asphalt	0.60	4.0	0.024
		Total	0.087

Eq. Panel Thickness: 0.12 in.
Est. Panel Weight: 0.6 lb/ft^2

Material Cost - 6 US¢/ft^2

Using an average 4.5 multiplier to obtain the sales prices for the two types of roofing, the foreign exchange requirements then represent 19% and 15 percent of the sales prices, respectively. The remaining 82-85% value of the roofing material would be added in the country manufacturing it.

The process can be conducted on a scale ranging from making fractions of a panel up to making numerous panels at a time; thus allowing for capital and equipment investment proportional to sales volume. Accordingly, the need for heavy investment at an early stage can be reduced. This investment can be spread also into a number of smaller plants throughout a country in order to take advantage of under-utilized labor forces.

Latitude is allowable in the final processing stage with respect to the amount and cost of ingredients. Thus, optimizing performance with respect to cost should be achievable with time and experience of manufacturers, product needs, and the controls set by the Governments.

Importantly, the utility of this product for roofing (interior walls, partitions and ceilings) applications is obvious. These uses should provide a broader base of manufacturing over which capital costs can be spread. This should assist in reducing processing costs and eventually bringing the price of these roofing panels down even further, or preventing them from escalating as others will do with inflation. None of the ingredients are expected to increase disproportionately in cost, or have any projected availability problems over the next few decades of time.

Several alternative compositions and process modifications have been discussed in the proceeding sections. These modifications can be expected to provide improved performance, reduced cost, or both.

3.1.5 Non-Roofing Applications for Candidate Materials Systems

Roofing applications require very high performance from materials with respect to both strength and outdoor durability. But, materials that are adequate for roofing may also be useful to construct other parts of a building, if the economics are favorable. Three of the four systems developed, as well as one rejected earlier for roofing, appear to be useful in this regard.

The materials systems originally developed for roofing can be made competitive for other structural and non-structural applications. However, it will be necessary to modify their physical form and lower the total raw material costs. Various applications are illustrated in Figure 25.

The bagasse-reinforced rubber system can be reformulated and the process modified to produce a flexible material on a more economical (shorter) vulcanization cycle. This flexible material could then be evaluated for floor tile, kitchen cabinet tops, molded kitchen sinks, etc., and other applications where flexibility, toughness, and resistance to water are important.

The bagasse-reinforced phenolic system is especially amenable to tailoring for lower cost. It was demonstrated in the Philippines that after the powdered bagasse and phenolic resin were blended, they could then be extended by mixing with very large quantities of ground wood chip filler. In this way, it was possible to produce strong, durable, thick or thin panels having resin contents of 20%, 10%, and even as low as 5%. Obviously, the lowest resin content materials would not be suitable for use in the more demanding roofing applications, but still might be completely satisfactory for sidewalls, interior walls, partitions, and ceilings (especially if painted).

- Bagasse Reinforced Phenolic -- BRP
- Bagasse Reinforced Hard Rubber -- BRR
- Phenolic Bonded Oriented Bagasse -- BOB
- Phenolic Bonded Clay -- PBC

Wall Panels	Acoustical Panels
Ceilings	Sinks
Flooring	Furniture
Counter Tops	Bricks
Fences	Doors
Siding	Shutters

Figure 25. The materials and processes developed for roofing have utility, when modified, for other applications in home building.

The "wood chip dilution" concept is of special interest in the Philippines because new applications for ground wood-waste products that could create larger markets for these raw materials are desired. Participants at the National Housing Corporation in the Philippines are considering constructing an entire model house based on 4 ft x 8 ft panels of the bagasse-reinforced phenolic system, including the "wood chip diluted" materials.

The phenolic-bonded, oriented bagasse fiber system can also be tailored to form much lower cost products suitable for interior applications by removing the waterproofing add-on ingredients and the associated fire retardants necessary for the waterproofer. Resin concentrations much lower than the present 4% level also are expected to be usable for applications that are not exposed to water. Molded panels containing as little as 1.5% phenolic resin binder have good dry strength and are projected as usable for interior ceilings and partitions. They deteriorate only on exposure to water. A slightly more porous form of bagasse fibers bonded with phenolic resin would also provide acoustical sound absorbing characteristics.

It may be possible to combine to advantage the bagasse-reinforced phenolic material (BRP) with the bonded, oriented bagasse fiber product (BOB). A panel of the phenolic-bonded, oriented bagasse could have one surface consisting of the pigmented bagasse reinforced-phenolic material integrally molded. In this way, a better combination of cost, strength, outdoor aging, and fire resistance could be obtained than in either system alone. Further investigation and possible development of this modification is suggested.

Some clay compositions, investigated to a limited degree in the experimental stages of the program, discussed in the Second Annual report, may also have utility in non-roofing applications.

Compositions of clay bonded with 2.5 to 7.5% wt. of phenolic resin had excellent compressive strength (4000-8000 psi), along with a useful level of flexural strength (2200 psi) when dry. At the 5 to 7.5% resin concentrations, the molded products also retained a useful level of compressive strength (2300 psi) when wet. It was envisioned that products of this type could be considered for exterior walls, which, in the tropics, are ordinarily protected from direct exposure to rainfall by the larger overhanging roofs. The relatively heavy weight of such unfired clay bricks might by itself contribute a measure of stability to the wall. Bricks or blocks of phenolic-bonded, unfired clay would have physical properties similar to those of "soil-cements and would function independent of the type or nature of the clay.

Thus, there are several avenues by which the basic systems developed might be modified and extended to broaden the field of application for these materials. Collaborators in the three participating countries are encouraged to investigate development of such products for non-roofing applications. Full utilization of the products in housing could have widespread and far-reaching beneficial effects in these three countries. These benefits could in time be extended to other countries (developing and developed) which have a good source of the prime raw material, sugar cane bagasse.

3.2 METHODOLOGY (Programatic Approach)

One of the key goals of the program was assuring that any developed technology was made available to and left with the participating countries. Achieving this goal was approached by getting participating country personnel and organizations actively involved in making decisions and the work. Financial and in-kind commitments were encouraged to assure direct involvement. The approach differed slightly in detail between the three participating countries.

The program methodology consisted of using two parallel paths shown in Figure 26, from the start to the completion of the effort. These two paths were used to better define the methodology separating the materials development per se from the collaborative efforts and the transfer of technology. The two paths are highly interdependent.

The materials development path is the one commonly used in the performance of an R&D effort such as this one. Basically, it concerned development of materials systems and demonstration of the benefits of these systems in the participating countries. The desired result was technology per se.

The second path, collaboration and transfer of technology, was set up to provide for intimate involvement of personnel and organizations in the participating countries to: (a) gain their expertise concerning the local situation, (b) coordinate the effort, and (c) most importantly, transfer the knowledge developed in the program so it would be available in the participating countries independent of AID's future involvement.

It was hoped that continued technology transfer in other interested countries could actually be performed through these knowledgeable individuals who would probably be better able to communicate the ideas and relate to the various socio-economic

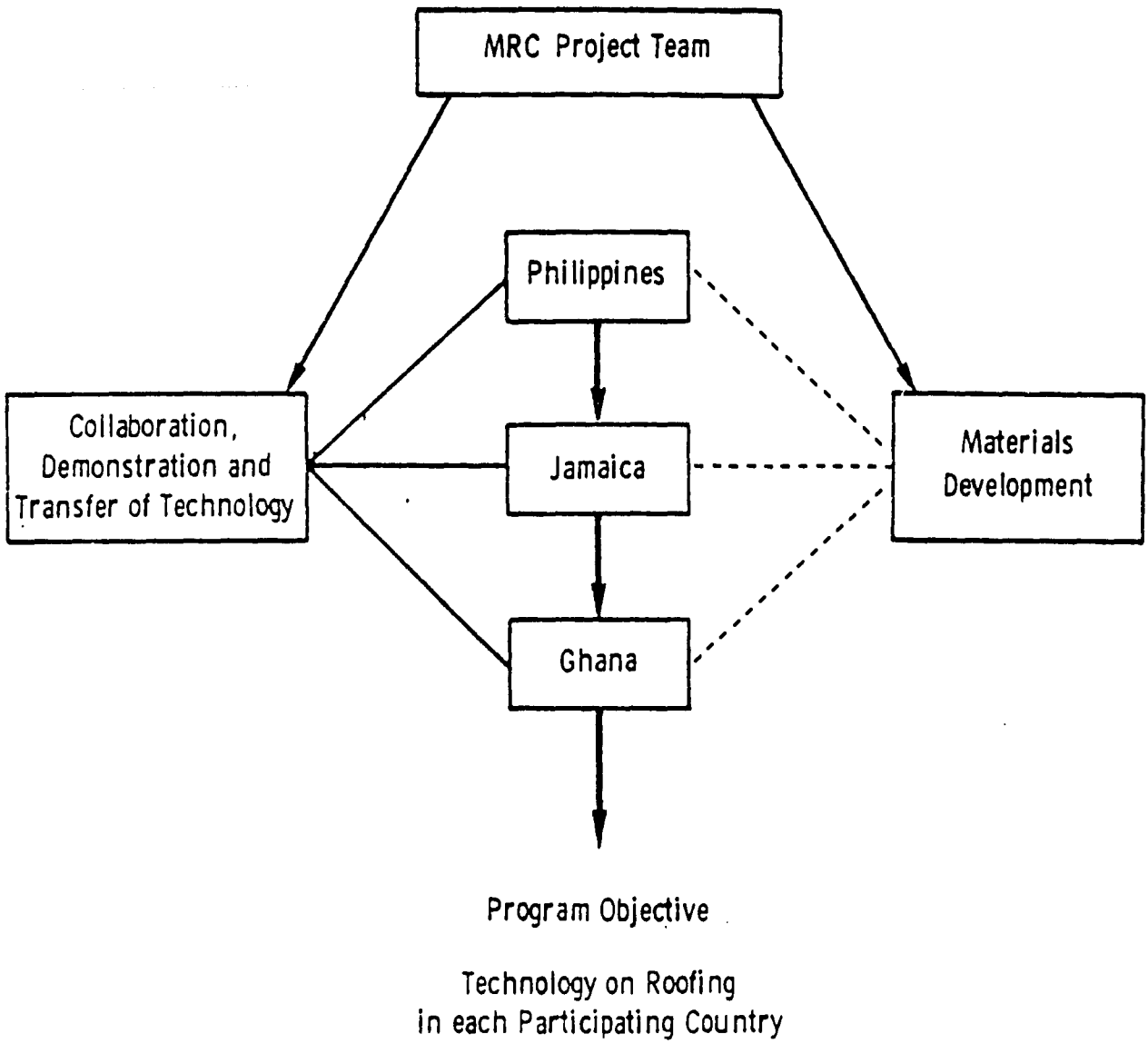


Figure 26. The methodology encompassed following two, parallel, interrelated paths toward meeting the program objectives in Asia, Africa, and Latin America.

needs. It was also designed to generate expansion of the participating individuals knowledge and interest in roofing and construction, with natural benefits to the host countries.

The total effort was conducted in three phases, each originally defined to encompass one calendar year (primarily for contract purposes). The program was actually conducted over a fifty-two month period, with phase one lasting twelve months, phase two sixteen months, and phase three, twenty-four months. The much longer time for phase three was judged necessary to allow time for shipping of materials, for events to occur and be analyzed before proceeding further, and for gaining the benefits of lessons learned in one participating country and transferring those benefits to the others.

3.2.1 Collaborative Effort and Transfer of Technology

The collaborative effort and transfer of technology was initiated at the start of the program and continued throughout its duration. This early and continued intimate inter-relationship between the MRC team and the participating countries was one of the most important aspects of the methodology.

Early in the program it was necessary to define the problem and to select one participating country each in Asia, Latin America, and Africa. Defining the problem, then, from the very start was done in conjunction with individuals and organizations in candidate participating countries.

The first stage, shown in Figure 27, provided for two needs: (a) defining the roofing and potential materials situation in the candidate participating countries, and (b) defining potential collaborative organizations and individuals with whom work in the program could be accomplished, and who could be responsive to following through with an effort even after AID support was concluded.

APPROACH

COLLABORATION, DEMONSTRATION AND TRANSFER OF TECHNOLOGY

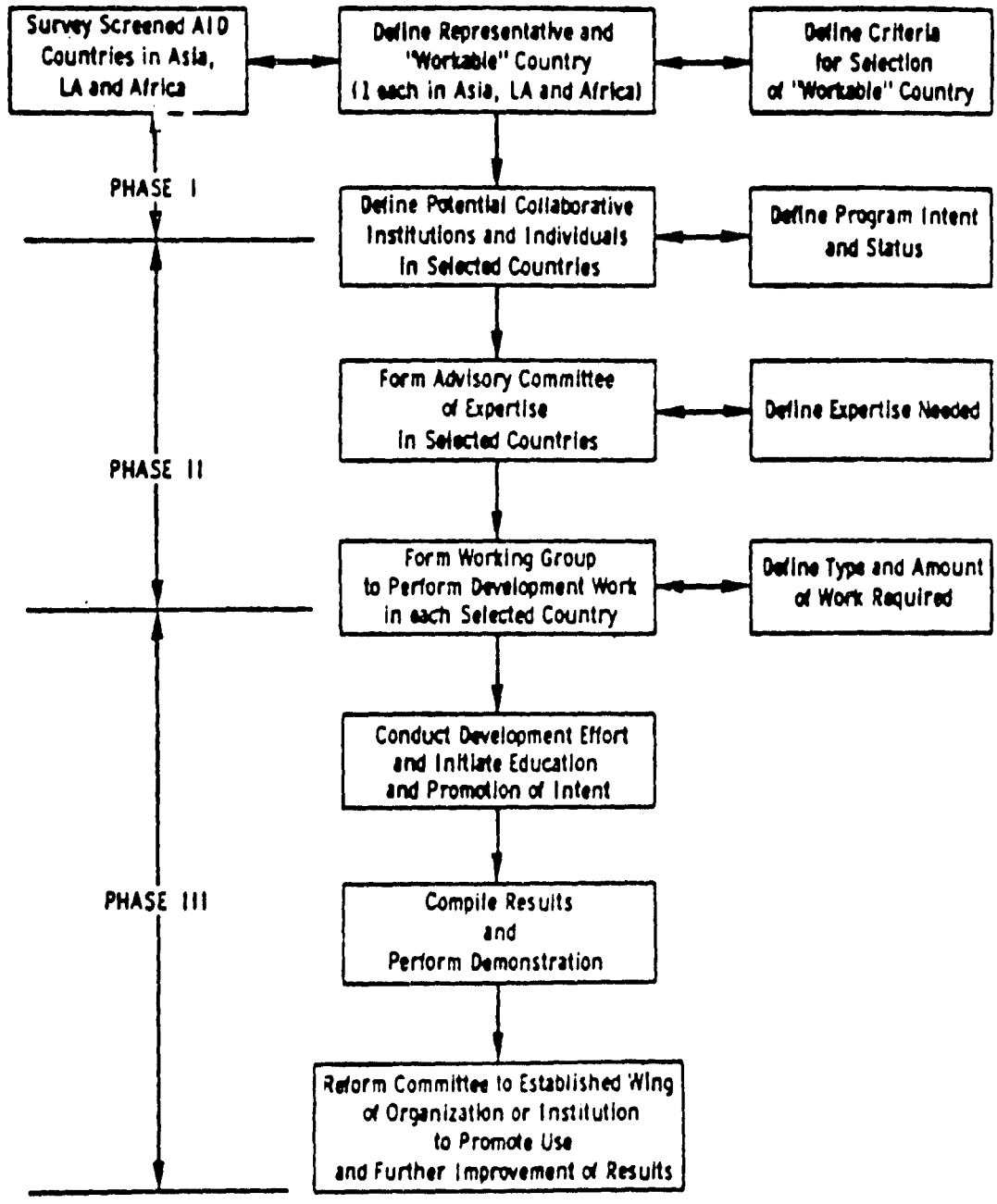


Figure 27. Collaboration, demonstration and transfer of technology were the components of one of the two methodology paths that put the developed technology into practical use.

The initial contacts made in the candidate countries eventually selected thus provided the framework for the future extensions of the program.

The first stage was the most difficult to perform since it was known only that roofing was the area of interest and that resin binders and indigenous materials were to be used in development. No specific information was available. The problem can best be illustrated by comparing the nature of an existing roofing, corrugated galvanized iron, and comparing it to a roofing panel made from bagasse. First of all, those individuals involved with corrugated galvanized iron roofing, while highly knowledgeable in its performance, characteristics, etc., would not be expected to know about the nature and properties of bagasse, resin binders, resin processing, etc. Such personnel and organizations thus would have little or even possibly a negative interest in the development of alternative systems. Thus, just who could contribute was difficult to determine.

3.2.1.1 Advisory Committees

> It was necessary to call on a wide variety of expertise in the areas of materials, processing, agricultural residues, roofing, architecture, building materials, etc., so that when the better systems were defined, potentially interested and skilled individuals would be available to pursue the effort. The approach taken was the formation of advisory committees with broad experience.

A prime objective was to define organizations and individuals who would probably be directly involved because of the nature of their business or who would have the versatility and open-mindedness to pursue a beneficial development. The obvious interest and enthusiasm of a host of individuals in the candidate countries assisted in reaching this objective.

The approach taken for making the desired expertise available was the formation of advisory committees, set up on at least a semiformal basis. Invited to participate on the advisory committees were those who were felt might have something to contribute, even to a minor extent. It was explained that as the program progressed certain participants might have trouble relating to what was being done, but their participation was still welcome. In a similar vein many of those on the committees might not have been able to participate until later in the program, but their knowledge of the evolution of the program would be highly valuable and would reduce the necessity for repetitive explanations of just why various conclusions had been reached.

A chairperson was elected or appointed for each of the advisory committees who acted as an overall coordinator for the effort. The chairperson saw to it that the various disciplines were represented on the committee and that replacements for individuals were made when members found they could no longer participate. It was important that this chairperson live in the vicinity of the activity, be able to communicate with the members of the committee, and be able to convene the committee when necessary. Membership in the committee just for the sake of holding that position and meetings just for the sake of having meetings were highly discouraged.

The members of the committees included individuals from the government, private industry, and academic institutions. Experts in the areas of finance, business, entrepreneurship, socio-economic requirements, etc., were also encouraged.

It was then important to obtain commitments from the advisory committee members for their participation in greater detail if

program developments should so warrant. It was necessary to define those who could make the commitment and those who would be selected to fulfill it (if not one and the same). For instance, usually a commitment had to be made by an individual in top management, who usually would then appoint a delegate to fulfill this obligation. Generally, these commitments were made without hesitation and assistance was made available at appropriate times. There is no doubt that this generous attitude was a key factor in obtaining the results that were achieved.

3.2.1.2 Technical Working Groups

> The working group was to consist of key individuals who were to be directly involved in the experimental effort and who would thus have detailed knowledge of the materials, process, and applications being considered. It is through these key individuals that technology was to be transferred.

A key important point in our methodology was the transfer of technology from person to person rather than through some inanimate structure such as a report. Reports and written material were to be used to aid the involved individuals, but nothing was to replace inter-personal communications.

The working groups were made up of those who could directly contribute to obtaining the necessary raw materials, manufacturing, developing, testing, utilizing the product, utilizing the technology, and constructing the demonstration roofs. The type of expertise required depend upon the system being considered at the time. The working group was to have a chairman or coordinator to facilitate its functioning.

The working group in all cases conducted laboratory or small scale pilot experiments to gain familiarity with the system or systems of interest. Attempts were made to relate the knowledge

gained to the particular materials and manufacturing situation anticipated. Experiments were done both in anticipated manufacturing facilities and also at independent laboratories (usually government sponsored) depending on the nature of the working group infrastructure.

Introducing the technology into a government laboratory that is free to make the information generally available was considered advantageous. However, introducing the technology into an organization having a vested interest in making a profit usually provided a better incentive to early adoption and utilization. Both types of relationships were encouraged, where possible, to achieve better short term results and guarantee long term utilization.

After transferring the technology to the working group and after having determined their competence by their performance in local experimental programs, a demonstration in the manufacture of roofing panels was scheduled. Additionally, the groundwork was laid for the utilization of these roofing panels on houses in the immediate local. Performing the demonstrations required the coordination of a great number of details, all of which had to occur on schedule. The complexity varied with the local situation; as few as three and as many as eight organizations were involved. At this stage the working group coordinators and the Advisory Committee chairmen played key roles and, in fact, determined the degree of success of the effort.

The final stage of the collaboration and transfer of technology was a review by the advisory committees and working groups of the results achieved, their analysis of overall performance, and recommendations for how the technology should be pursued.

It was recommended that the advisory committees remain in existence to assist the future development and use of roofing products and facilitate any interface required between industry, individuals, and the government (especially with respect to low cost housing which should be a prime target for the roofing materials).

3.2.2 Material and Process Development

The development of materials and processes for the manufacture of roofing panels was conducted in a systematic manner. The method comprised an initial extensive screening process, followed by an intensive laboratory program, and finally demonstrations involving actual construction of roofs in the three collaborating countries.

The materials and process development generally followed the recommendations of the special National Academies of Science Committee, set up by the United Nations to study the problem of roofing in developing countries. This committee recommended that available indigenous resources (e.g., agricultural or mineral residues) be investigated to determine those which were suitable for combining with minimum quantities of synthetic or natural resin binders to make functional low cost roofing.

The material development critical path, shown in Figure 28 can best be simplified by a brief discussion that follows it through its various stages.

The first step of the materials development aspect of the program was the determination of the availability and characteristics of low cost agricultural residues, etc., that could be raw materials for structural components: (a) first in all the candidate countries, and (b) second, in greater detail, in the three selected collaborating countries. The availability of these raw material components was a deciding factor in the

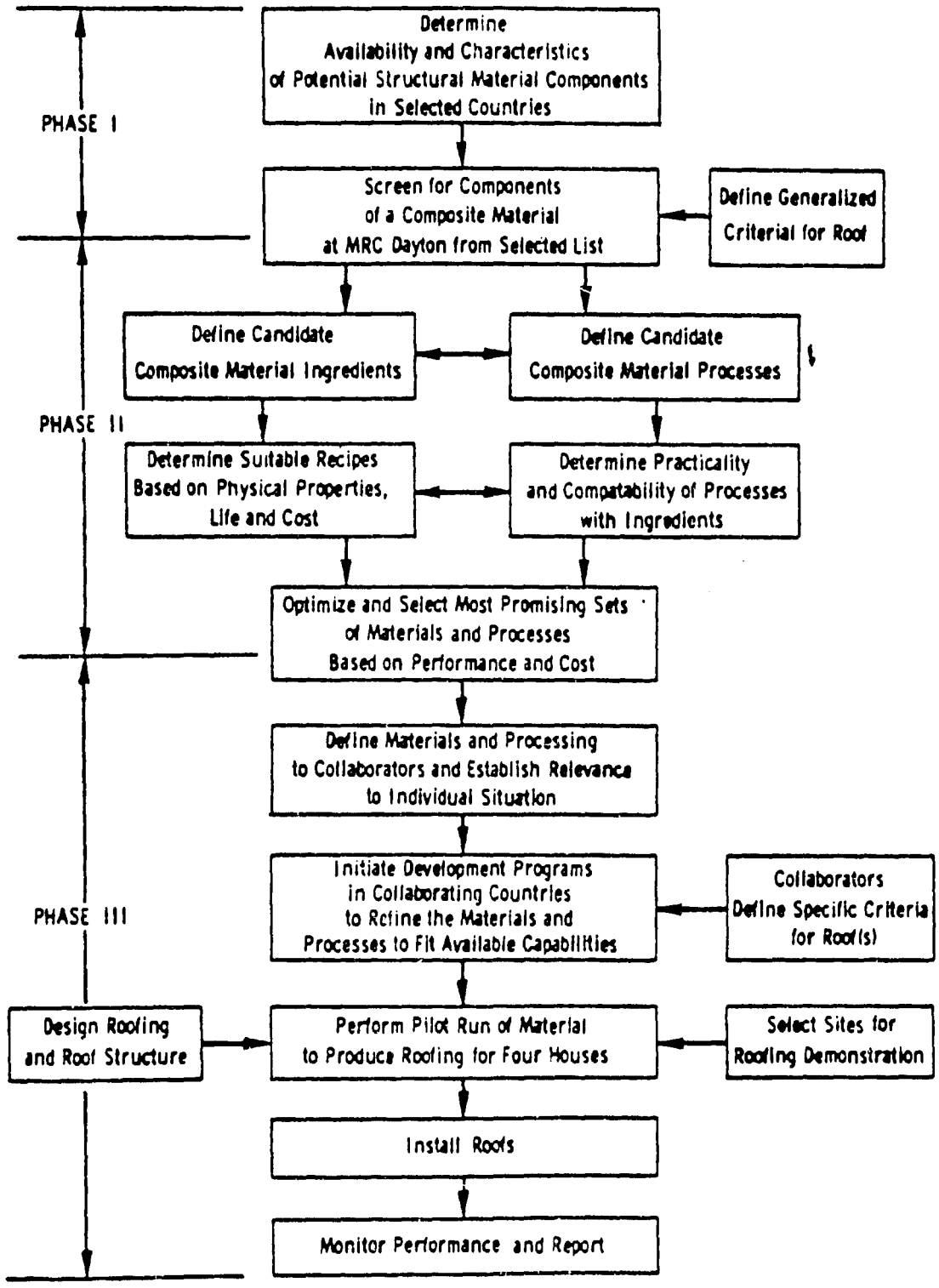


Figure 28. Material and process development constituted the main technical path of the methodology leading to the alternative roofing systems.

selection of the participating countries and therefore had to be done early, even though summarily, in phase one. Following selection of the participating countries, more detailed information was generated and actual samples of materials were collected for study in the laboratory. In this way candidate material components from three countries were obtained and introduced into an experimental program.

The experimental program was conducted initially at the Dayton Laboratory of MRC with support from Dr. Ben Bryant at the University of Washington. It consisted of a screening effort to eliminate obviously poor candidate materials and to provide some good alternatives for the future laboratory experimental effort. At this stage, some candidate roofing compositions were made using known processes, since it was the properties of a composite material that were expected to achieve the desired results. Individual evaluation of components of the composites was not adequate to project the desired performance.

As candidate roofing products became available from the screening experiments, and as better candidate samples became available during the material and process studies, they were delivered to the participating countries where they were put on outdoor exposure racks for measurements of durability. While some of the earlier samples did not have all the refinements of those systems produced later on, it was important that they be put out for exposure early in the program so that some realistic exposure time periods could be achieved. Fortunately, test fences of this type, usually used for exposing paints, were available in the participating countries, and the organizations who had them were most cooperative in providing space and analysis.

At the same time that the screening of the materials was conducted, a generalized set of criteria for roofing was defined

in conjunction with participating country personnel. This was necessary to define the functioning of a roof and what types of roofs were to be considered. Residential roofing and low cost housing which better fit in with AID's overall objectives of putting work where it would benefit the most poor people was stressed. Complicating the definition of a roof was guessing what material could be generated from a composite consisting of some sort of agricultural or mineral residue held together with a resin binder.

It could easily be said that all that was desired was a roofing material that performed as well as a corrugated metal roof but at lower cost. Given all of the metal roof's individual attributes, this result in fact could be achieved by nothing other than corrugated metal itself. It thus was necessary to determine qualitatively just what were the necessary and desirable features of the roof itself, the roofing panels, and the roofing materials from which they were made.

Having knowledge of potential raw materials and a preliminary definition of the desired properties of a manufactured roofing product, it was necessary to define a process for producing a roofing material from them. Accordingly, at this stage a preliminary feel for existing technology and facilities was required. For instance, manufacturing facilities of any kind that were available in the participating countries had to be factored into studies done in the selection of these countries. In all cases some facilities did exist. However, the availability and size of facilities and the manner in which they were being utilized was all important to the research program. Accordingly, a survey and inspection of facilities was conducted and information retained for future reference and use in the program.

3.2.2.1 Selection of Best Alternative Candidate System

Four candidate roofing material systems were developed in a laboratory program using knowledge of potentially available materials and facilities and established composite technology.

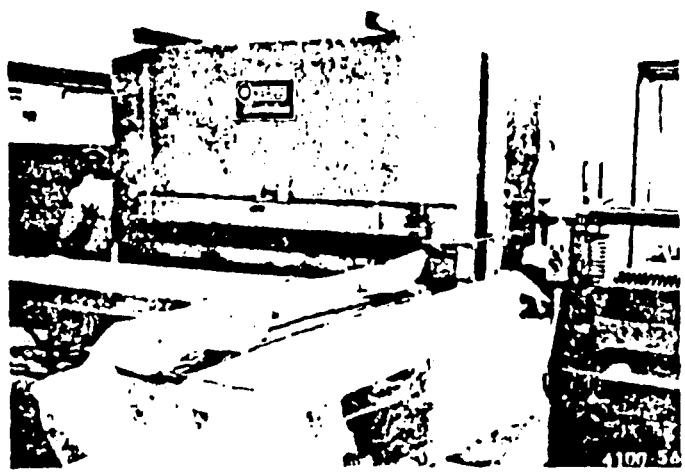
An experimental seed program to develop both composite materials and processes was undertaken in MRC's Dayton laboratory. It was conducted there because of the existence of: materials and composite technology derived from defense and space technology; processing facilities and skilled operators; and testing, analytical and weathering capabilities. Conducting this aspect of the work in the three countries would have probably required duplication of effort and would not have provided as broad a look at both materials and processes as could be achieved in one facility already set up for just such experimentation.

The experimental program took the form of defining candidate composite material ingredients and optimizing recipes based on the results of tests for physical properties, durability, and cost. Process development paralled the material analysis. Processes were necessary to fabricate specimens from the candidate materials. In some instances an expedient process was used to prepare a specimen so that it could be evaluated. As the effort progressed it was necessary to define and use more practical processes that could be scaled up into the plant manufacturing level.

It was felt that one of the processes needed refinement on a larger scale. Therefore, collaborators at the University of Washington set up a pilot facility for fabrication of full size corrugated panels, proceeded to detail the process and manufactured a small quantity of panels for evaluation. This is illustrated in Figure 29.

(a) A Sprout-Waldren defibrillator was used to wet fibrillate bagasse fibers after initial dry processing.

(b) Commercial water extractors incorporating screens and dense fabrics were used to introduce orientation and form a moist mat.



(c) A single opening side loading press was made available for molding at the American Plywood Association in Tacoma to complete the pilot plant.

Figure 29. A pilot facility to produce full size 2 ft x 7 ft corrugated BCB panels was set up by the University of Washington.

The culmination of this experimental effort (conducted in Phase II) was a laboratory optimization and the selection of four of the most promising material and process combinations. There were several reasons for not limiting the effort to just a few combinations at this stage.

First, throughout the duration of the program, the cost of materials, especially candidate resin binders, fluctuated and increased (probably more so than at any prior time in history). Therefore, the future cost effectiveness of any particular system was subject to later change. Some originally proposed strong candidates were ruled out at this stage because of that fact.

Second, the program was being conducted in three distinct countries each of which had its own set of conditions with respect to availabilities of materials, facilities, and technology. Thus, the best material/process combination for one country may not have been the best for another. Or, more than one combination may have been of particular interest in a given country.

Third, some of the systems looked more promising for the near term because they took advantage of existing materials, facilities and technology. Other systems appeared more attractive in the long term, where capital facilities could be added or some change in thinking could be introduced.

Finally, during this early research only relatively brief determinations of acceptability or durability could be achieved. Thus, it was necessary to have a number of alternatives available so that substitutions could be made should a flaw become apparent in one of the candidates. Such flaws could include some non-technical aspect, relating to a particular governmental, political, or socioeconomic climate. For instance, the importation

of materials can readily be made very easy or very difficult at the discretion of any government. Similarly, the government could either promote or suppress a particular industry for the overall benefit of the country, but this could possibly result in a demise of some part of one of the candidate systems. The availability of bagasse, for example, depends upon a healthy sugar industry which would have to follow not only political boundary lines but world demands.

3.2.2.2 Collaborating Countries Participation and Demonstration

> The knowledge of material and processes and their application to roofing were transferred to the collaborating countries. Transfer was achieved and demonstrated by laboratory experimentation, plant manufacture and actual construction of roofs in the participating countries with local manpower and facilities.

At this stage in the program the laboratory-optimized roofing materials and processes and the rationale behind them were explained to collaborators in the participating countries. The relevance of the candidate systems to the individual country was also confirmed. Contacts were also maintained with the participants throughout to maintain interest and continuity of work programs in the participating countries.

Development programs were initiated in each of the three participating countries. A generalized program work statement used in Jamaica is shown in Figure 30. This program was designed to make the participating working group intimately familiar with the candidate materials and processes. Experimental work was conducted on those systems that seemed to best fit the needs of the particular country. The work was to be done in a laboratory or small plant, relating as much as possible to existing facilities to be used in later, larger scale manufacturing.

IMPROVED ROOFING MATERIALS WITH
ECONOMIC TRADE BENEFITS TO JAMAICA

PROGRAM WORK STATEMENT

OBJECTIVE: To develop, define and demonstrate economically viable roof material candidates in Jamaica.

TASKS

1. Set up an advisory committee to provide advice, communication, coordination and planning.

2. Set up a working group to provide for performing the following tasks.

3. Review composite materials R&D work done by MRC and determine relevance to Jamaican situation.

4. Conduct cost analyses on the candidate material systems to determine their degree of viability with respect to other available roofing.

5. Assist MRC in determining functional life of candidate composite materials by providing proper exposure (environmental), testing and analysis of MRC and eventually Jamaican produced panels.

6. Conduct R&D program to optimize, upgrade, refine, etc. the composite materials systems using the MRC recipes (ingredients and lab process) as starting points.

7. Determine processing techniques and conditions for the more attractive material systems:

   (a) laboratory scale process

   (b) large scale factory process

   (c) low capitol-labor intensive process

8. Determine both necessary and desired criteria for a roof and a roofing material for low-cost housing in Jamaica.

9. Design roof and/or roofing product (panel, tile, etc.) based on the criteria in 7, the properties of the materials resulting from 4 and 5, the processability from 6, and knowledge of factors determining general acceptability, i.e. shape, color, size, strength, etc.

10. Define roof construction details, i.e. substructure, method of attachment, etc.

11. Determine criteria for and select site for at least four (4) demonstration roofs. Include visibility to public and decision makers, convenience to laboratory and project participants with respect to time and cost, availability of materials and necessary skills to make and install the roof, future acceptability, etc.

12. Fabricate sufficient roofing product for 5 roofs. Set up quality control and preliminary specifications.

13. Install roofs on at least 4 houses. Provide architectural supervision, record the installation process, record problem areas, submit data and analyses to the committee and MRC for review.

14. Monitor performance and user response of roofs with time (at least 6 months).

15. Write and submit final report covering all aspects of work. Monthly summary and detailed quarterlies are also required.

Figure 30. The program outlined to be conducted in Jamaica is typical of the nature of the work expected of the collaborating countries.

It was also at this stage that the in-country collaborators were to define as much as possible specific criteria for roofs that would guide the experimental work and dictate the best options available. Specific roofs had to be considered to determine how the roof must function.

The next, most complex stage of the work, included the actual production of roofing panels at a facility or facilities in the participating country, selecting housing sites for a roofing demonstration, and designing a roofing system and roof substructure compatible with the selected houses. The pilot runs to produce roofing panels were to utilize as much as possible existing facilities and locally available materials. Those materials (binders and/or additives) requiring foreign exchange were provided to the local participants at no charge.

Rather than build new houses on which to install roofs, houses already planned for construction were to be utilized both to minimize program cost and provide a more practical demonstration The roofing panels were to be provided at no cost, in exchange for their being installed on a roof. The selected houses dictated roof design and substructure. Intentionally, as little modification as necessary was made, but some changes were necessary to accommodate the particular roofing panels that were found to be practical for the pilot manufacturing.

The roof was to be designed so that performance, or lack of performance could be directly related to the material of construction rather than to the roof design. It was anticipated that all the materials could eventually be fabricated into any particular desired shape. The importance of installing the roofs was to get the materials into a roofing situation for outdoor exposure and practical evaluation of durability so that the life of the product could be determined.

Sufficient roofing panels to provide coverage for the equivalent of at least four houses (this arbitrary number having been selected by AID) were to be manufactured. These were then to be installed using local craftsmen having experience in installing roofing. Emphasis was to be placed on roofing panels that could be installed strictly by nailing and that could be cut to fit using normally available saws, knives, etc.

The final stage of the material and process development was to comprise monitoring the performance of the roofs and preparation of a report on their performance. It was hoped that the working group would be able to monitor the performance of the roof for a number of years so that actual long-term durability could be measured. This would require only simple visual examination of the roof from both the inside and outside and interviews with individuals who were then living under these roofs.

3.2.3 In-Country Participation Program Details

Programs were conducted in the Philippines, Jamaica, and Ghana, where collaborative efforts, transfer of technology, and material and process developments took place. The efforts varied in complexity and formality depending on the basic government and industry infrastructure. Cooperation and enthusiasm was good and assisted in moving the programs forward.

The MRC project team assisted in (a) defining the roofing problem, (b) developing reliable material and processing alternatives, (c) coordinating a developmental effort in the participating countries, (d) performing a demonstration utilizing the technology, and (e) transferring of the technology by visits to the participating countries at intervals throughout the four-year program period.

The timing and duration of the visits to the participating countries were selected to best utilize the available limited resources and to prevent repetition of mistakes. The duration of each visit was determined by establishing a cost/performance criterion, which included manpower, travel and per diem costs related to the length of a sustained, intensive effort that could be conducted within the country. Three to four weeks, ten to fourteen days, and two to three weeks were judged optimum, respectively, in the Philippines, Jamaica, and Ghana.

The intervals between visits were also optimized to provide time for work to be conducted in the participating countries between meetings, to allow for shipment of materials and their clearance through customs, to allow for trouble shooting experimental work at MRC's Dayton Laboratory and to allow for planning. These intervals were five to six months, three to four months, and six to eight months, respectively, for the Philippines, Jamaica, and Ghana.

Support was also given by the US AID Missions in the participating countries. This participation was most helpful and ranged from a very detailed involvement, including some coordination, to just smoothing the way by minimizing potentially redundant formalized reporting and contacting. Formal contacts were used when necessary, but informal proceedings were found to be more valuable especially through much of the period that included learning by all of the parties involved.

3.2.3.1 Philippine Program Coordination and Structure

> The more highly structured business, industrial, and government climate in the Philippines introduced a more formal working atmosphere there. Coordination with a much greater number of people in a variety of disciplines was necessary to fully evaluate the various alternative materials and processes developed.

In the Philippines, which has a population more than ten times that of Jamaica, it was judged necessary that a formalized advisory committee and technical working group be created. The principal function of the advisory committee was to coordinate the various aspects of the program, as well as to obtain credibility and acceptance of the results. The function of the technical working group, having at the most one representative from each of the organizations carrying out the various aspects of the program, was to actually implement the development and demonstration program.

The National Science Development Board (NSDB) was selected by the National Economic Development Authority (NEDA) as the scientific agency in the Philippines to carry out the in-country development for the AID roofing project. The chairman of the NSDB, General Florencio A. Medina, was selected to form and head a national advisory coordinating committee for low cost roofing.

This committee was formally constituted at a meeting at NSDB on February 12, 1975 and representatives of all the government agencies critically concerned with housing were invited. The membership of the national advisory coordinating committee is shown in Figure 31. Some changes in representatives have occurred throughout the program.

The chairman of the national advisory coordinating committee designated a technical working group with Ms. Lydia G. Tansinsin as chairperson. The first meeting of the entire technical working group was held on August 29, 1975.

The technical working group, which was to follow through with direct implementation of the work, including a demonstration, was made up of individuals from within the advisory committee and industrial organizations. Those involved in the technical working group are shown in Figure 32.

The National Science Development Board provided program and technical coordination. The National Housing Corporation provided extensive manpower and facilities for experimentation and actual manufacture of roofing products on a relatively large industrial scale. Jardine Davies made available a test exposure facility at one of their plant manufacturing sites and contributed samples of and information on sugar cane bagasse from its Hawaiian-Philippine Sugar Company. Goodyear Tire and Rubber Company provided manpower and facilities necessary for a portion of the manufacturing process and thus participated in the demonstration.

Latex Products Company made available manpower and facilities on a most timely basis early in the program to provide for the first pilot-scale manufacture of one of the roofing products in

LOW-COST ROOFING NATIONAL COMMITTEE (PHILIPPINES)

ADVISORY COMMITTEE MEMBERS

Organization	Representative	Title
National Science Development Board Bicutan, Taguig, Rizal	General Florencio A. Medina	Chairman and Country Coordinator
National Institute of Science & Technology National Science Development Board Bicutan, Taguig, Rizal	Dr. Jose R. Velasco	Commissioner
Forest Products Research and Industries Development Commission 872 (Isabel) Building Isabel St., Espana, Manila	Dr. Francisco U. Tamolang	Commissioner
Building Research Service University of the Philippines Diliman, Quezon City	Dr. Ernesto Tabujara (represented by G. Hanahan)	Officer-in-Charge
College of Architecture University of the Philippines Diliman, Quezon City	Aurelio T. Juguilon	Dean
College of Engineering Mindanao State University L and S Building Roxas Blvd., Manila	Rufino Ignacio	Dean
National Housing Corporation Tala, Caloocan City	General Gaudencio V. Tobias	Executive Vice President
Tondo Foreshore Development Authority Tondo, Manila		Executive Director
People's Homesite and Housing Corp. Elliptical Road, Quezon City	Mr. Sebastian B. Santiago	General Manager
Presidential Assistant on Housing and Resettlement Agency Quezon Blvd., Extension, Quezon City	Col. Jaime A. Venago	Officer-in-Charge
Philippine Institute of Environmental Planners Sikatuna Building Ayala Avenue Makati, Rizal	Dean Cesar H. Concio	Chairman, National Building Code Committee and President
Philippine Institute of Civil Engineering Delta Motor Sales Corporation Bldg. Quezon Blvd., Extension, Quezon City	Mr. Cesar A. Caliwara	President
Humanitarian and Prive Assistance United States Agency for International Development Ramon Magsaysay Center Roxas Blvd., Manila	Mr. Joseph Whelton	Assistant Director

Figure 31. The Philippine National Advisory committee on roofing provided extensive experience in their effort.

TECHNICAL WORKING GROUP FOR THE DEVELOPMENT OF A LOW-COST ROOFING (PHILIPPINES)

Organization	Representative	Title	Role
National Science Development Board Bicutan, Taguig, Rizal	Ms. Lydia G. Tanalinsin	Chairman of Committee	
National Institute of Science and Technology Bicutan, Taguig, Rizal	Dr. Vedasto R. Jose	Vice Chairman of Committee	
Forest Products Research and Industries Development Board Industries Development Commission 872 Isabel Building Isabel Street Espana, Manila	Joaquin Siopongco	Engineer	
University of the Philippines Building Research Service Diliman, Quezon City	Geronimo Manahan	Professor	
University of the Philippines College of Architecture Diliman, Quezon City	Anerillo T. Jugilon	Dean	
Mindanao State University L and S Building Roxas Blvd., Manila	Rufino Ignacio	Dean	
National Housing Corporation Tala, Caloocan City	Col. Alejandro R. Kabiling		
People's Homesite and Housing Corp. Elliptical Road, Quezon City	Ramon R. Veto	Engineer	
Presidential Assistant on Housing and Resettlement Agency Quezon Blvd., Extension Quezon City	Dr. Carlos Javier		
National Building Code Sikatuna Building Ayala Avenue Makati, Rizal	Cesar H. Concio	Dean	
Philippine Institute of Civil Engineers Sikatuna Building Ayala Avenue Makati, Rizal	Samuel Lazaro, Jr.	Engineer	
Food for Peace U.S. A.I.D. Ramon Magsaysay Center, Roxas Blvd., Manila	Albert S. Fraleigh Robert Halligan	Assistant Director Assistant Program Officer	
National Science Development Board Bicutan, Taguig, Rizal	Mr. Jose O. Jaug	Member-Secretary	

Figure 32. The Philippine Technical Working Group carried out the experimental wo[redacted]nd demonstrations.

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the Philippines. The Forest Products Research and Industrial Development Commission conducted an experimental effort to evaluate some of the alternative systems. They also provided the necessary personnel and excellent facilities. Monsanto-Philippines assisted in the importation of materials and provided a communications link between the collaborators and the MRC project team.

Many other individuals and organizations (e.g., Manila Rubber, Mabuhay Vinyl) also contributed meaningfully throughout the duration of the project, by providing some particular expertise, material, or facility that was needed at the time. The good telephone service that exists between the United States and the Philippines was also beneficial to the coordination effort.

The details of the four prime alternative candidate roofing systems were discussed with the Technical Working Group first in August 1975. Based on this information and input from the Technical Working Group and the Advisory Committee, a detailed experimental program was drawn up to guide the various participants who would be performing parts of the investigation. While the MRC project team originally had time and funds available for pursuing only one system in the Philippines, there was interest in pursuing at least three of these. Accordingly, secondary parallel programs were outlined for the collaborators to conduct these additional studies. US-AID Philippine project coordinators changed several times. However, much active and useful assistance was provided throughout the 4-year duration of the program. As will be discussed later, supplementary funds were made available by AID-Washington and US-AID-Philippines to pursue more than one alternative.

3.2.3.2 Jamaica Program Coordination and Structure

> The smaller physical size, the concentration of industry in one area (Kingston), the availability of relatively modern facilities and a more informal business, industrial and government climate provided a high degree of flexibility in the Jamaican program. A program coordinator directly responsible to MRC and major manpower and facilities commitments by industry and the government expedited the effort.

In Jamaica it was judged that a formal advisory committee on roofing would be highly desirable as the most effective means of making available the necessary expertise. A technical working group could then evolve from members in the advisory committee from those judged to be more relevant to the particular approach then being taken. The advisory committee is shown in Figure 33, with membership shown by organization. Throughout the term of the effort, personnel changes in various organizations required substitutions of representatives.

The Jamaican coordination effort was unique, among the three countries, in that the project coordinator had a direct responsibility under the MRC prime contract. This was accomplished by paying that individual for time spent on the project up to a limit of 500 hours.

There is no doubt that a greater degree of coordination could have been possible if more funds were available for use in the participating countries. The lack of such funding - except for materials and equipment - limited such coordination. However, in spite of these funding limitations, total funding of an AID effort in the participating countries was deemed less advisable since this would not have required a significant commitment on the part of our collaborators. It was felt that such a commitment was vital to encourage a continuing effort even after AID and MRC participation ended.

ADVISORY COMMITTEE MEMBERS

Organization	Representative	Title
Doust Brown Adams and Partners (DBAP) 7 Lismore Avenue Kingston 5 Phone: 926-3485	*Alfriss O. Adams Eric O. Brown	Chartered Engineer and Head Program Coordinator Chartered Engineer
Ministry of Housing (MH) 2 Hagley Park Road Kingston 10 Phone: 936-1590, Ext. 330	Rev. G. ... McLaughlin Ms. Nadine Isaacs Mr. Al Richards	Special Advisor to the Minister Architect Runts Bay Sites and Service Supervisor
Scientific Research Council (SRC) Old Hope Road, P.O. Box 350 Kingston 6 Phone: 937-9931 (32,22)	Dr. E. E. Magnus Mr. Fred Campbell Mr. Oran Bowen Mr. G. I. D. Williams	Technical Director Senior Principal Scientific Officer Scientific Officer Scientific Officer
Standard Building Products (Jamaica) Ltd. (SBP) P.O. Box 29 66 Carlatta Road Spanish Town Phone: 984-2295 (96)	Mr. Douglas Wynter Mr. H. K. S. Blagrey Mr. John Crafton Mr. Ralph Corning	Technical Director Vice President for Sales & Marketing President President to 9/76
Berger Paints (BP) 356 Spanish Town Road Kingston 11 Phone: 923-6326 (30)	Mr. H. S. Fennel Mr. Dervis R. Brown Mr. Ken Esposit	General Manager Technical Manager Laboratory Manager
Goodyear Jamaica Ltd (GT) Office - 29 Tobago Avenue Kingston 10 Plant - Morant Bay Phone: 926-8018 982-2353	Mr. T. S. Elliott Mr. Helmut Schueller Mr. William R. McKenzie Mr. Richard R. Greene	Manager, GMMC Technical Superintendent Managing Director Production Director
Bureau of Standards (JBS) 6 Winchester Road Kingston 10 Phone: 926-1140	Dr. A. S. Henry Mr. James Campbell Mr. A. K. Elliott	Director Head, Materials Administrative Secretary
U. of West Indies (UWI) Mona Road Kingston 7 Phone: 927-0751	Dr. Thomas Hughes	Professor of Material Science
Urban Development Corporation (UDC) 40 Harbour Street Kingston Phone: 929-2240	Mr. David Gregory-Jones	Chief Architect and Planner
Knox Development Foundation (KDF) P.O. Box 45 Spaldings Phone: 964-2359	Mr. Lewis Davidson	Director
National Housing Corp (NHC) 6a Oxford Road, P.O. Box 48 Kingston 6 Phone: 926-5654 (55,56)	Ms. T. Nelson	Research Officer Science and Technology
Thermoset Ltd. (TS) Office - 14 Dominica Drive Kingston 5 Plant - Hagga Head Phone: 936-5920 936-6394	Dr. Lester A. D. Chin Mr. James A. Blackwood Mr. Carol Morin	Technical Director Managing Director Director
Thermo-Plastics (Jamaica) Ltd. (TP) 45 Elma Crescent Boulevard P.A. Phone: 935-2190 925-1050	Mr. Desulme Mr. Yvon T. Desulme Mr. Ludwig Reisinger	President Purchasing Manager Manufacturing Manager
A. F. Pattinson Company (PAT) 2 Marcus Garvey Drive Kingston Phone: 932-0365	Mr. A. F. Pattinson	Manufacturer's Representative and Importer
Ministry of Industry Tourism and Foreign Trade Kingston	Mr. Roderick Rainford	Economist and Under-Secretary
Jamaica Society of Quantity Surveyors Kingston	Mr. Errol Spence	Past President
U. S. A.I.D. Mission (AID) to Jamaica Duke Street Kingston Phone: 932-6340	Mr. Peter Keler Mr. Rick J. Mariani	Program Officer to 6/76 Program Officer
Inc. Master Builders 19A Old Hope Road Kingston	E. G. Gabay	Member and President of E. G. Gabay Construction Company, Ltd.

*None with BRADA, Ltd., 8 Hope Road; 926-0111

Figure 33. The Jamaica Advisory Committee on roofing made available a broad area of expertise that was used as needed.

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Mr. Alfrico D. Adams, at that time*, a chartered engineering and partner in the consulting firm of Douet Brown Adams Consultants Limited, agreed to take on the task of program coordinator if supported by an advisory committee. He was also selected as chairman of the advisory committee.

It was felt that this on-the-spot project coordination represented an excellent way of conducting the program and should be pursued in any continuing or similar effort. The selection of a dedicated, knowledgeable, and personable individual such as Mr. Adams, with good communication skills, is highly critical. Strong support by and the cooperation of committee members is also required.

Mr. Adams was given the task of forming the advisory committee, starting with those individuals and organizations who had agreed to participate during earlier survey discussions. It was hoped that various of the committee members could represent two or more organizations or agencies, in order to minimize the size of the advisory committee. For example, a representative of some government or industry organization might have been able to perform a dual role in also acting as a representative from the Jamaican Society of Architects.

The technical working group, which actually followed through with direct implementation of the work, was made up of individuals from within the organizations participating in the advisory committee. Those involved in the technical working group are shown in Figure 34. The specific role of these individuals, discussed in detail in the next section, can be summarized as follows. The Scientific REsearch council provided technical coordination, an experimental effort, and use of facilities.

*Mr. Adams is presently with SMADA Ltd. in Kingston, Jamaica.

IMPROVED ROOFING MATERIALS WITH ECONOMIC TRADE BENEFITS TO JAMAICA; WORKING GROUP

Organization	Representative	Title	Role
Douet Brown Adams and Partners 7 Lismore Avenue Kingston 5 Phone: 926-3485	Alfrico D. Adams	Chartered Engineer and Roof Program Coordinator for Jamaica	Overall Program Coordination and Engineering
Ministry of Housing 2 Hagley Park Road Kingston 10 Phone: 936-1590	Ms. Nadine Isaacs Mr. Al Richards	Architect Architect	Architectural support Housing Selection
Scientific Research Council Old Hope Road, P.O. Box 350 Kingston 6	Mr. Fred Campbell Mr. Uran Bowen Mr. G. I. Denny Williams	Senior Principtal Scientific Officer Scientific Officer Scientific Officer	Materials and Design Research Production Technical Assistance
University of West Indies Mona Road Kingston 7 Phone: 927-0751	Dr. Thomas Hughes	Professor of Material Science	Composite Materials and Testing Consultant
Berger Paints 256 Spanish Town Road Kingston 11 Phone: 923-6226	Mr. Dervin R. Brown Mr. Ken Espeut Mr. Trevon Neal	Technical Manager Laboratory Manager Marketing Manager	Outdoor Exposure and Analysis
Standard Building Products (Jamaica) Ltd. (SBP) P.O. Box 29 66 Corletta Road Spanish Town Phone: 984-2295 (96)	Mr. John Crafton Mr. Douglas Wynter	President Technical Director	Pilot Manufacturing and Technical Support
Goodyear Jamaica Ltd. (GY) Office - 29 Tobago Avenue Kingston 10 Plant - Morant Bay Phone: 926-8018 982-2353	Mr. Richard Greene Mr. Helmet Schueller	Production Director Technical Superintendent	Banbury Pilot Manufacturing
Bureau of Standards 6 Winchester Road Kingston 10 Phone: 926-3140	Mr. James Campbell	Head, Materials	Physical Testing

Figure 34. The Jamaica Technical Working Group was constituted from within the Advisory Committee making available the personnel and facilities to develop and manufacture the materials systems and put them to use.

Standard Building Products, Ltd. provided technical support, manpower (thousands of hours), and facilities for manufacture of demonstration panels. Berger Paints, Ltd. provided an outdoor exposure effort and appropriate analysis starting with the very early stages of the program, and continuing through its completion. Berger has made a commitment to follow through with technical advice. Goodyear-Jamaica Limited made available manpower and facilities to perform a critical part of the manufacturing process. The Minstry of Housing provided considerable guidance in the roof design and made available houses for the roofing demonstration. The Bureau of Standards and the University of the West Indies provided valuable assistance in physical testing and analysis of the composite material systems. The remaining members of the advisory committee also contributed importantly with specific details in a positive manner. The excellent telephone system that exists between the United States and Jamaica allowed instant communications that played a major role in fulfilling program objectives.

3.2.3.3 Ghana Program Coordination and Structure

A relatively informal business, industrial, and government climate provided a very workable degree of flexibility in the Ghana program. The intense interest of relevant government agencies and industry to gain advantage from the program provided an excellent incentive. Commitments by government, business and industry and the availability of directly appropriate facilities also contributed. The lack of good telephone communications between the MRC project team and the collaborators and between the collaborators at different locations in the country was a significant barrier to efficient implementation. However, the interest and directly applicable expertise within the country outweighed this communication disadvantage.

It was judged that a separate advisory committee and technical working group were not necessary in Ghana. This was true because of the less complex business structure and the intense interest of the Building and Roads Research Institute (BRRI) and its director, Dr. J. W. S. de Graft-Johnson, to participate in the program. Dr. de Graft-Johnson stated that the necessary expertise with respect to materials, construction, roofing, etc. would be available from within BRRI and the Council for Scientific and Industrial Research (CSIR). This expertise, combined with that from business and industry, should be adequate to provide the necessary knowledge and technology needed for an optimum development in Ghana.

Dr. de Graft-Johnson agreed to a single, combined advisory/technical working group for roofing in Ghana and to appoint to it a variety of individuals knowledgeable in anticipated relevant areas. Those organizations and individuals appointed to this committee are shown in Figures 35 and 36.

Dr. de Graft-Johnson also agreed to assign an associate from BRRI to act as technical coordinator for any effort to be conducted within BRRI and outside industry. This individual,

IMPROVED ROOFING MATERIALS WITH ECONOMIC TRADE BENEFITS TO GHANA; ADVISORY COMMITTEE

ADVISORY COMMITTEE MEMBERS

Organization	Representative	Title
Building and Roads Research Institute Kumasi Phone: 4221/2	*Dr. J. W. S. deGraft-Johnson Mr. John Nutsugah Mr. A. K. Chatterjee Kofi Obeng Mr. J. N. Okyere	Director and Roof Program Coordinator Research Officer, Architecture Div. Chief Research Officer, Materials Chemical Engineer Acting Head of Materials
University of Science and Technology Kumasi	Dr. B. Biswas Dr. Alex Scheinesson Dr. Kuffour Dr. F. A. Abloh	Sr. Associate Professor, Department of Chemistry Sr. Project Advisor, Technology Consultancy Centre Professor Chemistry Head, Dept. of Housing and Planning Research, Faculty of Architecture
Ghana Rubber Products, Ltd. Industrial Area Accra Phone: 21771	Mr. Kahl Farhry Mr. Phillip Westray Mr. Jeri Subert Mr. Ivo Caganek	Managing Director General Manager Technical Manager Technical Manager
Ghana Sugar Estates, Ltd. Accra Phone: 63424	Mr. Dim Van der Heeden Mr. R. Beirman	Managing Director Asustare Mill
Firestone-Ghana, Ltd. Accra	Mr. C. C. Hoyt	Comptroller
Logs and Lumber Ltd. Kumasi	Mr. Nadim Bitar	Owner-Manager
Reiss and Company (Ghana) Ltd. Accra Phone: 65105	Mr. N.B.X.P.M. Meijer Mr. Jan Assenberg	Technical Sales Representative to 6/76 Technical Sales Representative
Forest Products Research Institute Kumasi Phone: 5770	Mr. F. W. Addo-Ashong	Director
TEMA Development Corporation TEMA	Mr. Vik Adegbite	Chief Development Officer
Crops Research Institute	Mr. P. A. Biaku	Director
U.S. A.I.D. Mission to Ghana Accra	Mr. Haven North Mr. David Dibble Ms. Louanne Douris	Mission Director Private Enterprise Officer to 6/76 Acting Private Enterprise Officer

Figure 35. The Ghana Advisory Committee on [illegible]ing was established primarily from within the Building and Roads Research Institute and Industry.

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IMPROVED ROOFING MATERIALS WITH ECONOMIC TRADE BENEFITS TO GHANA; WORKING GROUP

WORKING GROUP MEMBERS

Organization	Representative	Title	Role
Building and Roads Research Institute Kumasi Phone: 4221/2	*Dr. J. W. S. deGraft-Johnson	Director and Roof Program Coordinator	Overall coordination, roof criteria, house selection, technical support
	Mr. John Mutsugah	Research Officer, Architecture Div.	
	Mr. A. K. Chatterjee	Chief Research Officer, Materials	
	Kofi Obeng	Chemical Engineer	
	Mr. J. N. Okyere	Acting Head of Materials	
	Mr. Afele	Architect	
Ghana Rubber Products, Ltd. Industrial Area Accra Phone: 21771	Mr. Kahl Farhry	Managing Director	Pilot Manufacturing and technical support
	Mr. Phillip Westray	General Manager	
	Mr. Jeri Subert	Technical Manager to 7/77	
	Mr. Ivo Cayanek	Technical Manager	
Ghana Sugar Estates, Ltd. Accra Phone: 63424	Mr. Dim Van der Heeden	Managing Director	Supply bagasse
	Mr. R. Heirman	Agustare Mill	
Reiss and Company (Ghana) Ltd. Accra Phone: 65105	Mr. N.B.X.P.M. Meijer	Technical Sales Representative	Assist importing
	Mr. Jan Assenberg	Technical Sales Representative	
University of Science and Technology Kumasi	Dr. B. Biswas	Sr. Associate Professor, Department of Chemistry	Technical Consulting
	Dr. Alex Scheinesson	Sr. Project Advisor, Technology Consultancy Centre	
	Dr. Kuffour	Professor Chemistry	
	Dr. F. A. Abloh	Head, Dept. of Housing and Planning Research, Faculty of Architecture	
Forest Products Research Institute Kumasi Phone: 5770	Mr. F. W. Addo-Ashong	Director	Facilities support

Figure 36. The manufacturing and roofing installations were carried out by the Ghana Technical Working Group.

Kofi Obeng, a chemical engineer, was assigned to become knowledgeable in the roofing material and process alternatives developed in the effort; to perform some experimental work to demonstrate his knowledge; and to coordinate the obtaining of materials, shipping of panels, roof installation, etc. necessary for the roofing demonstration.

The main objective of the program at BRRI was to obtain enough data to verify the process, properties, and costs of the alternative roofing materials. Such data obtained locally, would be sufficient to verify for the government of Ghana that these roofing products should be adopted and used in typical housing. Dr. de Graft-Johnson agreed that this work at BRRI would be performed as part of their normal budget, with a priority diverted to it. He pointed out clearly, however, that it would be absolutely essential for any foreign exchange requirements to be supplied by the AID contract. It was agreed by BRRI and MRC that a formal agreement would not be necessary for the performance as agreed upon.

There were four major participating organizations in the Ghana roofing development and demonstration program. These included: BRRI, in their role as discussed above; Ghana Rubber Products, which contributed major amounts of manpower and facilities for the manufacture of roofing product; Ghana Sugar Estates, which made available and delivered the necessary bagasse; and Reiss and Company, which assisted with the importation of materials and at times provided for timely intercontinental communications. The Forest Products Research Institute was to have made available some needed facilities but was unable to do so.

Discussions by the roofing committee were held in 1975 and 1976, covering all aspects of the effort with emphasis on the rural,

low-income housing situation. Based on the information generated, a detailed experimental program was drawn up to guide the various participants who would be performing parts of the investigation and demonstration.

3.3 TECHNOLOGY DEMONSTRATIONS IN THE PARTICIPATING COUNTRIES

One goal of the program was to demonstrate the utility of the various roofing material candidates by manufacturing at least one of them within each of the participating countries and installing roofs that would allow their evaluation. The bagasse-reinforced hard rubber system was demonstrated in the Philippines and Ghana, and the bagasse-reinforced phenolic system in Ghana, Jamaica, and the Philippines. These demonstrations helped force a transfer of technology. Secondary systems and alternative uses for the products were also explored.

One goal of this program, which was achieved, was to manufacture at least one of the alternative roofing systems in each of the three participating countries using available facilities and manpower. These demonstrations had a number of purposes, which included: (a) illustrating the practicality of the system for the local situation; (b) illustrating that the technology had indeed been transferred; (c) establishing a baseline for durability studies; and (d) illustrating the validity of a scaleup from the laboratory studies. Figure 37 summarizes the scope of the demonstration effort.

The bagasse-reinforced hard rubber (BRR) system was used for demonstrations in the Philippines and Ghana. The bagasse-reinforced phenolic (BRP) was demonstrated in Jamaica, Ghana, and the Philippines. In the Philippines, Ghana, and Jamaica, materials were compounded, panels were fabricated, and roofs constructed. In Ghana BRR materials were also compounded, but only small samples were molded, since adequate mold temperatures could not be reached in the plant of Ghana Rubber Company. The Ghana Rubber Company, however, is highly committed to going ahead with the product, and it has therefore scheduled the installation of a new boiler that will allow achieving the necessary steam temperatures. This facilitity should be operational in the first quarter of 1978.

	Philippines	Jamaica	Ghana
Primary Demonstrations	BRR — Materials, Panels, Roofs	BRP — Materials, Panels, Roofs	BRR — Materials; ——— ; ———
	BRP — Materials, Panels, Roofs	BOB Roof	BRP — Materials, Panels, Roofs
Secondary Interest	BOB Experimental	BOB Experimental	BOB Experimental
	BRP — Construction Materials Demonstration	———	———

Figure 37. Technology demonstrations were conducted in all three countries with the proof evidenced by the existence of roofs manufactured and installed locally.

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The most extensive (and largest scale) demonstrations of roofing materials manufacture, and roofing installations, was conduct in the Philippines. Many tons of both BRR and BRP materials were manufactured (primarily at the National Housing Corporation). BRR roofs were installed on four full size houses. Sufficient BRP material was made to fabricate at least one entire model house, including walls.

Interest in alternative and supplementary material systems also existed in the participating countries. Accordingly, experimental programs to examine the alternative systems were set up. This secondary emphasis in the Philippines, and Jamaica was placed on the bonded, oriented bagasse fiber (BOB) system. The BOB system was studied some in the Philippines with considerable interest at the Forest Products Research and Industries Development Commission (FORPRIDECOM).

The ground work for successful demonstrations was introduced through the implementation of experimental programs at laboratories and factories in the countries. Members of the advisory committees and working groups became knowledgable in the systems, materials, processes, and products and in their applications. The most formal program was conducted in Jamaica where coordination was easier and where the Scientific Research Council agreed to conduct the experimental work. Good participation by all of the members of the Advisory Committee and working groups was achieved through stimulation by a local program coordinator. The coordinator played a major role in having work conducted, especially with respect to defining the criteria for roofs that were desirable.

Reports and extensive correspondence were generated throughout the three parallel efforts. While all the information would be

informative, its inclusion would require at least doubling the size of this report. Accordingly, selected documentation is reproduced in an appendix. The purpose of the documentation is to illustrate both what was done and how it was done, since the methodology used in this program was judged to be as significant as the technical achievements themselves.

3.3.1 Philippines - Roofing

The facilities required for manufacture of the bagasse-reinforced hard rubber (BRR) and the bagasse-reinforced phenolic (BRP) roofing existed in the Philippines. Thus, both BRR and BRP flat roofing shinges were manufactured in the Manila area and installed on at least five houses. The demonstration was facilitated by the technical working group, which became familiar with the system while planning for the demonstration. The demonstrations encompassed the manufacture of 50 tons of materials and thousands of square feet of roofing shingles, enough to cover a substantial number of houses.

The roofing development program in the Philippines went through three separate stages, as depicted in Figure 38. The first stage was a learning, teaching, and selling experience for both the MRC project team and the potential Philippine collaborators. In-depth surveys of natural resources and available facilities were made. Working relationships were established with appropriate personnel in the government, industry, and the academic community. The second stage involved small-scale research on three of the candidate roofing material systems, beginning in August 1975 and continuing through 1976. The third stage included two separate demonstrations involving large scale manufacture and installation of roofs of (a) bagasse-reinforced natural rubber, and (b) bagasse-reinforced phenolic roofing. These demonstrations were carried out from September to October 1976 and from June to July 1977 and roofs are shown in Figure 4.

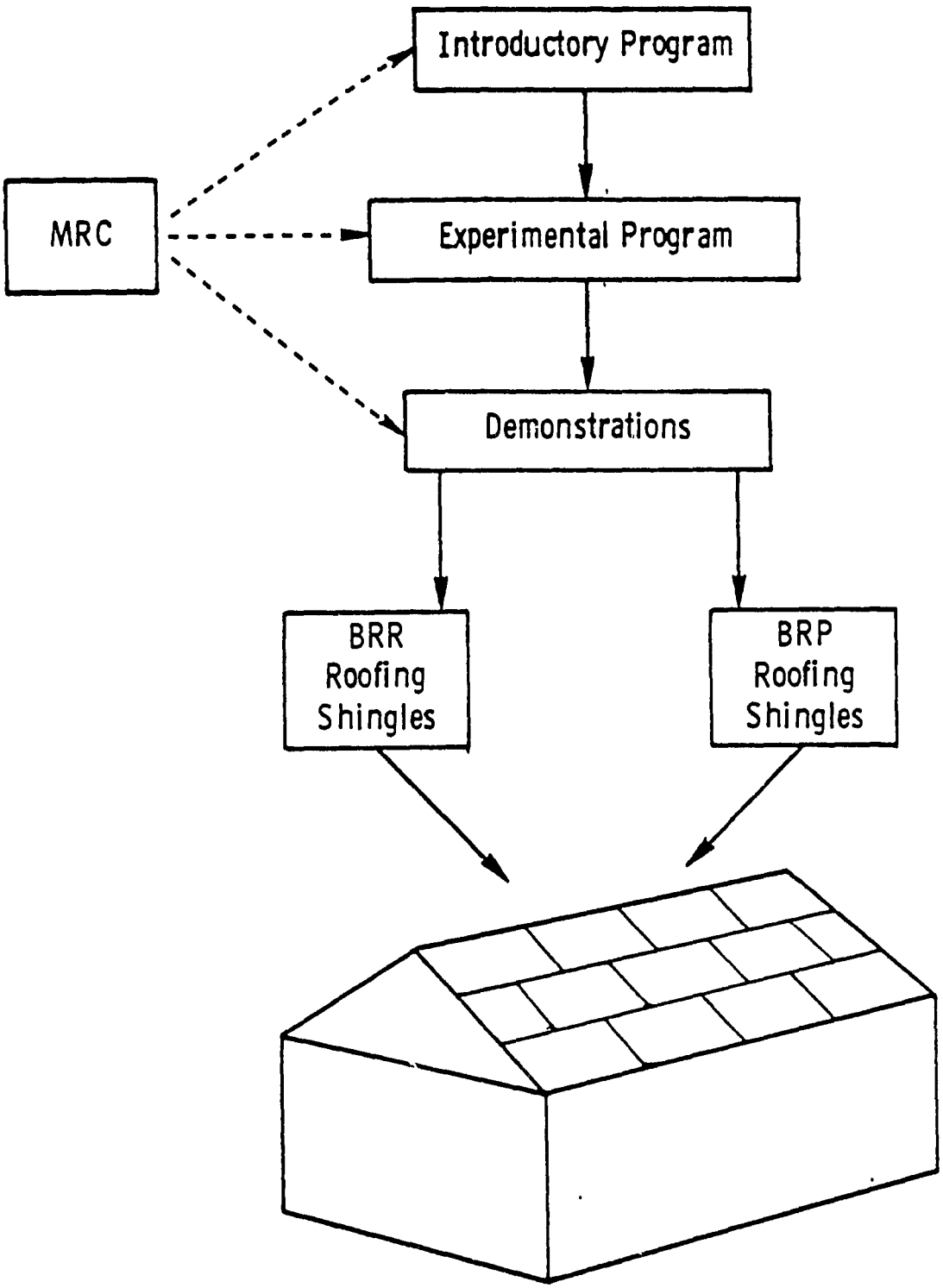

Figure 38. The roofing development program in the Philippines went through introductory, experimental, and demonstration stages to achieve goals.

The cooperative program was conducted based on an informal, "gentlemens' agreement", since several attempts at achieving a more formalized working agreement encountered bureaucratic road blocks that could not have been resolved within the time frame of the program.

3.3.1.1 Experimental Program

> The experimental program was designed to bring together the necessary expertise and facilities in the Philippines, to prepare and test candidate alternative roofing materials in conjunction with the efforts of Monsanto Research Corporation. The research was done in two government laboratories and was augmented by experiments at industrial sites. Industrial organizations which might become involved in future production of the roofing material were kept informed. The experimental program introduced first-hand experience and confidence that led to subsequent large-scale manufacture and a roofing demonstration.

The experimental program got underway in the Philippines in August 1975, when a National Advisory Coordinating Committee for roofing was formed. The experimental program for roofing development was outlined and agreed upon at a meeting of the Technical Working Group in Manila on August 29, 1975. The experimental work was conducted at two locations: the Forest Products Research and Industries Development Commission (FORPRIDECOM), Los Banos; and the National Housing Corporation (NHC), Caloocan City. The experimental work continued through 1976 when it became part of the demonstration program.

The experimental effort at FORPRIDECOM concentrated on the BOB system, including a study of the process parameters. Small scale equipment was available there for fibrillating the bagasse, preparing randomly oriented mats, molding the resin-impregnated mats, and testing the products.

Initially, the NHC concentrated on developing the BRR system, and eventually the BRP system. Facilities at Latex Products Company were used to prepare ∿300 pounds of BRR compound, which was then molded into large, flat test panels at the NHC on their laminating press. Smaller test specimens were molded on a laboratory press at Mabuhay Vinyl Corporation and FORPRIDECOM. Evaluation, including strength tests on all specimens, were performed at the NHC.

It became apparent, as time went on, that the organization having the most pertinent capabilities and highest interest in commercializing a roofing system was the NHC. This was understandable, since the NHC is a quasi-private corporation which makes components for houses (trusses, lightweight block, and urea/formaldehyde particle board). The NHC's particle board press is a high capacity production type that was projected to be usable to produce roofing of the type contemplated, with reasonably little modification.

Accordingly, the entire experimental program was gradually taken over by the NHC, since they would be responsible for the production demonstration phase. Thus, the overall direction of the program shifted to General G. V. Tobias, Executive Vice President of the NHC. General Tobias, in turn, delegated Mr. Victor Cedro, superintendent of the PVC plant, as coordinator of the experimental program and any demonstration project.

The experimental program was largely concluded in the fall of 1976 when pilot plant production was started. Thereafter, most of the experiments (variations in formulation, curing time and temperature) were done in plant production equipment.

Simultaneously with the experimental program, outdoor exposure of panels of the candidate roofing systems was conducted (starting in August 1975). The paint test fence facility of the Sherwin Williams Paint Company outside of Manila was used. This company is a partially owned subsidiary of Jardine Davies, a large corporation that produces a variety of products, including sugar. These panels were visually examined periodically, and photographed. Other than for some early surface "roughening", giving a "flat" surface appearance, little change occurred after more than two years outdoor exposure. These tests of outdoor stability will be continued for five years, or until the program is completed (whichever occurs first).

3.3.1.2 Roofing Demonstration - Manufacturing

Two of the composite roofing systems, the bagasse-reinforced hard rubber and the bagasse-reinforced phenolic, were manufactured in the Philippines as a basis for a demonstration. Flat, rigid 4 ft x 16 ft BRR panels were manufactured and subsequently cut into 2 ft x 4 ft flat roofing shingles. About 14,000 sq ft of similar panels of the BRP were also manufactured. The lower curing temperatures and shorter cure times made the BRP process more attractive.

Manufacture of two complete alternative roofing systems was demonstrated in the Philippines (see Figure 39). The details of the demonstration project plan, results, and future efforts are presented in three reports reproduced in Appendix H. The project plans are contained in a report dated 12 August 1976 and the results of two efforts in the area of manufacturing are described in the reports dated 30 October 1976 and 9 July 1977.

There were two separate demonstrations of plant scale manufacture, at the National Housing Corporation, of the BRR and BRP composite roofing materials. In the first of two demonstrations, both the BRR and the BRP materials (7 tons and 1/2 ton, respectively)

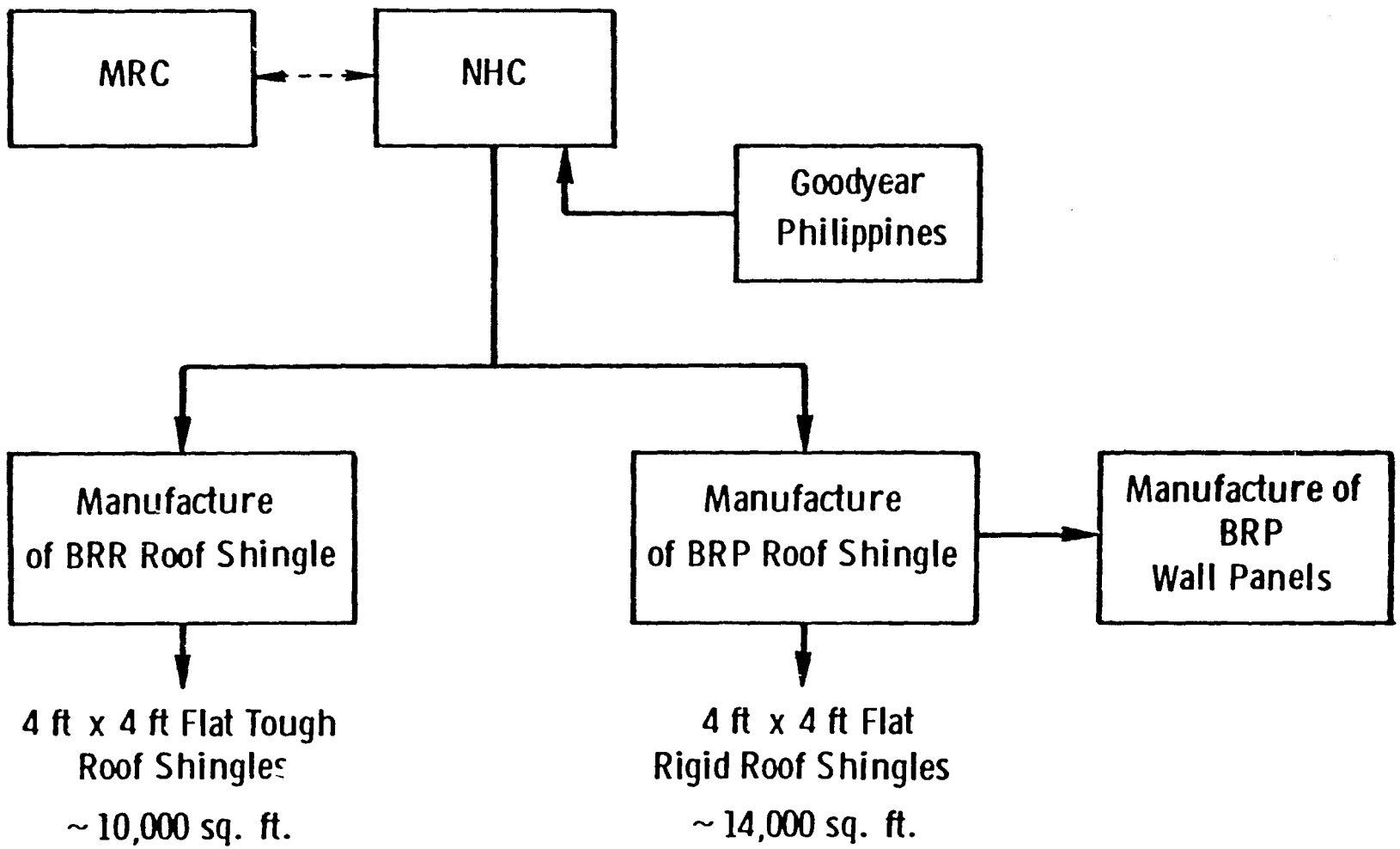

Figure 39. Two complete alternative roofing materials were demonstrated in the Philippines by plant manufacture of large quantities of shingles.

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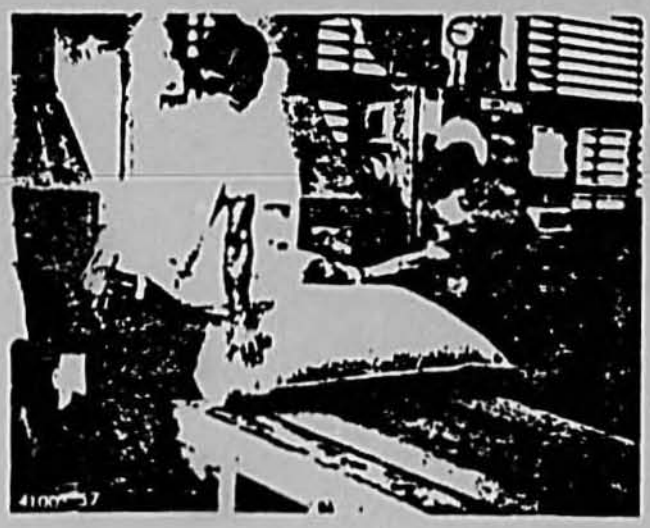
were manufactured using a combination of the processing facilities at Goodyear-Philippines Ltd. and the National Housing Corporation. The field report on this demonstration, dated 30 October 1976, is in Appendix H.

The BRR composition was compounded in a Banbury mixer and calendered into sheet at Goodyear-Philippines, illustrated in Figure 40. A total of 15,033 pounds of BRR, compounded in the form of sheet, was prepared using the standard fire-retarded and low-cost formulations described in section 3.1.2. Bagasse in various forms was also examined. In particular, bagasse that had been depithed was evaluated against raw, whole bagasse in both the fire retarded and lowest cost formulations.

The compounding went as expected, with only one exception to the recommended process. This exception involved the time for addition of the accelerator and sulfur to the compounded ingredients in the Banbury. Because of the high efficiency and relatively high temperature generated in the Banbury mixer at Goodyear-Philippines, the compound was elevated to too high of a temperature to allow the addition of the accelerator or sulfur. Accordingly, all materials except the accelerator and sulfur were first compounded in the Banbury. They were then dropped out of the Banbury and left to cool. After cooling, the mixture was reintroduced to the Banbury for addition of the accelerator and sulfur and brief mixing.

The compounded material was then dropped directly from the Banbury onto a two-roll mill where it was formed into a thick sheet that was removed continuously. This sheet was fed to a calender to further refine and then rolled up. The sheets were at least 50 inches wide and about 1/8 inch thick.



(a) The ingredients were introduced into a Banbury intensive mixer usually used to compound rubber for automobile tires and tubes.

(b) All necessary compounding was done in the intensive mixer where the bagasse fibers were completely surrounded with the rubber matrix.

(c) Large irregular lumps of compounded material were converted to a handleable sheet on a calender, rolled up, and transferred to a molding press.

Figure 4[illegible] Over seven tons of the BRR composition were compounded and calendered into sheet at the Goodyear Tire and Rubber Plant, Manila.

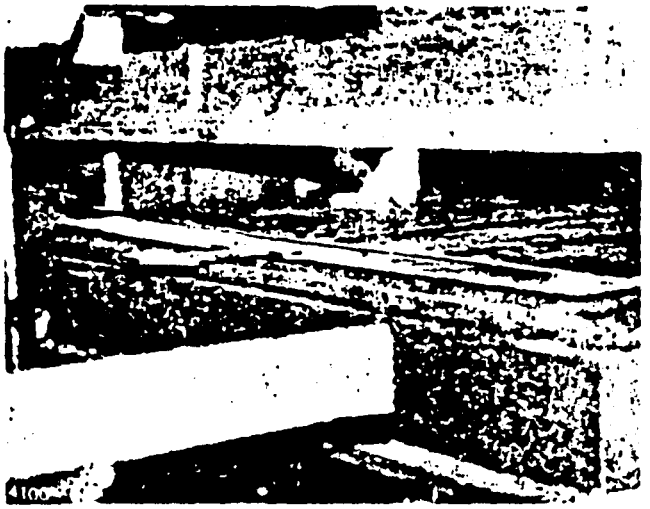
The rolled sheets were taken to the National Housing Corporation where they were press-cured into 4 ft x 16 ft panels in a large, five-opening automated press. The curing cycle was 30 minutes at 330°F at a pressure of 300 psi. Cooling the part was found to be necessary before removal of pressure and removal from the mold; otherwise, blistering occurred. Achieving these press temperatures was difficult because available boilers had not been designed for this purpose and were wood-fired.

Following cool-down of the panels, and their removal from the mold, shown in Figure 41, they were trimmed square and even and cut into 2 ft x 4 ft roofing shingles (some 1 ft x 4 ft and 4 ft x 4 ft shingles) to provide for best fit on the anticipated roofs. These panels were then delivered to a housing site for installation.

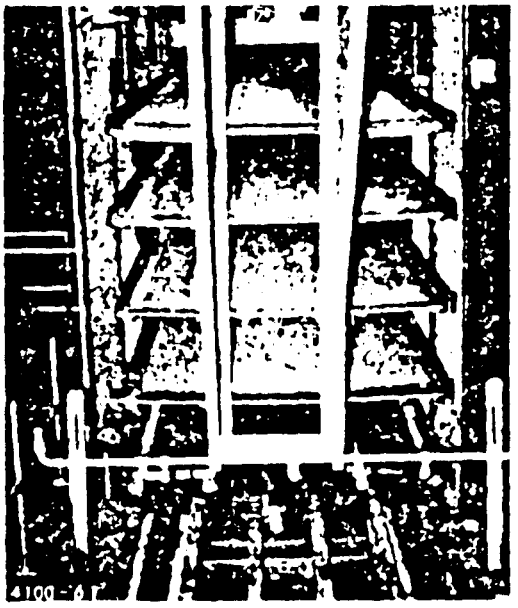
During the October 1976 period, and again in June 1977, very large quantities (multitons) of the BRP product were manufactured for use as roofing materials.

The process used for the BRP composition was that described in section 3.1.1 using similar materials, but with modification. This modification consisted of examining the use of a fire-retarded liquid (Chlorowax-40) in place of the processing oil (Mobilsol-30), to achieve an even higher level of fire resistance. The Banbury-processed bagasse was dry-blended with 30% Monsanto PR-736 phenolic molding powder in a concrete mixer. The concrete mixer was found to efficiently provide a high degree of uniformity

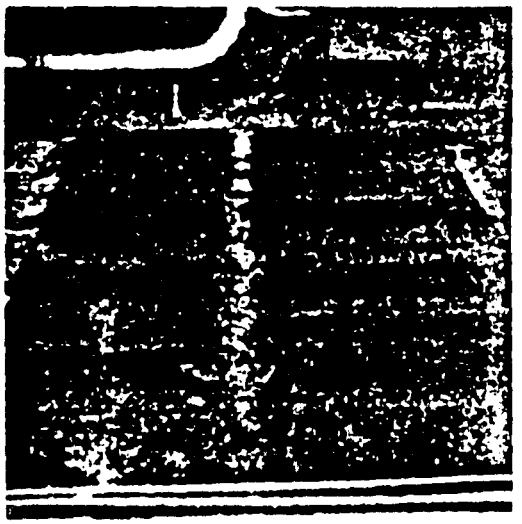
The blended molding compound was then fitted into the molding and pressing operation of the National Housing Corporation Particle Board Plant. This material system fit beautifully with the existing facilities that originally had been set up for wet process hard board, but more recently had been used for a dry



(a) The flexible rubber sheet was placed between smooth flat aluminum caul sheets treated with release agent prior to inserting into a press.



(b) The sheets in their molds were inserted into a five-opening heated hydraulic press for curing.



(c) Four ft x 16 ft panels were molded in the press, removed and cut into 4 ft x 8 ft pieces, that were eventually cut into 2 ft x 4 ft shingles.

Figure 41. The calendered BRR sheet was rigidized into panels in molding presses at the National Housing Corporation, Caloocan City.

process. The molding powder was dumped into 4 ft x 16 ft trays and leveled with comb-like devices. After leveling, the product was put between rough aluminum caul sheets coated with Moldwiz E06 release agent and subjected to pressures of about 300 psi and temperatures of 290°F. It was found that cycle times could be reduced to as little as 10 minutes. Following curing, the panels were removed hot, left to cool, and then cut into 2 ft x 4 ft shingles.

Along with this effort, some bagasse was chopped, cut, and screened in the National Housing Corporation particle board plant chip processing equipment. This was to determine if something other than a Banbury mixer could be used for this bagasse processing. Initial indications were that indeed the bagasse could be prepared using this equipment of the particle board plant. Accordingly, the National Housing Corporation particle board plant could be used as it presently exists for the manufacture of the bagasse-reinforced phenolic roofing panel system.

Most of the molding was done with imported Monsanto Company phenolic resin (Resinox 736), but locally manufactured Borden MC-282 phenolic powder and a plywood liquid glue (Borden HL-4645) were also used, as is discussed in Appendix H.

3.3.1.3 Roofing Demonstration - Construction

Bagasse-reinforced hard rubber (BRR) roofs were installed on four low cost employee houses located at the National Housing Corporation (NHC) near Manila in November 1976. The roof consisted of 24 in. x 48 in. x 1/8 in. BRR shingles nailed to a wood purlin and stiffener substructure. NHC employees have since been living in the houses and monitoring performance. Bagasse-reinforced phenolic (BRP) panels, manufactured in July 1977, also were to be used to roof one model house at a site near Manila.

Employee houses were needed at NHC. Thus it made good sense, logistically, to build demonstration houses there and install roofs on them. The employees' housing site is located adjacent to the NHC factory, where the roof panels were made, in Caloocan City, outside Manila. It was originally anticipated that the four demonstration roofs would be installed on low-cost houses in a squatter resettlement area near Manila, such as Das Marines. However, Das Marines is located some distance from NHC and transportatation of equipment, building materials, and personnel to that site for just four houses was considered to be too time-consuming and expensive.

The houses selected were of a simple, single story design with 488 sq ft floor area, identical in size and shape to other nearby employee houses. The foundation, extending 18 in. below ground level, and the floor, were poured concrete. The walls consisted of NHC-manufactured lightweight concrete blocks, tied together at the roof line with reinforcing steel wire. There were two rooms (kitchen/living area and bedroom) plus a bath (shower/toilet).

The design and construction of the house and roof framing was done by NHC employees. The roofing shingles were installed by a local contractor. An outline of the demonstration effort is shown in Figure 42.

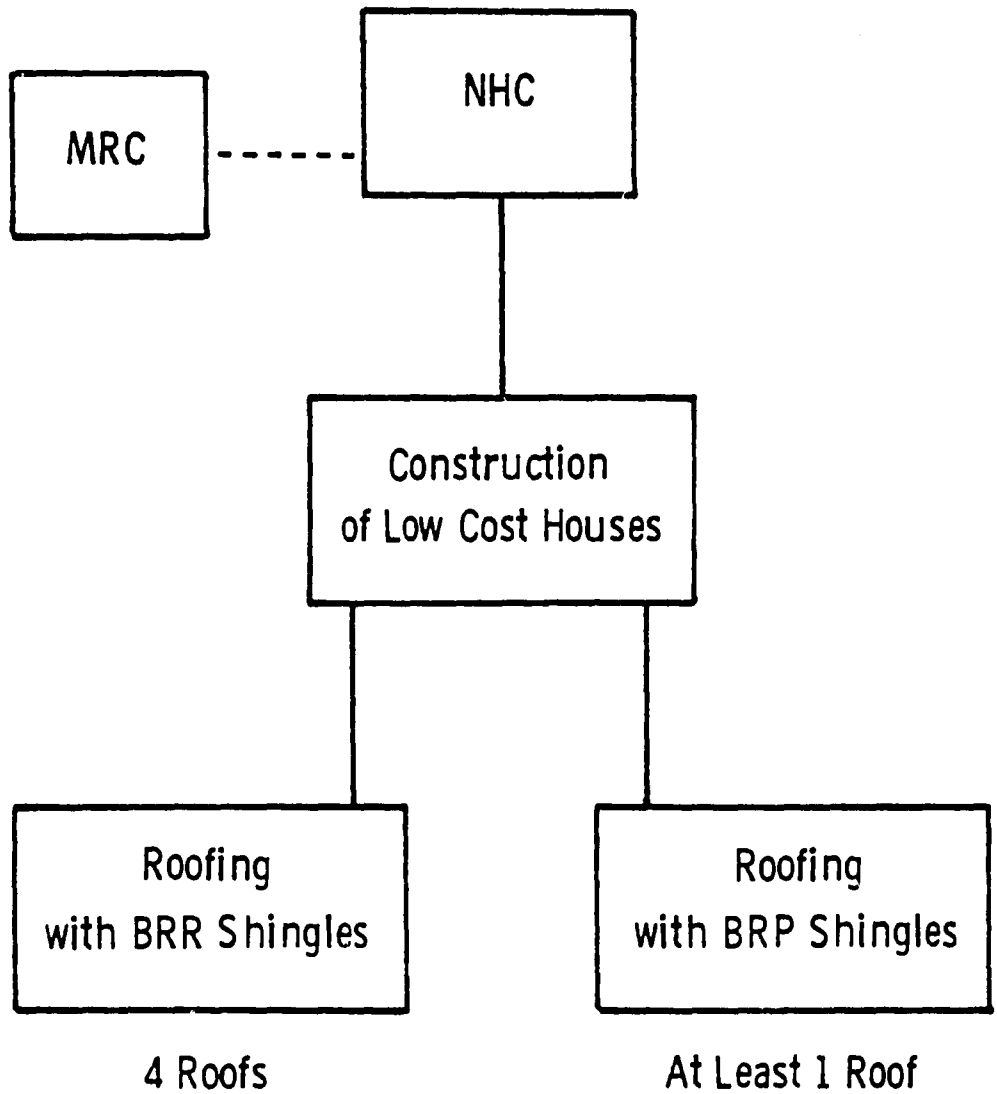


Figure 42. Manufactured BRR and BRP shingles were used to roof houses selected by the National Housing Corporation, Caloocan City.

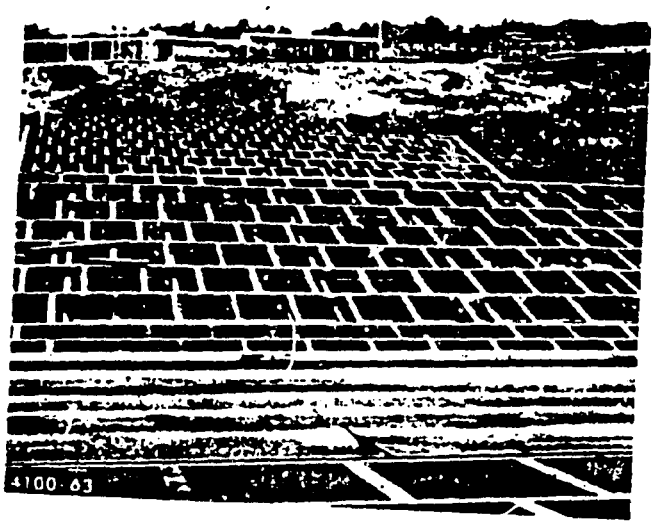
The roof consisted of prefabricated trusses with a 30° double pitch and a 24 in. overhang on all sides of the house. Roof area totaled 849 sq ft. A wood purlin and stiffener substructure was designed to accomodate the 2 ft x 4 ft shingles. The shingles were fastened to the wood substructure using conventional steel flat head roofing nails. In the nailing pattern, most of the nail heads were hidden. Figure 43 shows the roofs as installed.

One minor problem encountered during the installation of the roof was the unexpected "slipperiness" of the smooth molded surface of the BRR shingles on the 30° slope of the roof. This problem was resolved by the Filipino roofers removing their shoes and working barefooted.

Installation of the four roofs was completed in November 1976, and the houses were immediately occupied by NHC employee families. Performance has been monitored by NHC technical employees.

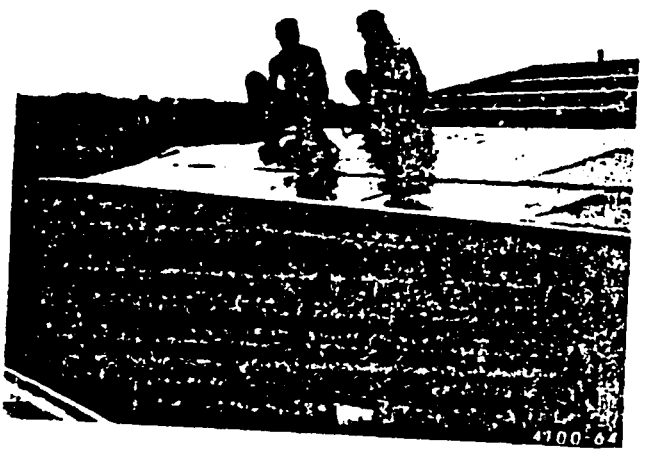
There have been only two recorded minor problems. One of the four BRR roofs leaked. When investigated, this leak was found to result from a roof nail that had been driven entirely through the roof. The hole was clearly visible from the bottom and was repaired. The occupant of this house also reported a noticeable odor of rubber vulcanizate (sulfur) in the house. A visit to the house by MRC and NHC technical personnel failed to confirm any detectable odor. Some warping of the flat shingles has also been noticed.

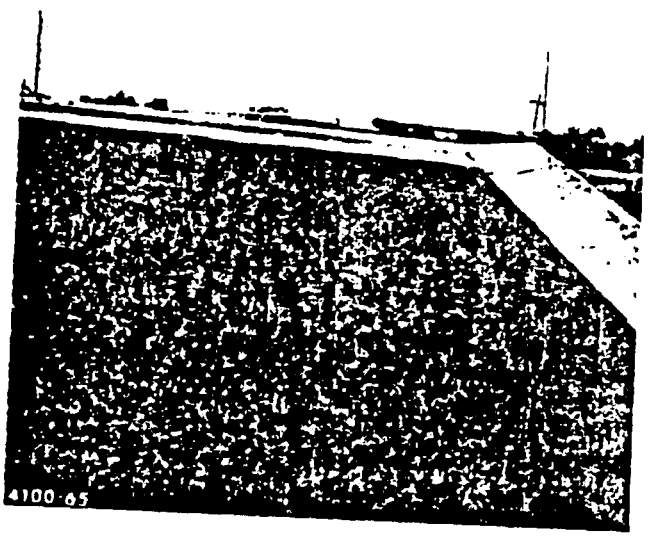
During June-July 1977, multiton quantities of thin BRP roofing panels and thicker BRP wall panels were manufactured at NHC. Using these materials, at least one complete model house is scheduled to be built and roofed subsequently.



(a) The shingles were attached to a wood purlin and stiffener substructure designed to withstand local severe wind conditions.

(b) The 2 ft x 4 ft shingles were attached by nailing and could be cut with available carpenters saws and knives.





(c) After one year exposure the roofs exhibited only the expected minor surface wear and some warping, but otherwise performed well according to those living in the houses.

Figure 43. Four NHC employee houses were roofed with the BRR shingles in November 1976.

feature factory (NHC) prefabricated panels, on wood frames, which were to be assembled on site, based on a concept of J.P.R. Falconer. The model house(s) is to be located at a "more visible site" near Manila (NHC is more than a 1-hour drive from Manila). Construction of several of these model houses is planned to follow.

3.3.2 Jamaica - Roofing

The various facilities required for manufacture of the bagasse-reinforced phenolic (BRP) roofing existed in Jamaica. Thus, BRP flat roofing shingles were manufactured in the Kingston area and installed on the equivalent of four houses. The demonstration was facilitated by the technical working group who conducted experimental work and became familiar with the systems prior to the demonstration. An initial interest in the bonded, oriented bagasse fiber (BOB) system was exploited by the installation of a corrugated roof from panels manufactured at the University of Washington pilot plant.

The effort in Jamaica consisted of three parts, arbitrarily separated into the experimental program, the manufacturing demonstration, and the construction demonstration. The effort is illustrated in Figure 44.

The experimental program led directly into the roofing manufacturing and construction demonstration program, but was much broader in scope. Three of the available candidate roofing systems were examined in the laboratory by the technical working group to assist in determining their viability in Jamaica and, also to gain experience on working with these new systems. Becoming knowledgeable in composite materials was a very important part of this experimental effort to understand the role of the various ingredients in generating structural materials from components that themselves are unsatisfactory.

The experimental program was conducted by a combination of the Advisory Committee, the Technical Working Group and the MRC Project Team in Jamaica. The nature of the effort changed as the needs dictated.

A complete manufacturing and roofing demonstration was conducted on just one system (the BRP). The pertinent details concerning the effort to manufacture roofing panels made with that material

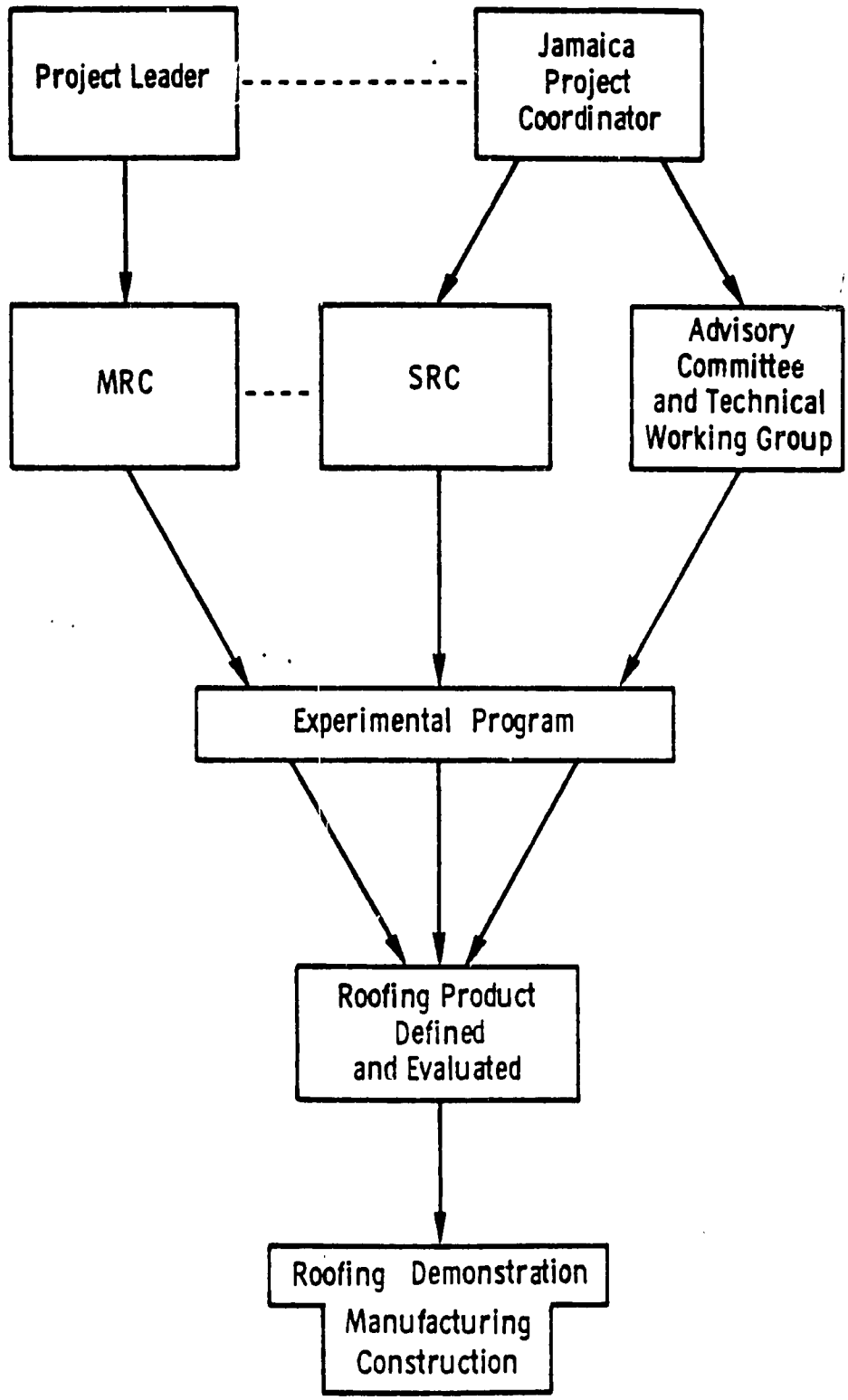


Figure 44. In Jamaica an experimental program was conducted to preceed the manufacturing and construction demonstration stages and overall coordination was done locally.

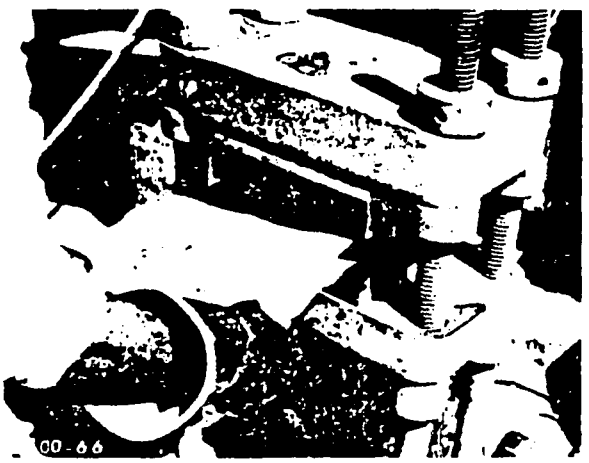
and install roofs will be discussed. A roof was also installed consisting of corrugated painted BOB panels, that had been made at the U. of Washington pilot plant. Other work proceeded continously in support of these demonstrations, providing economic, social, and other information of necessity to the roofing systems. Flat, BRP roofing panels were manufactured and roofs installed in order to initiate a practical durability exposure. However, it is suggested that more appropriate corrugated panels (like the BOB) that better fit in with roofing designs, be considered to further validate the efficacy of the recommended material.

3.3.2.1 Experimental Program

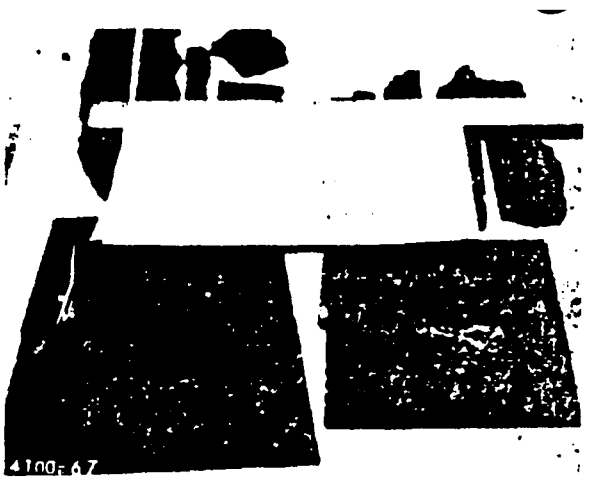
The experimental program was designed to bring together the expertise in Jamaica to define, manufacture, and evaluate a viable roofing alternative based on the work done by Monsanto Research Corporation in conjunction with the early work of the Jamaican Roofing Advisory Committee. The effort included experimental work at the Scientific Research Council, analysis of roofing criteria by members of the Advisory Committee, selection of candidate roofing sites by the Ministry of Housing, and outdoor exposure studies at Berger Paints. The result was the basis for a roofing product demonstration.

The Board of Directors of the Scientific Research Council (SRC) agreed to provide the manpower and facilities for conducting an experimental program to further the roofing product development in Jamaica. This fit in directly with the designated objective for the SRC, namely, transferring technology for the betterment of Jamaica. One man plus supporting personnel were made available for a period of 18 months. They were not able, however, to contribute funds for incidentals, materials or equipment requiring foreign exchange.

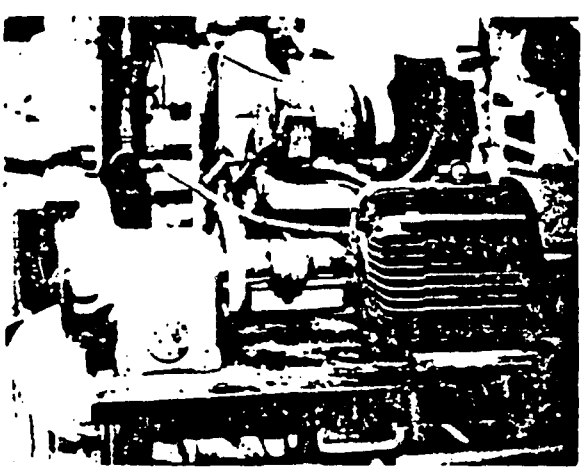
The effort at SRC consisted of conducting experiments in the laboratory (see Figure 45) to duplicate, verify and extend the experimental work done by MRC at its Dayton Laboratory. At the



(a) An electric heated lab hydraulic press was used to make BPP and BOB samples.



(b) Various BRP formulations and molding schedules were examined toward optimization and learning.



(c) A defibrillator was set up for experimental work on the BOB system with AID funds.

(d) The largest commercial Boch water extractor for orienting bagasse in the BOB process was supplied with AID funds.

Figure 45. The experimental program in Jamaica was performed by the Scientific Research Council with their facilities and some equipment supplied under the AID contract.

time that the effort was initiated, only two of the roofing systems seemed appropriate for Jamaica. These included the BOB and the BRP. The others, which at that time also included a clay-based system, were considered to be inappropriate for the Jamaican situation due to higher binder costs within the local economy.

The experimental program was a joint effort between the Jamaican Scientific Research Council, the Roofing Advisory Committee and Technical Working Group, and the AID-sponsored Monsanto Research Corporation project team. The overall coordination of the program in Jamaica was handled by Mr. Alfrico Adams, who brought together the needed expertise. Mr. G. I. Denny Williams was the technical investigator for the Scientific Research Council and was supervised by Mr. Uran Bowen, a principal scientific officer, and Mr. Fred E. Campbell, a senior scientific officer. The Advisory Committee and Technical Working Group effort was coordinated by Mr. Adams with strong support from Messrs. Doug Wynter of Standard Building Products, Tom Hughes of the University of the West Indies (Mona Campus), Al Richards and Nadine Isaacs of the Ministry of Housing, Ken Espeut of Berger Paints, Jimmy Campbell of the Bureau of Standards, and Richard R. Greene of Goodyear Jamaica Ltd. The MRC team coordinator in Jamaica was Mr. George L. Ball III.

The experimental emphasis in the SRC laboratory was on the BOB system with mats being spun in a small Bock water extractor supplied with AID funds. A progress report, dated July 1976, is in Appendix D, containing data generated by Mr. Denny Williams of SRC. While this report did not completely confirm the results achieved at MRC's Dayton Laboratory, it did illustrate knowledge of the product and process, which was considered to be more important. Their experiments and

analysis in the areas of waterproofing, particle size effects, and moisture contents demonstrated their understanding of the system and ability to tailor it as required.

Only one large Banbury intensive mixer existed in Jamaica and it could not be used in small laboratory experiments. Experimental work was conducted on the BRP system at SRC. Included were studies on various alternate (to Banbury mixer) ways of preparing the bagasse fibers, blending techniques, molding cycles, molding temperatures, molding pressures and times, types of molds, mold filling techniques and other latitudes in the molding cycle. No other piece of equipment was found to work as well as the Banbury for intimate mixing, for fibrillating the bagasse fibers, coating them with oil, pigment, etc. Good laboratory specimens were prepared, however, from bagasse fibers prepared in the MRC Dayton Laboratory, verifying results and laying the ground work for a scale up into a demonstration program.

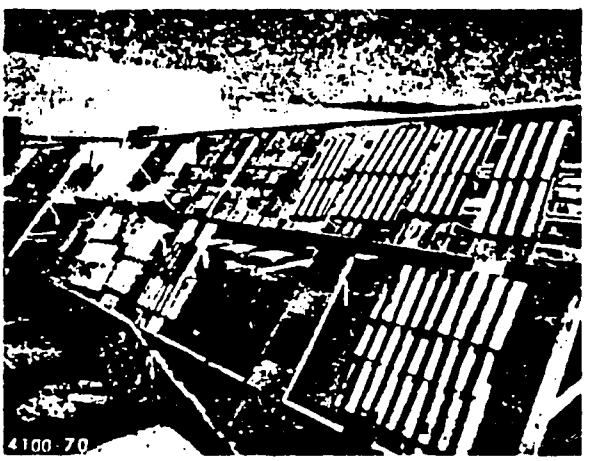
Paralleling the laboratory experimental work was an effort by the Advisory Committee and its coordinator concerning selection and analysis of criteria for roofing materials. This work was done using guidelines set up by MRC for the original material screening effort. The purpose of this study was to obtain Jamaican ideas on just what a roof should do, what it should look like, how much it should cost, etc. Interim reports dated 9 January and 16 February 1976 concerning this analysis are provided in Appendix E. The basic requirements for a roofing system in Jamaica, including both highly desirable and desirable characteristics, were examined. The judgements made were very similar to those reached by the MRC project team, indicating a strong relationship between acceptable performance and cost.

Contrasting with information previously derived in discussions, reports, etc. was the high desirability and acceptability of wooden shingles. It was judged that this did not actually contradict what had been found earlier, but instead reflected a desirability for better quality, higher cost housing. The association of the wood shingles with higher cost housing was indeed significant, especially when compared to the association of corrugated panel roofing with low cost housing.

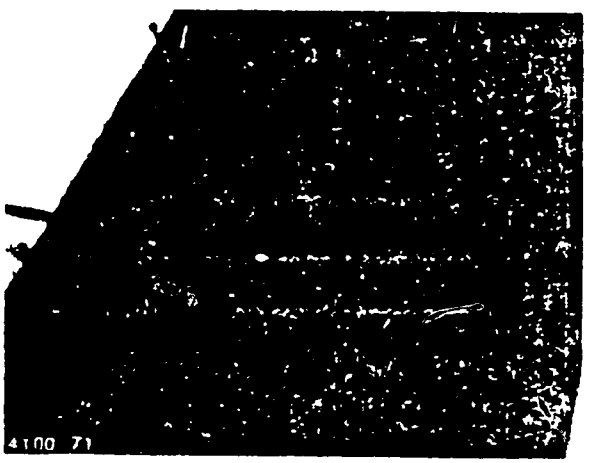
The basic requirements determined by the Advisory Committee were considered mandatory for any roofing product and were in complete accord with the basic criteria developed by the MRC project team in their original analysis.

A very significant part of the experimental work was the performance of outdoor exposure testing and analysis conducted on panels prepared by the MRC Dayton Laboratory and SRC. The exposure was conducted on paint exposure fences at Berger Paints, located adjacent to the demonstration housing site finally selected in Kingston. These fences were positioned to the south at 45° according to accepted ASTM procedures. Ken Espeut supervised the installation and monitoring of the test panels on the fences at Berger Paints, providing this service from very early in the program through its completion.

Analysis of the test panels consisted of periodic visual examination and recording of observed changes, as shown in Figure 46, on the panels with time under the climatic and environmental conditions of the Kingston seashore area. The results are reflected in the discussions in section 3.1 concerning the nature of the roofing products. The aging results were very good-to-excellent for all the materials exposed, including those eventually of less interest in Jamaica. These timely exposures provided an evaluation basis for the entire world-wide roofing development program.



(a) Dozens of test panels were placed on the Berger test fence during the program and will remain there to provide long-term information.



(b) Typical of exposed panels is the BRR panel marked 75-08B which was installed in August 1975 and is shown here in October 1977.

Berger Paints Ltd.
EXPOSURE RECORD

FINISH [illegible] EXPOSURE NO 75-08B
DATE APPLIED DATE EXPOSED 21 8 75
PLACE EXPOSED Jamaica Exposure Farm (Kingston) DATE COMPLETED
FORMULA REF NO 184140 - 1NR TOTAL TIME EXPOSED

INSPECTION DATE	CHECKING	CHALKING	GLOSS	COLOUR	BLISTERING	CORROSION	FUNGUS GROWTH	DIRT COLLECTION	DIRT RETENTION	REMARKS
21-8-75	NIL	NIL	97	[illegible]	NIL	NIL	NIL	NIL	[illegible]	[illegible]
[illegible]	NIL	[illegible]	FLAT	[illegible]	NIL	NIL	[illegible]	[illegible]	NIL	
[illegible]	NIL	[illegible]	FLAT	[illegible]	NIL	NIL	[illegible]	[illegible]	NIL	
28/6/76	NIL	[illegible]	FLAT	[illegible]	NIL	NIL	[illegible]	[illegible]	NIL	[illegible]
2-9-76	NIL	[illegible]	[illegible]	[illegible]	NIL	NIL	[illegible]	[illegible]	NIL	" "
8-2-77	NIL	[illegible]	FLAT	[illegible]	NIL	[illegible]	[illegible]	[illegible]	NIL	[illegible]
21-6-77	NIL	[illegible]	FLAT	[illegible]	NIL	[illegible]	[illegible]	[illegible]	FLAT	[illegible]

Bergerse Reinforced Rubber (BRR) specimen
No [illegible] placed

(c) Data for the typical BRR panel is shown as generated by Berger using paint exposure terms.

Figure 46. Outdoor exposure and analysis was performed at Berger Paints, Ltd., Kingston, starting in May 1975 and continuing throughout the program.

3.3.2.2 Roofing Demonstration - Manufacturing

A practical demonstration of the bagasse-reinforced phenolic roofing material was conducted. Only the resin binder, pigment, and stabilizer were imported. Otherwise, local materials, facilities, and manpower were used to manufacture roofing panels. 3400 square feet of flat roofing shingles were manufactured.

The details of the demonstration project plan, results, and future efforts are presented in three consecutive reports reproduced in Appendix F. The project plans are contained in the report dated 6 September 1976, and the changes in these plans, the results, modifications, and future plans are contained in the reports dated 12 November 1976 and 26 October 1977. The reports itemize point-by-point both what was to be done and who was to do it. The effort involved eleven different organizations and over 80 individuals. Figure 47 depicts the relationship among the organizations and the work done by each.

The demonstration program was tailored specifically to the local situation, taking advantage of a variety of facilities and expertise at different locations. The fact that all facilities were not available within one organization increased the need for coordination.

The raw materials for the project were made available by Standard Building Products and Monsanto Research Corporation. The bulk of the raw materials (63%), consisting of indigenous whole sugar cane bagasse, came from Standard Building Products storage, and originally came from a nearby sugar mill. The remaining materials (37%), consisting of phenolic powder, pigment and stabilizers, were imported from the United States by MRC under the AID contract.

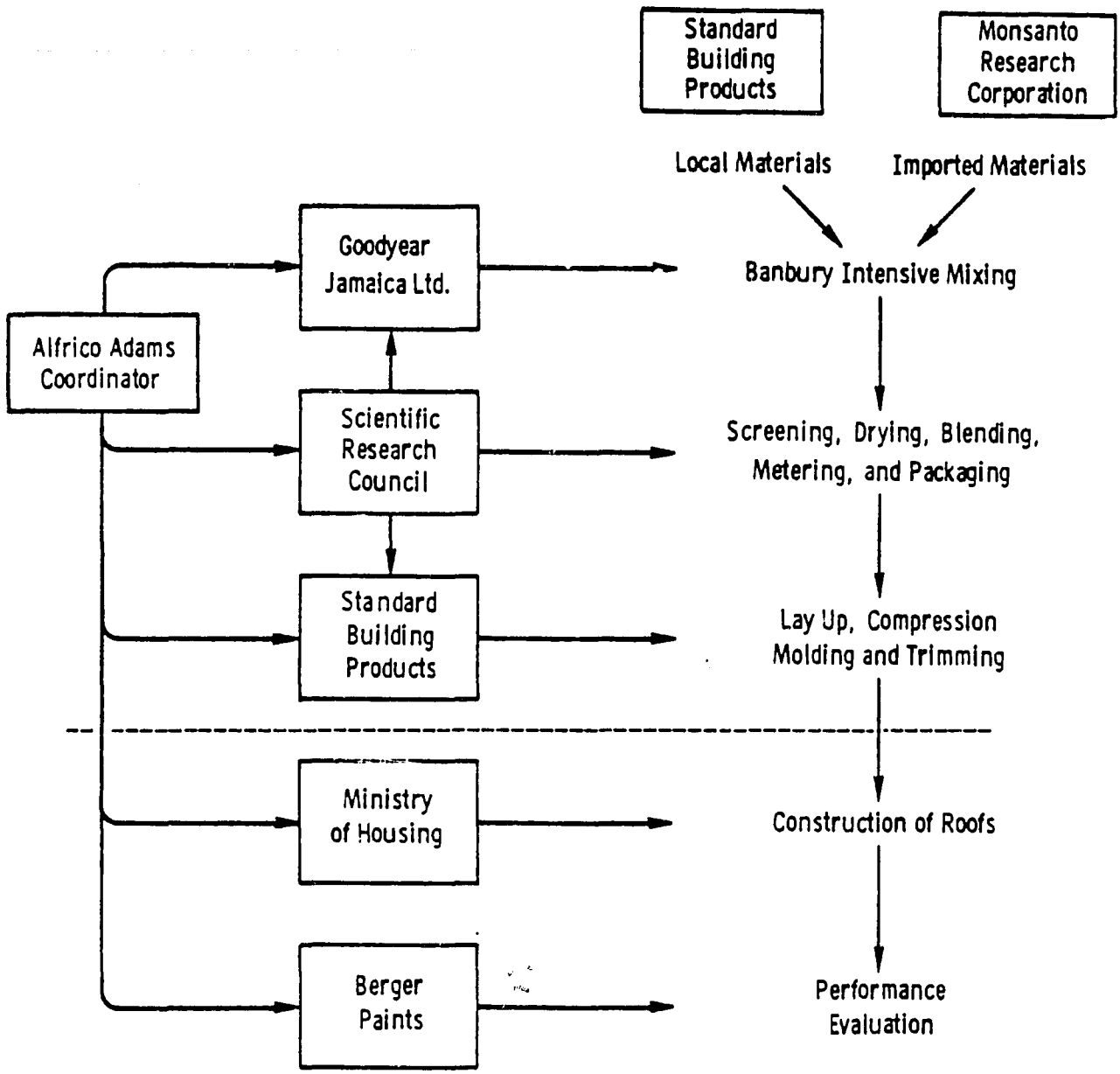


Figure 47. The Jamaica demonstration involved a number of organizations which cooperated to provide the needed expertise, manpower, and facilities.

The conversion of these raw materials into roofing was conducted at three sites (all within a 25-mile radius in the vicinity of Kingston). These three sites included the Goodyear Jamaica Ltd. Tire Manufacturing Plant in Morant Bay, The Scientific Research Council (SRC) pilot plant in Kingston and the Standard Building Products bagasse board plant in Spanish Town. A critical aspect of the coordination, which sometimes was more difficult than would have been expected, was the simple transportation of materials first to Goodyear, then from Goodyear to SRC, then from SRC to Standard Building Products and finally to the roofing site.

Banbury intensive mixing was conducted at the Goodyear Jamaica site in equipment normally used to compound the ingredients for rubber tires and belting. Required was one 8-hour shift involving an eight man crew plus supervisory and support technical personnel (a relatively large crew because of the experimental nature of the effort). The compounding was straightforward, being conducted by a skilled Banbury operator who required little or no supervision after the proper size batch was determined. The only modification to the equipment, as shown in Figure 48, was the insertion of a large plywood box and chute into which the product was dumped from the Banbury (normally the rubber from the Banbury goes on to a roll mill, which was not required for this process). The material was then scooped into plastic bags for transport.

One isolated problem occurred during optimization of the batch size. It was found that if too much bagasse were introduced into the Banbury at one time, the bagasse bridged in the neck of the Banbury causing it to plug. This phenomenon had never before or since been observed in any other experimental work and is not expected to create any future problems. Goodyear-Jamaica provided help that minimized the cost of this occurrence to the program.

(a) About 350 pounds of bagasse shown going into the Banbury were processed in each batch.

(b) The processed, oiled, pigmented bagasse was collected on a plywood box, the only modification to the equipment, and pulled from there into bags.

(c) The processed bagasse, considerably reduced in volume, was shipped in bags to the Scientific Research Council laboratories.

Figure 48. Compounding of tons of bagasse with oil, pigments, and stabilizer for the BRP material was conducted in a Banbury mixer at Goodyear-Jamaica, Morant Bay.

The proper amount of ingredients to make one panel (14 lb) was placed in a polyethylene bag. The material was blended by vigorously shaking the ingredients within the plastic bag by hand until a uniformly pink color was achieved. More efficient mixing facilities that were available, would have introduced undesirable contaminants. It was suggested, but not shown, that better mixing could be achieved in a large, slow-speed concrete mixer.

The final manufacturing stage for the roofing panels was conducted at Standard Building Products. It consisting of laying up the molding powder into 2.5 ft by 9 ft cavities, compression molding the layups, and trimming and cutting of the panels to ∿2 ft x 4 ft (0.1 in. thick) panels. Part of this work is illustrated in Figure 49.

The molds consisted of two pieces (3 ft x 10 ft) of 18 gauge aluminum, treated on the contacting side with a very thin film of Moldwiz EQ6 release agent. A temporary spacer for gauging the thickness of the molding powder onto the mold sheet consisted of a 0.25 inch thick 3.5 ft x 10 ft bagasse board into which had been cut a 2.5 ft x 9 ft cavity. This "picture frame" was laid on one of the treated aluminum plates, and one plastic bag (14 lb) of molding powder was dumped into the cavity and distributed uniformly within it using the edges of large spatulas. A final leveling was achieved using a 4 ft wide draftsman's straight edge to slightly pack the material into the cavity and to assure uniform distribution.

The layup process was one of the most tedious, but one of the most important aspects of the molding step. The molding powder has essentially no flow, thus it must be physically distributed and leveled within the mold before it is heated. In the compression molding step the temporary picture frame is removed

(a) At SRC the compound was screened to remove large unprocessed bagasse chunks, dried to remove moisture, mixed with phenolic powder and weighed and bagged into lots the size needed for one panel.

(b) The molding compound was cast onto a treated 3 ft x 10 ft aluminum caul sheet at SBP using a picture frame to gage thickness.

(c) A treated aluminum caul sheet was placed over the cast compound completing the mold.

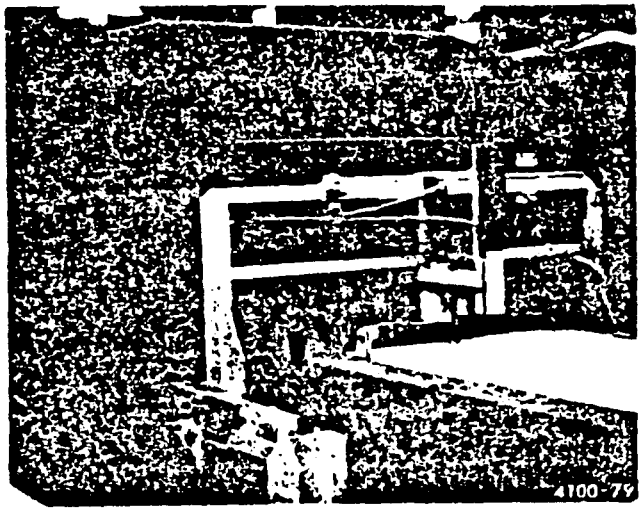
Figure 49. Further processing was conducted on the BRP compound at the Scientific Research Council (SRC) and then delivered to Standard Building Products (SBP), Spanish Town, for lay up and molding.

and the material is molded without edge constraints. The fact that the powder does not flow after distribution and removal of the frame actually simplifies the overall process.

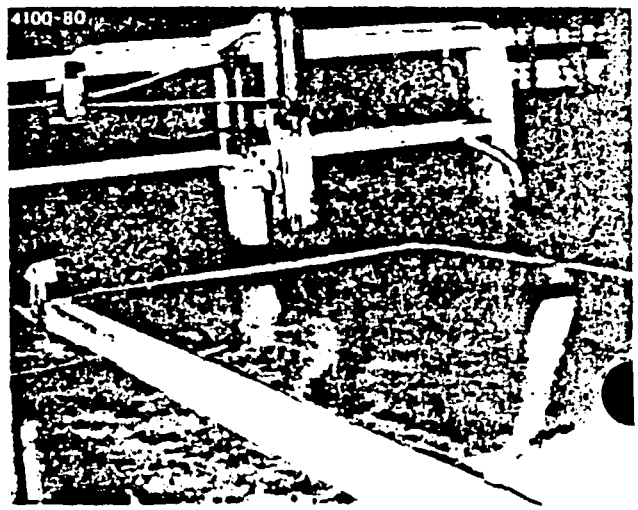
After removal of the temporary gauging frame, the second treated aluminum sheet is laid over the top of the molding powder. The edges of the top and bottom aluminum plates were taped together in spots. This prevented shifting of the aluminum plates and facilitated removal of the part (and the mold) with vacuum chucks (which existed as part of the compression molding equipment). The molding and finishing steps are illustrated in Figure 50.

The molding press was preheated to 275°F (135°C) and preset to close slowly (fast closing resulted in blowing away of some of the molding powder). The press was opened, the filled mold inserted, and pressure applied. The pressure was then released by opening the press to allow the expulsion of volatiles, and immediately reclosed (which took about 50 seconds). The pressure (~700 psi) was then reapplied and held for an additional 15 minutes (this time probably can be reduced to 5 minutes, but faster molding was not required since it took at least 15 minutes to prepare the next mold for insertion). At the end of the 15-minute period the press was opened and the mold and panel were removed as a package with vacuum chucks. The mold was then opened by cutting the tapes, and the sandwich was separated by lifting. No release problems were encountered as long as the release agent was properly used. The molded panels were then stacked on a flat surface and allowed to cool.

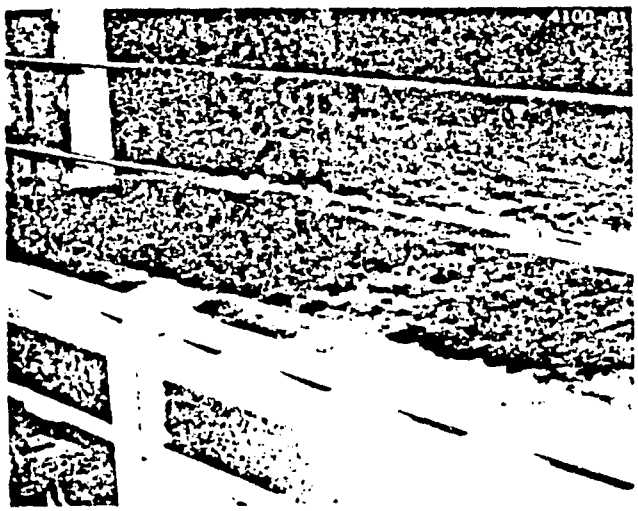
These panels, which were about 2.5 ft x 9 ft were then trimmed with circular saws into individual 26 in. x 52 in. panels and were stacked on pallets ready for shipment and use.



(a) A 5 ft x 10 ft heated hydraulic laminating press was used for molding.



(b) Inserted into the press were the two thin aluminum caul sheets containing the leveled compound.



(c) The caul sheets and panel were removed from the press with vacuum chucks and separated from each other simply by lifting apart.

Figure 50. Molding of thousands of square feet of 2.5 ft x 9 ft BRP panels was conducted in the laminating press at Standard Building Products.

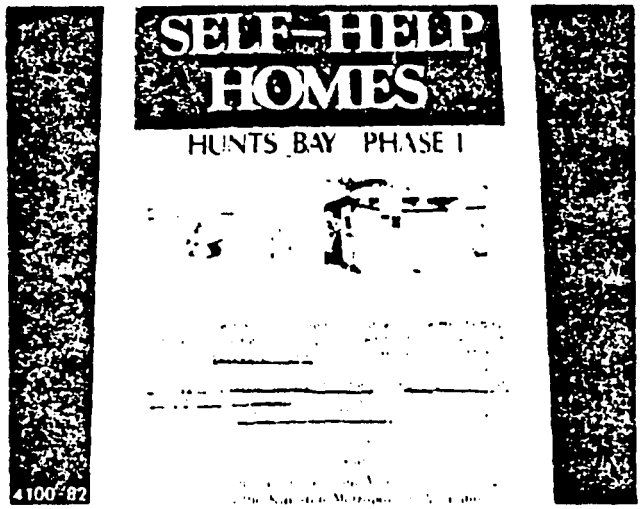
3.3.2.3 Roofing Demonstration - Construction

Eight BRP core roofs were installed at the Hunts Bay low cost housing project. The remaining BRP shingles are to be installed on a house to be constructed. The first roof was installed 11 November 1976. Flat ∿2 ft x 4 ft shingles were manufactured as an expedient substitute for larger corrugated panels. Performance of the roofing material during the first year exposure was good. Long-term performance of the roofing installation will be monitored by the Advisory Committee. A painted corrugated BOB roof was also installed at SRC in October 1977.

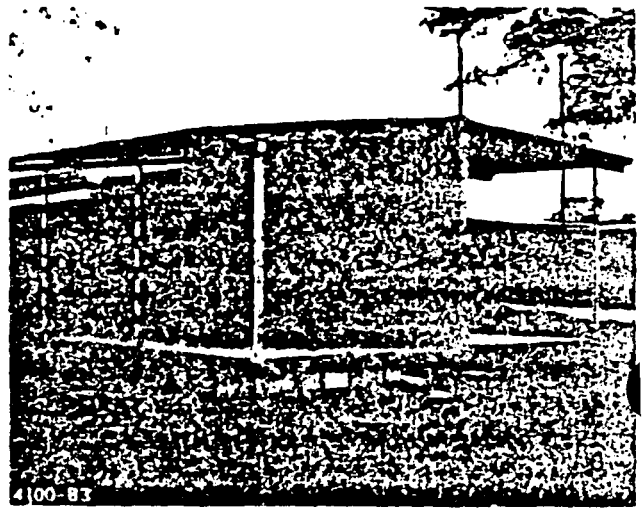
The houses to be roofed were selected by the Ministry of Housing and, in particular, a group involved with World Bank Site and Service Facilities. Houses at these sites are low-cost core and shelter expandable houses that provide an alternative to squatter housing. One complication of this type housing with respect to the program was that the roofing for the shelter is usually not provided, but is purchased and installed by the eventual home owner. However, roofing for the core (bathroom) is provided and installed as part of the basic housing unit that is sold as shown in Figure 51.

The particular housing units vary from duplexes to quadruplexes. For a demonstration effort the quadruplex was of particular value. The quadruplexes are joined together by the four cores at a common center. A roof is provided over these four core units which has an area of about 200 square feet and a double pitch from a center peak. These roofs were ideal from the standpoint of a demonstration since all aspects of roofing, that needed to be considered with respect to coverage, sealing, joining, etc. were present, but large amounts of roofing material did not need to be consumed.

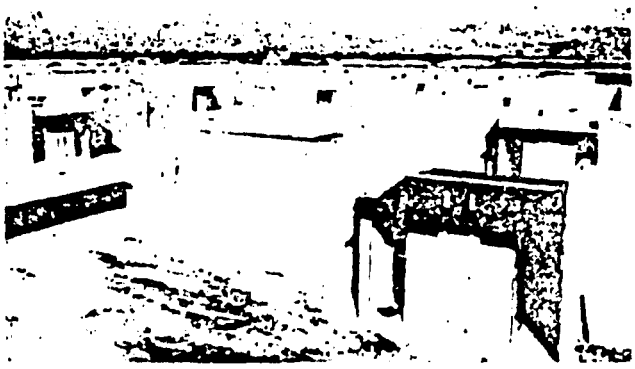
The roofs over these cores normally consist of corrugated aluminum nailed to 1 in. x 2 in. lathing spaced at 2-ft intervals. The pitch of the roof is 10°, easily accommodated



(a) The Hunts Bay homes fit into the category of low cost augmented by the efforts of the purchaser.



(b) Roofing of the corrugated aluminum type is only partially provided in the Hunts Bay homes and then just over the core bathroom area.



(c) The homes are quads joined at their bathroom cores which forms a single roof element of 200 sq ft used in the demonstration.

Figure 51. Some of the houses selected for roofing in Jamaica were of self-help type in the World Bank, Hunts Bay Site and Service project, Kingston.

by the continuous sheets of corrugated aluminum which are precut to the required length. Thus, no horizontal seams exist other than at the peak of the roof which is covered with an arched aluminum cap. Sealing of the corrugated sheet to the ridge cap is provided by scalloped foamed neoprene rubber that fits in between the ridge cap and the corrugated sheet and is compressed by the ridge cap when it is nailed. The vertical seams are sealed by a one or two corrugation overlap. The panels are nailed with flat-head aluminum roofing nails which sometimes contain a rubber washer seal.

Rather than introduce any redesign to the basic structure, which would have been desirable especially from the standpoint of increasing the pitch of the roof to at least 30°, the existing basic roofing substructure was utilized as is. The only addition was the incorporation of 1 in. x 2 in. lathing at one foot intervals (instead of 2 ft.) to accomodate the 26 in. long shingles (which would overlap approximately 55%.) Sketches were made of the desired roof starting with the Ministry of Housing Plans, but it was found that actual dimensions varied considerably from those in the plans. Therefore, the greatest value of the plans was in predicting the number of shingles required for a roof.

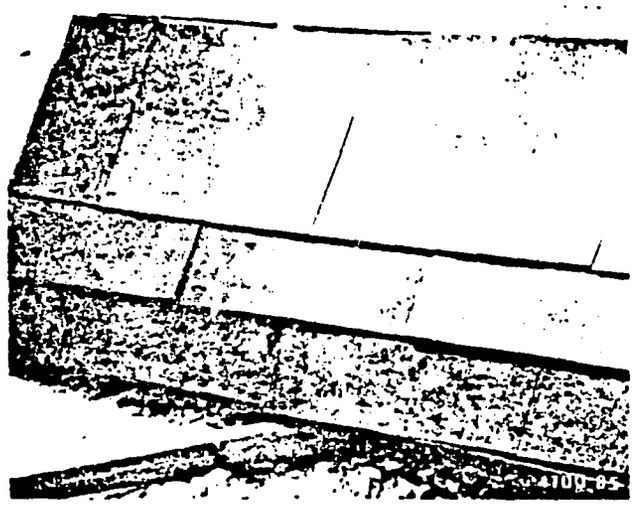
The roof was to be made up of 26 in. x 52 in. shingles with complete double overlap and no straight through paths at any seams. This was straightforward and typical of any large shingle-type roofing (typified in the United States by asphalt shingles). When laid up in this manner, the shingles were attached by two rows of nails, one along the top edge and the second slightly above the middle. Shingles laid up in this fashion would cover all nails so that none would then be visible. This was to provide a better appearance and reduce exposure to the nails, thus increasing their life.

The actual approach used in fabricating the roofs was simplified intentionally. It consisted of taking a stack of the panels, hiring a skilled carpenter, telling him that a 1 ft lath spacing was necessary, and finally telling him to go ahead and make a roof from the shingles. Support and assistance was given by the project coordinators and technical team, but basically the carpenter took the shingles and made a roof, shown in Figure 52.

The same carpenter had been used earlier to make a half scale model of a roof from the first manufactured panels primarily to determine nailability of the shingles, but also to disclose possibly undefined problems. Very importantly in this model construction it was shown that the shingles could be nailed with relatively large aluminum roofing nails, they could be cut with available hand saws, and they could also be trimmed with a pocket knife allowing intricate hand fitting.

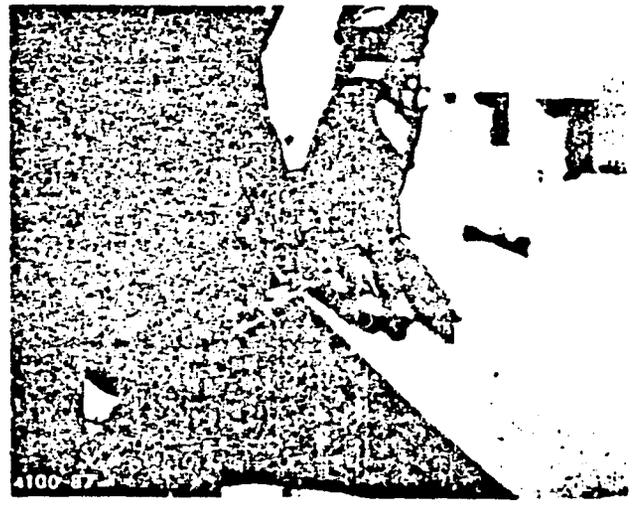
Roofs were fabricated as described above with the carpenter first laying down the 1 in. x 2 in. lathing on 1 ft spacing (with a half spacing to accommodate a half shingle at the bottom edge). Additionally, because the roofs were so flat, which could allow water to be blown up under the shingles, a commercial roofing sealant was used to seal the shingles together by applying a layer over both rows of nails and pressing down (the sealer was used only to accommodate the shingle type roof with its very low pitch). In any future application it is anticipated that either long corrugated panels would be used on a low pitch roof or shingles would be smaller in size and used on a roof with a pitch of at least 30°.

Fabrication of the roofs was straightforward; only one problem was observed. This problem was that the shingles were slightly warped. When nailed down with two rows of nails this was



(a) A mock up roof section was designed and put together by the carpenter using 12 in. x 24 in. shingles to determine in advance nailability.

(b) The shingles were nailed with one inch large head galvanized steel nails to the same lathing as used for the corrugated aluminum.



(c) The shingles could be trimmed with a knife or cut with a saw much like wood.

Figure 52. The BRP roofs were installed at Hunts Bay as 26 in. x 52 in. flat shingles by a skilled carpenter using only available tools and experience.

reflected in a bending up of the exposed portion of the shingles leaving a gap between shingles as observed from the edge of the roof. This warping was attributed to a non-uniformity in density across the thickness of the roofing panels. Accordingly, a third row of nails was added to the shingles at the bottom edges (unfortunately exposed) to bend these shingles back down. This was done to accommodate this specific demonstration that was primarily to evaluate the performance of the roofing material and not its design.

The first roof was fabricated 11 November and the other in December 1976. The remaining shingles were installed on a house selected by the Ministry of Housing in November 1977, as mentioned in Appendix F. The site was Davidson Crescent, Drewsland, Kingston.

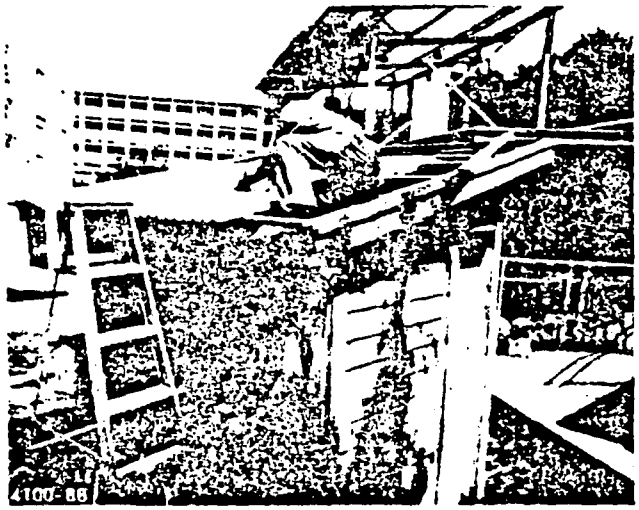
The management of Berger Paints has agreed to provide inspection and documentation of the long-term performance of the roofing. They are in an ideal position functionally and geographically to fulfill this commitment. First, they have an exposure fence which is examined periodically by skilled technicians who have the expertise required for the examination. Second, their laboratory site is only a few hundred yards away from the installed roofs. Thus, access is quite easy.

Berger has agreed to continue the exposure testing of the dozens of roofing test panels that are presently on their exposure fence (amounting to at least 100 square feet of exposed surface). Continued evaluation of these exposed coupons will provide at least a two-year lead time in projecting the performance of the materials on the Hunts Bay roofs, and also on the roofs constructed or to be constructed in the Philippines and Ghana. The more readily available access to these test coupons by either the MRC project team or AID representatives, because of

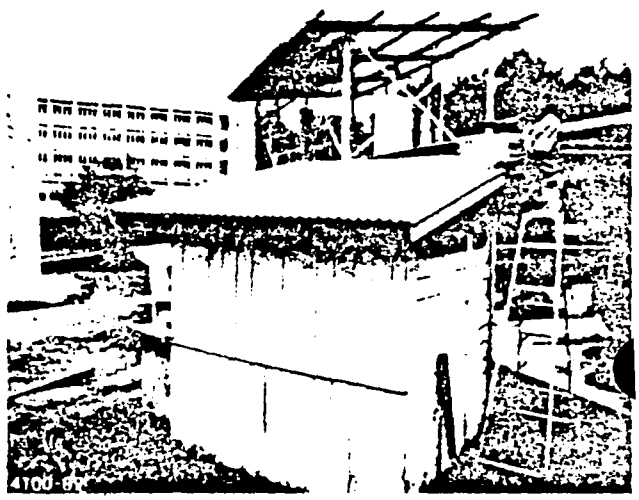
of their proximity to the United States, is also high advantageous since it allows for first-hand evaluation at various intervals.

The roofing advisory committee members had also agreed to continue in their role until all of the aspects of the roofing development were wrapped up. Accordingly, the advisory committee will continue to function and be appraised of the situation with respect to the performance of the various roofing materials as time goes on. When they are fully satisfied that the roofing is satisfactory with respect to all the necessary performance, cost, and availability criteria, they will then be in a position to recommend its appropriate usage. A more active participation by any of the committee members or technical working group will depend upon future funding either by the Jamaica government, industry, AID, or other international organizations.

A roof was also fabricated from painted corrugated 2.5 ft x 7 ft BOB panels. These panels were manufactured at the University of Washington pilot plant as discussed in Section 3.1.4. The roof site was at the SRC laboratory consisting of a storage building requiring a ~100 sq ft roof. The details of this construction are contained in the 26 October 1977 report in Appendix F. Generally, the installation went well with the only problem being the slightly greater than desired panel thickness. It is necessary to overlap 4 panels in a roof construction and these 4 layers ended up being relatively thick. An improved manufacturing process (and mold) will eliminate this problem. The installation and roof are shown in Figure 53. A discussion of the molds is contained in Appendix J.



(a) The corrugated panels were 2.5 ft x 7 ft and were installed like any other corrugated panel would be in Jamaica.



(b) The roof had an area of 100 sq ft and is located on a shed at the Scientific Research Council.

(c) Aluminum roofing nails and wood fillets for corrugated aluminum or cement asbestos sheets were used.

Figure 53. A roof was installed in Jamaica consisting of full-size painted corrugated BOB panels representing one of the lower cost approaches.

3.3.3 Ghana - Roofing

The facilities required for the manufacture of the bagasse-reinforced hard rubber (BRR) and bagasse-reinforced phenolic (BRP) roofing existed in Ghana with one major exception: high temperature steam to heat the molds properly for the BRR did not exist. Thus, BRR material was compounded and fabricated into flexible sheets, but adequately rigid roofing shingles could not be made. In spite of this shortcoming, the technology for manufacturing the BRR product was demonstrated by Ghana Rubber Products Ltd. In November 1977 a quantity of BRP roofing shingles were manufactured and a roof constructed in Accra.

The effort in Ghana consisted of three parts which are arbitrarily separated into the "experimental program," a "manufacturing demonstration," and a "construction demonstration". The experimental program led into the manufacturing demonstration, but the latter was broader in scope with respect to materials considered. Because of the very strong interest in the BRR system by a local industry, the other roofing systems were of lesser interest, except for providing supportive background into new types of materials and roofing (for instance, many of those involved did not know what bagasse was, or had never seen it or worked with it).

The experimental and demonstration efforts were greatly facilitated by the coordination of the requirements for roofing, defining of criteria, etc., by one agency, the Building and Roads Research Institute; and the manufacturing all being done by one organization at one location (Ghana Rubber Products Ltd.).

The experimental program encompassed the work done by the Advisory Committee, the Working Group and the MRC team in Ghana. The manufacturing demonstration included only the direct effort applicable to manufacture of roofing panels. The construction effort incorporated accumulated thoughts and commitments to install roofs from fabricated panels.

The work in Ghana followed that conducted in Jamaica and the Philippines and, in fact, was initiated a year and a half later than the other two. Consequently, lessons learned in Jamaica and the Philippines were able to be utilized to great advantage, significantly reducing the effort required in Ghana. At this later stage, the materials had been better developed and the poorer candidates were not even considered in Ghana.

3.3.3.1 Experimental Program

> The experimental program was designed to bring together the expertise in Ghana to define, manufacture, and evaluate a viable roofing alternative based on the work done by Monsanto Research Corporation in conjunction with a Ghana roofing advisory committee. The effort included experimental work, analysis of roofing criteria, and outdoor exposure studies and analysis as the basis for selecting candidate roofing sites. This ground work for performing a manufacturing demonstration at Ghana Rubber Products Ltd. was conducted by the Building and Roads Research Institute. The result was the basis for a roofing material manufacturing demonstration.

The director of the Building and Roads Research Institute (BRRI), Dr. J. W. S. de Graft-Johnson, agreed to make available manpower and facilities for conducting an experimental program to further a roofing product development in Ghana. Such an effort related directly to the interests and responsibilities of BRRI. Incidentals, materials or equipment requiring foreign exchange were to be supplied by AID contract funds, but any purchases that could be satisfied with local currency would be made available by BRRI.

BRRI assigned one man full time to the project, to be available through its completion (at least 24 months). Supporting personnel were also committed as required for the program. This included supervisory and technician personnel, and those individuals from within BRRI, the Council for Scientific Industrial

Research Institutes, and the University of Science and Technology knowledgeable in the areas of chemistry, construction materials, roofing, housing, architecture, and related socio-economic fields. The fact that all this expertise was committed, available from, and coordinated through the one institute was highly beneficial to overall coordination of the program effort.

The effort at BRRI consisted of conducting experiments in the laboratory and at local manufacturing facilities to duplicate, verify, and extend the experimental work done by the MRC Dayton Laboratories. At the time that the effort was initiated, three of the roofing systems seemed potentially appropriate for Ghana. These included the BRR, the BOB, and the BRP roofing systems. However, the potential for demonstrating all of these did not exist (especially the BOB) because of the lack of available local facilities.

The experimental program was a joint effort between the Building and Roads Research Institute, a roofing advisory committee made up primarily of individuals from BRRI, Ghana Rubber Products Ltd., and the AID-sponsored Monsanto Research Corporation project team. The overall coordination of the program in Ghana was handled by Dr. de Graft-Johnson. Mr. Kofi Obeng, the technical investigator for BRRI, was supervised by Mr. A. K. Chatterjee, Chief Research Officer for Materials. Some general coordination, especially with respect to outdoor exposure was provided by Mr. Okyere.

Support in the area of defining roof criteria and selection of houses was provided by Mr. John Neutsugah, Research Officer, Architectural Division and Mr. Afele, an architect involved in rural housing schemes. Dr. B. Biswas, Senior Associate Professor of the Department of Chemistry, UST, provided technical support,

especially with respect to resin binder chemistry. Strong technical support was provided by Mr. Phil Westray, General Manager and Mr. Jiri Subert, Technical Manager, both of Ghana Rubber Products Ltd. Supplies of bagasse were provided by Mr. Dim Van der Heeden, Managing Director of Ghana Sugar Estates Ltd. The MRC team coordinator in Ghana was Mr. George L. Ball III.

Experimental work was conducted on all three systems by BRRI using their facilities and those of Ghana Rubber Products Ltd. Although emphasis was to be placed on the BRR system, the lack of availability of laboratory-size equipment prevented small-scale work from being conducted. This, however, was no problem since pilot-scale manufacture could be conducted at Ghana Rubber Products. This is discussed under the "manufacturing demonstration" rather than at this point.

Interest also existed in the BRP system, and small panels were to be molded at BRRI from bagasse processed at Ghana Rubber Products just for this purpose. Laboratory work was also conducted on the BOB system with respect to refining bagasse fibers, adding liquid phenolic resins, and molding laboratory specimens. Orientation was omitted, however, since extractors could not be located.

The very significant difference in these roofing systems compared to usual construction materials handled by BRRI made experimental work difficult because the necessary lab equipment was not available. However, the experimental work conducted was highly effective in transferring the technology to the individuals involved by giving them a feel for the type systems being considered.

BRRI was able to provide outdoor exposure for candidate roofing test coupons made at MRC's Dayton Laboratory. The particular exposure at BRRI was probably the most practical of that conducted in any of the other three countries with respect to its relevance to a roofing situation as shown in Figure 2.

The outdoor exposure facility at BRRI was set up to evaluate materials of construction, rather than to test paints, as was usually the case elsewhere. Accordingly, the particular test rack for the roofing materials consisted of frames set at a 10° pitch which is more representative of roofing for low cost housing. Such a placement of panels puts emphasis on the moisture and humidity situation, since rain water is retained on these panels, clings to edges, and actually hangs from the bottom side. This provides very severe exposure which is not duplicated by panels set at a 45° angle (where water is normally drained away).

The fact that severe water and humidity exposure was introduced was reflected on composite control samples that deteriorated very rapidly and exhibited extreme mold growth (blackening) compared with similar samples set out on 45° racks. The better systems, including the BRR, BOB, BRT and BRP, all performed well. These outdoor exposures provided strong support for their recommended use, not only in Ghana, but in Jamaica and the Philippines as well. Exposure of these specimens will continue and, BRRI is to make inspections and record observations over at least the next ten years.

Presently there is no excess bagasse in Ghana, and although additional sugar mills are planned with the intent of making Ghana self-sufficient in sugar, it is projected that it will be at least 10 years before any excess bagasse will be available.

100% of the bagasse is now required to fire the sugar mills because of the inefficiency of existing equipment and imperfections in the scheduling of the cutting of the crop.

"Mini sugar mills" are being examined and probably have a good future. The bagasse from these mills is less attractive because of its much higher sugar content and its coarse structure because it is chopped to a much lesser degree. Additionally, smaller quantities of bagasse would be spread over a much larger geographical area adding handling and transportation costs. It would be preferable to burn this particular bagasse as fuel. Some fuel oil could be substituted for the bagasse in the sugar mill boilers. However, the existing boilers can only withstand a small amount of oil and the associated higher temperatures without malfunction or introducing maintenance problems.

An experimental effort was proposed, but has only been conducted in part, which calls for substituting hard wood residues or sawdust for all or a portion of the bagasse in the candidate roofing compositions. This effort has been outlined and the materials made available for the work to be conducted in a combined effort between BRRI and Ghana Rubber Products Ltd. The immediate future of the BRR roofing system in Ghana will depend upon the reliability of this system, which is projected as being good. One such experiment is shown in Figure 54 and discussed in Appendix G where mahogany wood shavings were substituted for half of the bagasse.

Parallel with the laboratory experimental work was an informational exchange with the rest of the technical working group. This kept those, who were to eventually be involved in the program, up to date on the materials development and the nature of the products to be manufactured. The work conducted was described in detail with the various participants, in meetings

(a) Mahogany wood shavings from a furniture factory are abundantly available.

(b) The Banbury processed product containing wood shavings was much finer and lacked good, long bagasse fibers desirable for tensile strength.

(c) Panels ranging from 0 to 50 percent of wood shavings in place of the bagasse were examined.

Figure 54. Locally available mahogany wood shavings were substituted for a portion of the bagasse in a BRP formulation at Ghana Rubber Products, Accra.

with both groups and individuals. At the same time, assistance in selecting the criteria for roofing was solicited.

The acceptable criteria for roofs was found to fit very closely to that originally learned by the MRC project team, but additional emphasis was given to the need for fire resistance. It was pointed out that the utilization of wood in Ghana had been confined due to an inordinate fear of fire. Roofing materials thus must have a reasonably high degree of fire resistance. The dilemma of roofing costs was also pointed out with respect to the designated official price not really being representative. It is usually impossible to get CGI sheets at those prices. The actual cost of CGI sheeting ranged from two to three times the official price, due in part to the difference in valuation of local money with respect to world markets.

3.3.3.2 Roofing Demonstration - Manufacturing

Practical demonstrations of the manufacture of both the bagasse-reinforced hard rubber and bagasse-reinforced phenolic roofing materials were conducted wherein only the oils, pigments, stabilizers and additives were imported. Otherwise, local materials including bagasse and natural rubber, facilities and manpower were used to manufacture the roofing compound. About 300 pounds of BRR roofing compound were manufactured, but could not be converted to rigid shingles because of the lack of availability of molding presses that could achieve high enough temperatures. About 300 sq ft of the BRP roofing in the form of 10 in. x 20 in. shingles were manufactured in November 1977.

Details of the demonstration project plan, results, and suggested future work are represented in three reports reproduced in Appendix G. The project plans are contained in the report dated 12 August 1976, and the changes in these plans, results, modifications and recommended future work are contained in the reports dated 25 October 1976 and 11 November 1977. The reports attempted to itemize point-by-point both what was done and who

was to do it, along with contingent plans to be utilized, depending on the interim results. The effort involved basically five different organizations and at least 30 individuals.

The demonstration program was tailored specifically to the local situation, taking advantage of the comprehensive facilities at Ghana Rubber Products Ltd. and support from BRRI. Additional interface included only that from the MRC project team and the various materials suppliers and their intermediaries. This minimal number of involved organizations no doubt simplified the effort in Ghana. Because of the relatively poor communications network to and within Ghana, a more complex program could have been managed only with great difficulty.

The raw materials for the BRR project were made available by Ghana Rubber Products Ltd., Ghana Sugar Estates Ltd., and Monsanto Research Corporation. The bulk of the raw materials (84%) were made available locally. These consisted of the indigenous whole sugar cane bagasse from Ghana Sugar Estates (54%) and the natural rubber, sulfur, sulfuric acid, zinc oxide, and iron oxide pigment (30%) from Ghana Rubber Products Ltd. The remaining materials (16%) consisting of chlorinated paraffin oil, magnesium oxide pigment, stabilizers, accelerator, and fire retardants were imported from the United States by MRC under the AID contract. Reiss and Company, Accra, provided valuable assistance in facilitating importation at no cost to the program.

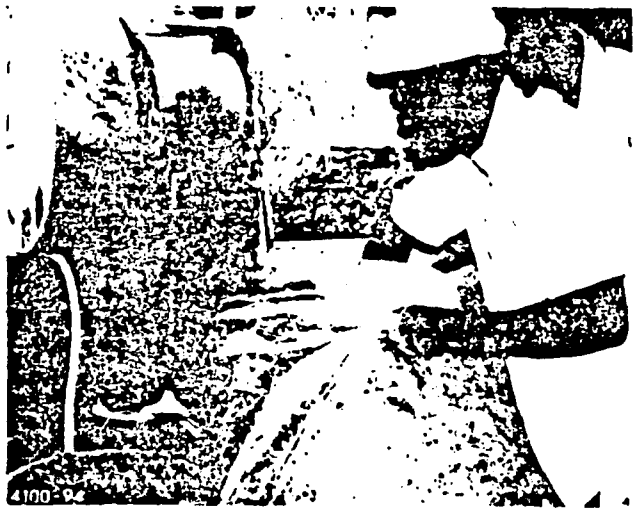
The conversion of the raw materials into a BRR roofing compound was conducted at one primary site. The drying operation was done in a plant down the street from the site. The primary site was the Ghana Rubber Products Ltd. plant in the industrial area of the capital and seaport city of Accra.

The bagasse was first dried within burlap sacks (sugar bags) in a wood kiln located in a plant near Ghana Rubber Products. Drying required two days because the bagasse was contained within the bags and because of the relatively poor drying efficiency of the kiln. After drying, the bagasse was transferred into plastic polyethylene bags to prevent moisture pickup, and was transported and stored in this manner at Ghana Rubber Products.

Banbury intensive mixing was conducted in equipment shown in Figure 55, normally used to compound the ingredients for rubber products, primarily shoes and shoe soles. Four-hour segments of time were made available for compounding all of the ingredients together into a compound that could be further processed. Usually a six-man crew plus supervisory and support technical personnel were utilized.

The BRR compounding was straightforward, being conducted by a skilled Banbury operator who required little supervision except guidance on the proper order of addition of the various ingredients and the processing time. No modification to existing equipment was required. The Banbury accommodated about 90 pounds of material which, after it was processed, was dumped as a block onto the floor (the usual operating procedure).

It was found that all the ingredients could be added in this particular size Banbury, including the accelerator and sulfur, since temperatures high enough to set off curing of the system were not generated during the processing. The accelerator was added about two minutes before dropping the material and the sulfur about one minute before dropping to insure that no curing (crosslinking) took place within the Banbury. No problems were encountered in this process stage. It was a direct scale up of the laboratory process.



(a) The intensive mixer had a capacity of 90 pounds of product, over half of which was bagasse, here shown being introduced into the throat.

(b) Rubber in the form of smoked sheet from Ghana was introduced into the Banbury after the bagasse.

(c) The compounded product from the Banbury is in the form of a large, hot chunk.

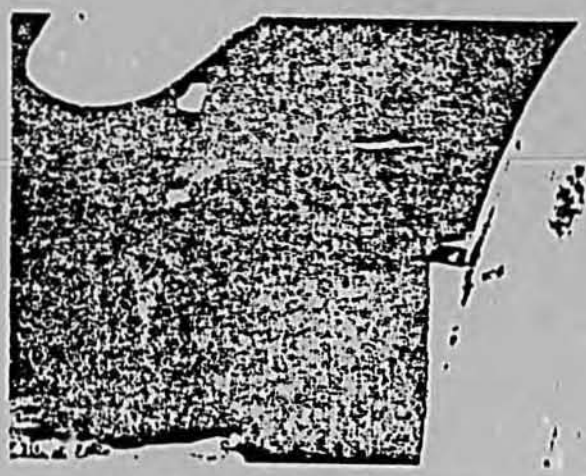
Figure 55. The BRR material was compounded at Ghana Rubber Products in a Banbury intensive mixer normally used to compound ingredients for rubber products such as shoes.

The large blocks of compounded bagasse-filled rubber were cut into smaller pieces (approximately 20 pounds each) using a standard rubber guillotine. The smaller chunks of compound were then fed to a two-roll mill (though which cooling water was continuously circulating) which further densified it and generated a thick (1/4 to 1/2 in.) sheet. There was a slight amount of difficulty at this stage, which had been expected due to the high filler loading of the rubber. This was reflected in a slightly longer time required to band the compound onto the mill roll. The adhesion to the mill rolls was poorer than that usually encountered with rubber compounds. This was a relatively minor point which was easily accommodated by the plant workers who were skilled in correcting for such deviations.

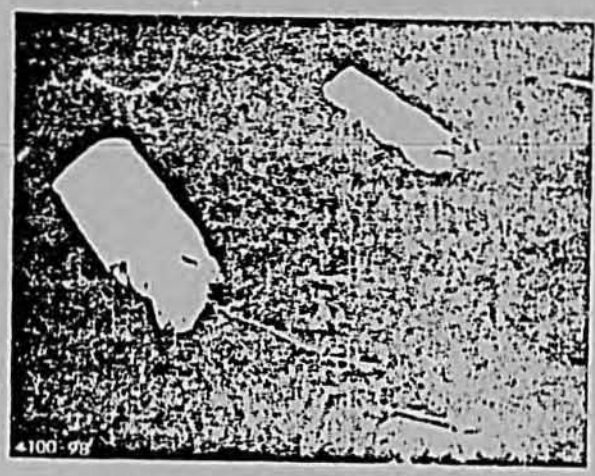
The next process stage further refined the compound from a relatively coarse, thick sheet to a uniform sheet with a thickness slightly greater than that finally desired. This was achieved by calendering on a two roll mill and batching off sheets about 26 in. wide, 5 ft long, and about 1/8 in. thick. This was the simplest form of a calender (two rolls), but was adequate for the job and was a part of routine processing. Again, no changes in standard operating procedures or equipment were required. These operations are shown in Figure 56.

Following the calendering, the large sheets were laid on a wooden table and a metal "picture frame" with a cavity was used as a guide to trim out 24 in. x 24 in. pieces for insertion into a mold. Brass knives were used for cutting the rubber compound sheets to size.

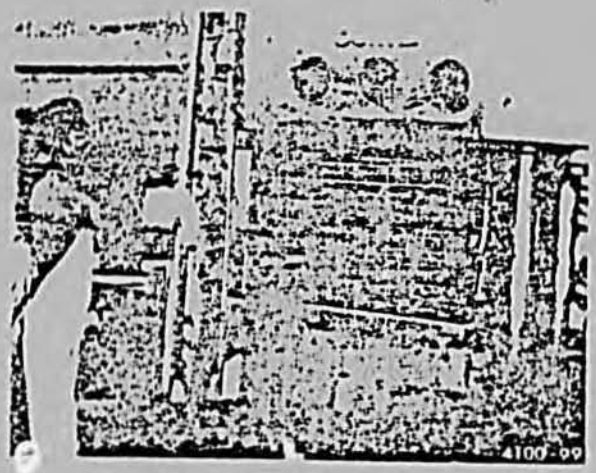
The control finally used to determine the desirable thickness for this sheet was its weight. It was assumed that the material to be inserted into the mold should equal the



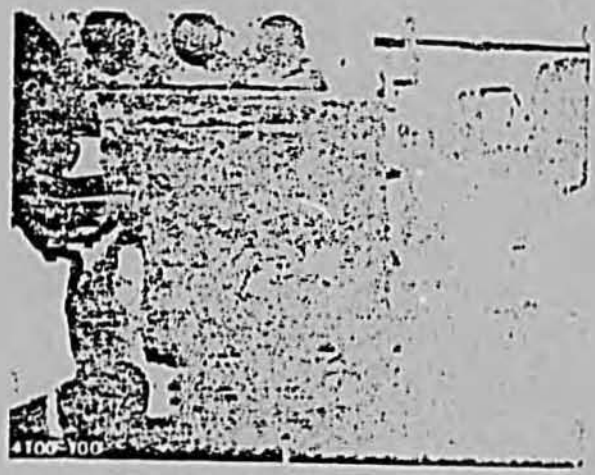
(a) The large chunk of compounded material from the Banbury was converted to a sheet on a two mill roll.



(b) A piece of the sheet approximately 0.13 in. thick was cut to 24 in. x 24 in. and placed between steel caul plates for molding.



(c) The material in the mold was heated under pressure to densify the part and cure the rubber to a rigid state.



(d) The molded panel was removed hot from the press and popped from the mold.

Figure 56. Calendering and molding of BRR material was conducted at Ghana Rubber Products on existing manufacturing facilities.

Best Available Document

weight of the final panel plus 10%. These square flexible sheets were preforms for the molding operation.

The final stage of the BRR process was compression molding. In this stage the intent was to convert the slightly thick flexible rubber sheet into a rigid dense flat roofing shingle. This required only the application of pressure and temperature for a given period of time within a proper mold.

The 24 in. x 24 in. dimensions of the shingle were determined by the limitations of the available molding presses (rounded to English units). Molds for this size part were not available at Ghana Rubber Products, so five were made at their expense. Fortunately, this rubber compound was tailored to be usable in very simple molds, which reduced their cost and made them more readily available. The molds consisted of about 1/16 in. thick steel plates (two pieces) and a 0.10 in. thick steel picture frame with a 24 in. x 24 in. square cavity cut into it.

The molding was conducted in a five daylight (opening), horizontal platen, steam-heated press, with a hydraulic pressure application system. It was in a building with about six other similar presses. They are used on a 24 hour basis in the manufacturing plant.

The molding process consisted of the following steps. First the mold surfaces were sprayed with a release agent (silicone or stearate) that was available in spray guns at each molding press. The rubber sheet was then sandwiched between the two metal plates with the picture frame around its perimeter (mainly to gauge thickness rather than to confine the material at the edges).

The press was preheated (remaining hot all the time) to as high a temperature as could be achieved, which was about 300°F. The press was then opened and the five molds with the materials in them were inserted in the five cavities of the press. The press was then closed and a pressure of about 500 psi applied immediately. The press was held closed for 45 minutes, opened, the molds with their parts in them removed from the press, the molds opened, the parts taken out, and the cycle started over again by refilling the molds (recoating with release agent about once every three moldings).

After extensive adjustment of the steam boiler system during the duration of the demonstration effort and afterwards by maintenance personnel and outside service people, it was found that temperatures of no greater than 300°F could be achieved with the existing plant system. Molding temperatures are very critical with the BRR system and below 325°F longer times cannot make up for lower temperatures. Molding at these lower temperatures produced only semi-rigid panels which were not deemed adequate for the roofing demonstration. They may have some utility in the future, especially if some sort of corrugated pattern is used.

The possibility that there was something wrong with the ingredients was thoroughly eliminated when small quantities of the roofing composition were molded in an electrically heated laboratory press. Four inch thick discs were manufactured. This particular point is very important, since it illustrates that all of the necessary technology for manufacturing this roofing product was made available at Ghana Rubber Products. Thus, roofing can be manufactured with the BRR system at any time that temperatures of at least 325°F can be provided to the molds.

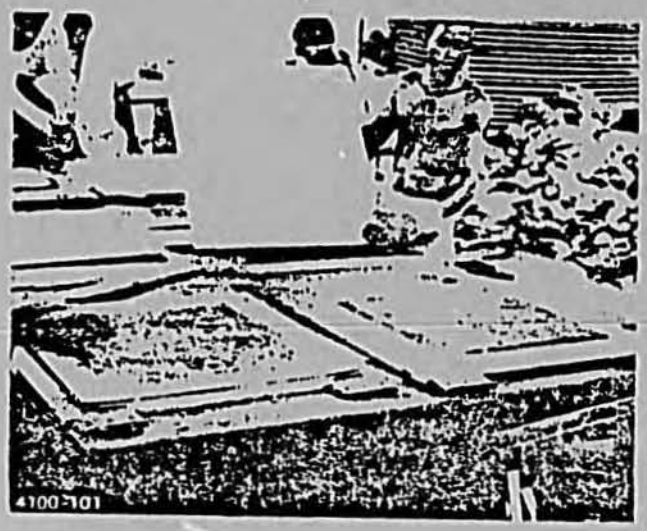
Unfortunately, this shortcoming terminated any further demonstration of this system with respect to making usable rigid roofing shingles that could be used in a roofing demonstration. Ghana Rubber Products, however, has an intense interest in moving ahead with this product and therefore are purchasing a new boiler which should be installed and in operation early in 1978. This is a very sizable commitment which helps to assure their continued interest. Achieving the higher temperatures of the new boiler is of little value elsewhere in their plant.

A manufacturing demonstration of BRP roofing shingles was also conducted in Ghana, although late in the program (November 1977). The details of this plant run are given in a trip report 11 November 1977, in Appendix G. Included in the demonstration was the manufacture of 20 in. x 20 in. BRP panels that contained a filler consisting of 75% bagasse and 25% mahogony wood shavings. The manufacturing went like clock work using methods identical to those described for Jamaica. The only differences were the incorporation of the wood residues, the smaller panel size, and the reduction in cure time to 1.5 minutes. Over 300 sq ft of 10 in. x 20 in. roofing shingles were manufactured at Ghana Rubber Products Ltd., Accra. The process details are illustrated in Figures 10 and 57, and the molded untrimmed panels in Figure 11.

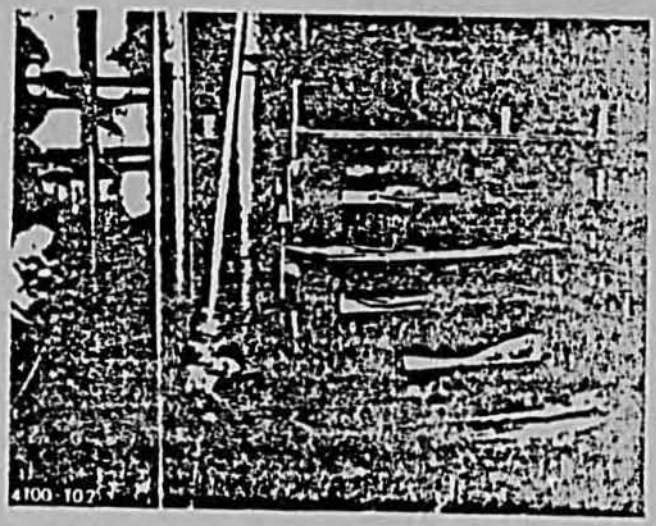
3.3.3.3 Roofing Demonstration - Construction

One roof of ~100 sq ft was installed using 10 in. x 20 in. BRP shingles at the C.S.I.R. Secretariet in Accra. No BRR roofs were actually fabricated since shingles could not be manufactured. However, plans were developed for fabricating BRR roofs by BRRI utilizing a low cost rural housing scheme. It is hoped that BRR roofs will actually be constructed in 1978 based on these plans using shingles to be manufactured by Ghana Rubber Products. Long-term performance of the roofing installations will be monitored by the Building and Roads Research Institute.

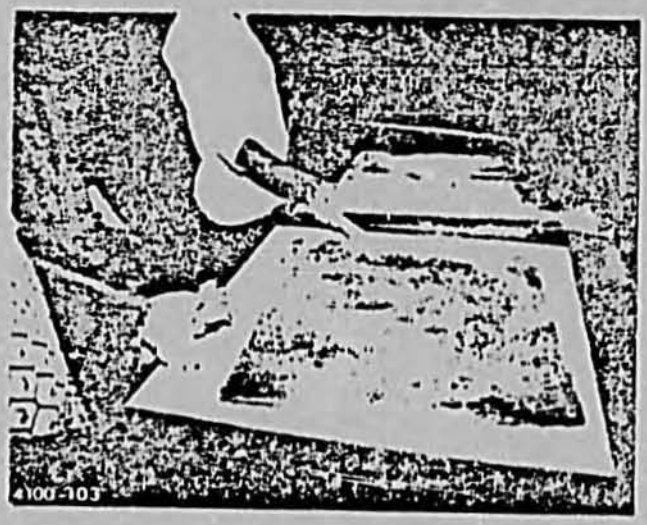
The houses to be roofed were selected by the Building and Roads Research Institute (BRRI) and were to be compatible with their



(a) BRP molding compound was cast on to treated aluminum cauls using a plywood spacer to gage thickness.



(b) Two panels were molded simultaneously on a 1.5 minute cycle in a five-opening hydraulic press maintained at 280°F.



(c) 21 in. x 21 in. x 0.1 in. panels were removed from the mold hot, left to cool and then cut with a circular saw into 10 in. x 20 in. shingles.

Figure 57. BRP shingles were manufactured at Ghana Rubber Products using a small assembly line operation and the same facilities used to make the BRR panels.

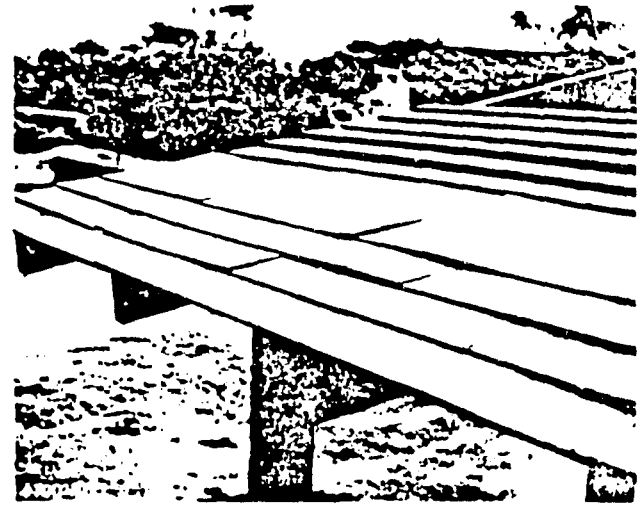
planning with respect to low cost housing, especially in rural areas. It was expected that roofing useful for housing based on BRRI's brick and wood utilization program would be considered.

The building to be covered with the BRP shingles was selected for its appropriate type and size (with respect to available shingles), location (with respect to control by BRRI), and availability. It was a security house under construction at the C.S.I.R. Secretariet in Accra. The roof was designed to have a relatively high pitch (1 ft in 4 ft) which could accomodate a shingle type system. The building had a floor area of 60 sq ft and thus required ~100 sq ft of roof area. The C.S.I.R. location put it under the control of BRRI so that it could be monitored in the future and be viewed easily by interested outside parties. It was under construction in November 1977 when the BRP shingles were made available.

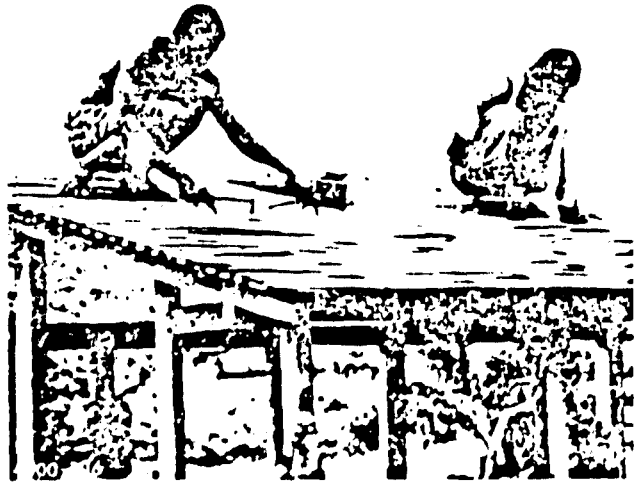
The roof consisted of 10 in. x 20 in. BRP shingles nailed to 1/2 in. x 2 in. purlins spaced at 3.5 in. centers (more closely spaced than necessary to improve appearance). These purlins were attached to 2 in. x 4 in. rafters. An overhang of at least 1.5 ft was provided on all sides. Construction of the roof is shown in Figure 58, and the completed roof in Figure 4.

The plans for defining additional houses and detailing their construction are presented in the 25 October 1976 report in Appendix G. The housing scheme is a rural one being developed at BRRI through Mr. Afele. Various type houses and housing arrangements are being considered in this housing scheme. Some have been tried, with various degrees of success, and further work is being restructured to remedy initial objections.

(a) Purlins consisted of lathing nailed on 3.5 in. centers to form a strong, wind-resistant roof.



(b) The exposed portion of the shingles was only 3.5 x 20 in. to help achieve a rustic appearance.



(c) The singles were nailed with 1 in. flat head galvanized nails and were cut with hand saws for proper fit.

Figure 58. Construction of the BRP roof was performed at the C.S.I.R. Secretariat in Accra by their carpenters using available tools.

It appeared during discussions on the rural housing scheme that materials of construction presented no real problems, except the use of more indigenous materials was highly desired, especially with respect to roofing. The main problems hinged on social aspects, which were related to economics. For example, cost-saving designs that introduced social changes, such as shared kitchens and outdoor and indoor living areas, were meeting with some opposition. The problem seemed to be compounded in the rural situation where the average family size was about 14 persons. Thus sharing space, where more than one family was involved, required accommodating relatively intimate interactions between upwards of 20 to 30 people.

The relationship of this roofing development program towards assisting and solving some of the social problems hinged on making available lower cost materials so that some form of separate housing could be considered for each family unit. It was then up to BRRI personnel to plan for the best utilization of these materials. Unfortunately, it is probably unrealistic to think that such a major reduction in roofing costs could be achieved with the proposed roofing system to accommodate this intent entirely. However, the cost benefits (especially as related to Ghana government support and a reduced requirement for foreign exchange) were expected to increase their latitude in designing specific houses or housing schemes.

It is anticipated that a roofing demonstration using the BRR system will take place in 1978 through the efforts of Ghana Rubber Products and BRRI. It is recommended that the primary intent of the demonstration be to make materials, fabricate roofs from them, and initiate a test for their durability under Ghana climatic, environmental and socio-economic conditions.

Then, while further developmental efforts with respect to roofing design and defining of the desired type houses are conducted, evidence will be gathered to demonstrate that indeed the materials system is viable.

BRRI has agreed to provide a complete evaluation of the roofing by observing it and performing tests as necessary over the ensuing years. They will then have the necessary information available for consideration of this material system, along with others that are presently being considered in their Institute, with respect to aspects of construction.

3.3.4 Philippines - Non-roofing Construction Material Applications

The availability of facilities and a very strong interest in the Philippines provided a unique opportunity to evaluate the bagasse-reinforced phenolic (BRP) material for construction applications other than roofing. The BRP system is highly tailorable in this respect, which was demonstrated in the Philippines, providing the materials for the construction of total houses from these material systems.

The bagasse-reinforced phenolic (BRP) dry-blend system for fabricating 4 ft x 16 ft panels was intensively studied in the Philippines by National Housing Corporation personnel. The details of these studies are contained in Appendix H.

The BRP system was examined at various levels of resin content (from 5 to 30%) to achieve the lower cost panels necessary for non-roofing applications, such as wall panels, ceiling panels, etc. Such lowering of resin content would compromise water resistance somewhat, but this was not expected to be a problem for interior applications.

Five tons of bagasse in various forms (whole, cut, wet-depithed, coarse and fine) were processed in the Banbury mixer at Goodyear Rubber Company with the necessary oils and pigments. These five types of refined bagasse were transported to the National Housing Corporation where they were dry-blended in a cement mixer with a powdered or liquid phenolic resin and molded into 4 ft x 16 ft panels.

Simultaneously, a comparable quantity of whole bagasse was cut and screened in standard National Housing Corporation particle board plant processing equipment to determine whether this type of refined bagasse could be used in the BRP process. This

equipment would eliminate the need for a Banbury and allow all processing to be conducted at the National Housing Corporation facility.

The practical and economically feasible range of powdered phenolic resin binder was established to be 5 to 30% by weight. The higher resin contents are required for the roofing application; progressively less could be used for exterior siding, interior wall panels, etc.

The possibility existed of developing even lower density materials based on the BRP system. These very low resin content materials could be used where their acoustical or thermal insulation characteristics are of value. The inherently good fire resistance qualities of the phenolic-bonded bagasse make it attractive for these applications.

Three phenolic resins were examined, including one of a liquid type. These included the imported Monsanto Company resin, Resinox 736; a locally manufactured phenolic powder, Borden MC-282; and a liquid plywood glue, Borden HL-4645. The use of the liquid phenolic resin was of particular importance, since it would permit the existing National Housing Corporation chip board plant equipment to be used with minimum modification. The liquid resins are also much cheaper. The liquid phenolic resins were anticipated as being useful in these slightly lower density, non-roofing applications.

The extension of the bagasse-reinforced phenolic with ground up wood chips was examined. The starting point was a BRP system with 40% dry phenolic powder. Compositions were made incorporating either coarse or fine wood chips at levels of 25, 50 or 75%. The optimum ratio of bagasse to wood chips in the composite

panel was tentatively established at a level of 50% fine wood chips to 50% bagasse, although this point is still being investigated.

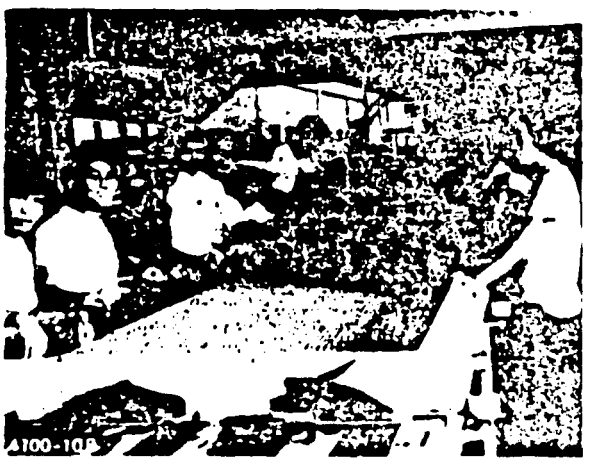
Curing cycles were also examined to establish minimum curing times and temperatures. Good cures were achieved in 6 to 10-minute cycles at 260°F and even at 3 minutes at 300°F, in small-scale tests.

The physical properties of the products, including density, modulus of rupture, water absorption, and swelling of the products were determined on all of the products; these data are provided in Appendix H. The densities were greater than 1 g/cc over the entire range of resin concentrations from 7.5 to 30%. Modulus of rupture (strength) values were high at all resin levels. For example, at 10% resin concentration, strengths up to 6500 psi (460 kg/cm^2) were obtained. Moisture contents and percent swell were also low for all samples, averaging about 5%.

Panels from 1/8 in. to 1/2 in. thick, shown in Figure 59, were molded in the same facilities used to make the roofing panels discussed in section 3.3.1. The process was identical except for the blending in of additional wood chips. One problem that was encountered was difficult release of the molded boards from the aluminum caul plates. In a few instances sticking was severe, due in part to the roughness of the aluminum caul plates. Better surface finish and controlled application of the mold release can assuredly solve this problem (as was demonstrated in Jamaica).

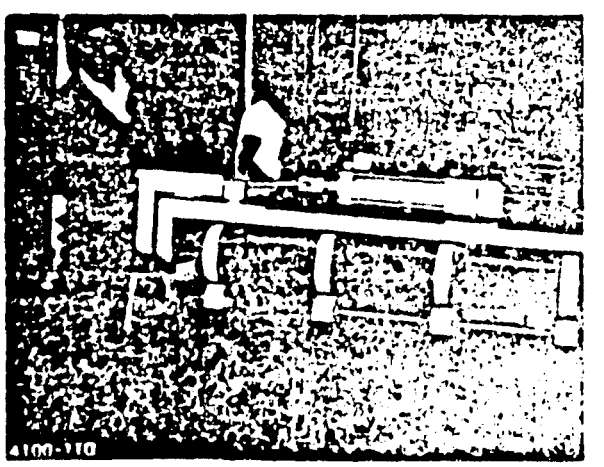
It appeared that an economically viable process for manufacturing building panels, based on wood chip-extended, bagasse-reinforced phenolic composites had been demonstrated. This was judged

(a) The processed bagasse was blended with the phenolic resin and wood chips in a concrete mixer to achieve uniformity.



(b) The compound was cast into pans ideally suited for its dry nature and leveled with combs.

(c) The cast molding compound on a caul sheet, with the pan removed, was covered and inserted into a molding press to be densified and rigidized.



(d) Molded panels were removed from the press and trimmed to size with saws.

Figure 59. Four ft x 16 ft panels of wood chip extended BFP material were manufactured in the National Housing Corporation particle board plant in thicknesses from 1/8 to 1/2 inch.

from the physical properties and the anticipated material manufacturing costs. These materials can be manufactured on a continuous production basis, with only very minor modifications to the National Housing Corporation particle board plant. Thus, materials for other parts of a house, not just roofs, can be developed around the BRP system demonstrated in this program. Fabrication of one or more model houses from these materials is scheduled, as illustrated in Figure 60.

Several general conclusions can be stated, based on the results of the demonstration of the BRP system for non-roofing applications. First, the most useful form or type of bagasse appears to be whole bagasse which is dried and cut, without separation, in the NHC particle board plant chopping and refining equipment. Thus, it appeared that a Banbury would not be required.

Second, minimum and useful ranges of resin binder content were established for several anticipated applications. Extending the BRP system with wood chip fillers was investigated, and optimum ranges of compositions are being established. The phenolic-bonded bagasse acts as a continuous phase surrounding the wood chip particles in this particular system.

Third, physical properties of the products, including density, modulus of rupture, moisture uptake, and swelling in water have been shown to be very good, compared to urea/formaldehyde-bonded wood chip particle board.

Finally, the anticipated low raw material and manufacturing costs of the bagasse-reinforced phenolic composite material make it suitable for a wide range of applications. The use of the phenolic (phenol/formaldehyde) resins was successfully introduced to NHC personnel, effecting the technology transfer in the processing and curing of these resins.

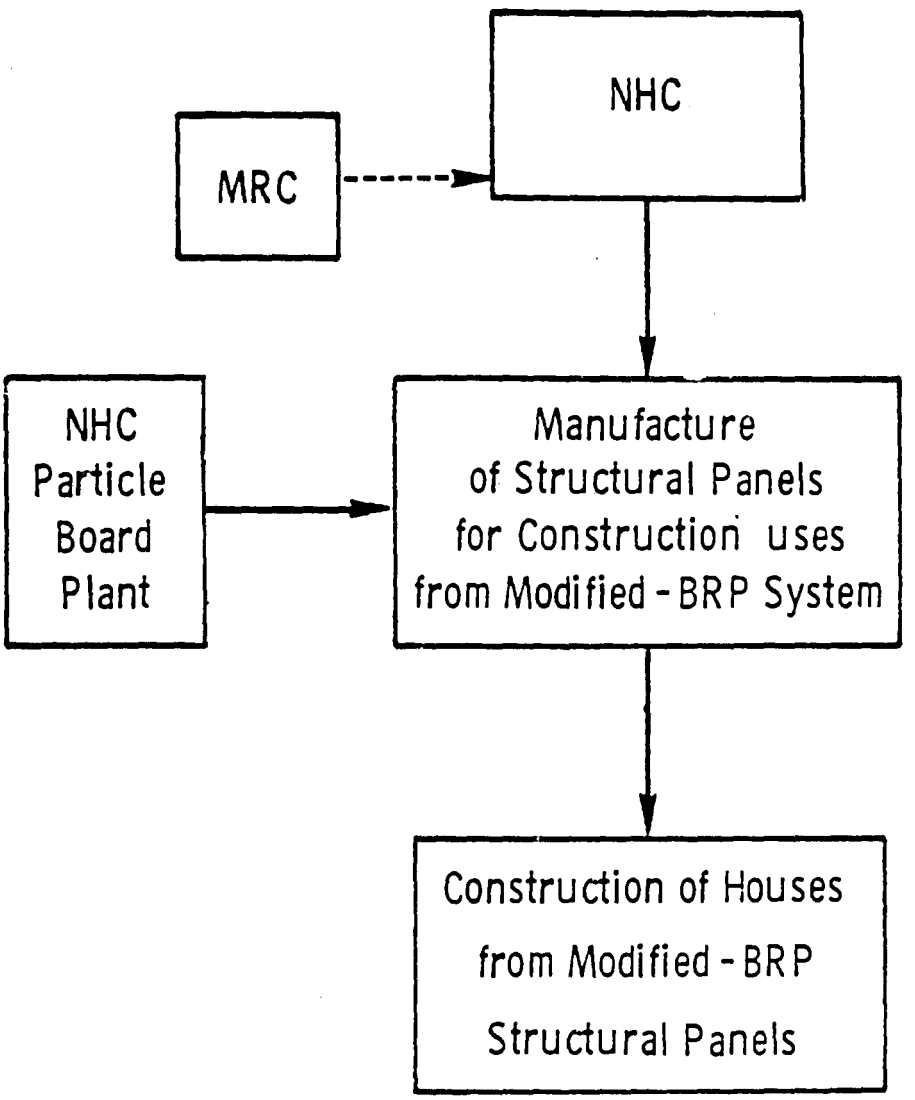


Figure 60. The BRP material system is highly tailorable with respect to lowering of cost while retaining structural integrity necessary for construction materials. This was demonstrated in the Philippines.

3.4 ENVIRONMENTAL IMPACT EXAMINATION

The possible effects of the wide scale manufacture and use of the developed roofing on the land, water quality, atmosphere, natural resources and cultural, socio-economic, health and general aspects of habitation were given an "initial environmental examination". It is concluded that the roofing will not have a signficant effect, and certainly not a negative effect on the environment in the participating countries.

As a matter of policy, AID is commited to a careful consideration of the environmental implications of all AID-supported projects. Accordingly, all AID projects must include an "initial environmental examination" in which the possible effects of the wide scale application of the results (positive or negative) are considered.

Major areas to be addressed include the effects on: land use, water quality, atmosphere, natural resources, and the cultural, socio-economic, health, and general aspects of the inhabitants. Of the eight areas listed for evaluation, in only three is there any (slight) environmental impact. The three areas where there is, or could be, some limited (not necessarily negative) environmental impact are in the areas of water quality, natural resources, and health.

3.4.1 Water Quality

In three of the four processes developed, including the ones most likely to be implemented for wide scale use, there are no by-products introduced into the plant process effluent water, and therefore no environmental effect on water quality.

The fourth process, phenolic-bonded oriented, bagasse fiber panels includes inorganic acid salts to precipitate the phenolic resin. These acid salts, along with soluble organic compounds from the pith, are carried out with the process water. In these respects, this process is similar to those in the U.S., and other developed countries, for manufacturing wood hard board and paper. Accordingly, if this process is used on a large-scale, established methods of treating this type of waste water will be applied.

3.4.2 Natural Resources

3.4.2.1 Diversion of Bagasse to Manufacture of Roofing

The anticipated effects of diverting bagasse from its present use to manufacture of roofing differs in the three participating countries.

In the Philippines, the production of sugar (and bagasse) is so large that the 15-25% excess, over that required to fire the boilers at the sugar mills, presents a waste disposition problem. Utilizing a fraction of the excess for roofing should have positive benefits in reducing pollution of streams, where the excess is now dumped.

In Ghana, the bagasse is used exclusively for firing the boilers at the sugar mills, and there is, at present, no excess. Government planners project that increasing sugar production (already scheduled) will insure excess which could be diverted to roofing in about 3 years. An interim use of bagasse in quantity for roofing would require that the sugar mills convert to residual oil firing (from Ghanian petroleum refining). The Government of Ghana reportedly would like to "encourage" usage of the excess residual oil for fuel applications.

Alternatively, saw dust, the second best filler for roofing composites, could be used in Ghana to make products similar to those from bagasse.

In Jamaica, the sugar mills are now fueled with bagasse (∿75%) and petroleum (∿25%). Some of the bagasse by-product is utilized in making a bagasse board that is bonded with urea/formaldehyde resin. Because of the deficient moisture resistance of the binder, there is a limited market for this bagasse board, and the plant (Standard Building Products) operates at much less than its capacity. Partial or complete conversion of the bagasse board plant to production of the more durable bagasse reinforced phenol/formaldehyde bonded composite should have only favorable results (larger markets, increased employment, etc.). The management of Standard Building Products, with whom we have been working, are strongly in favor of this development.

3.4.2.2 Effects of Diverting Natural Rubber to Production of Roofing Composites

Natural rubber is produced in excess to current use in both the Philippines and Ghana. Diversion of some or all of the excess production should have no negative environmental impact. However, positive benefits (increased markets, employment, etc.) should result from full utilization of this natural renewable resource.

Natural rubber is not produced in Jamaica, and there is no intention of importing rubber for a process there. Thus, there would be no use, and no environmental impact in Jamaica.

3.4.3 Health

There should be no significant impact on the health and safety of workers manufacturing the roofing, or people living in the roofed houses. The processes recommended are already being used in both developed and developing countries for other applications. Thus, no new hazards will be introduced by the wide scale manufacture of the roofing.

However, depending on the specific formulation, there are two areas of possible, or slight, impact which AID has requested to be included in the initial environmental examination, and these are discussed below.

3.4.3.1 Fire Resistance of Roofing

Bagasse, the major component in the composite roofing, is primarily cellulosic, and has significant silica content. As a result, bagasse will burn only slowly and cleanly (little smoke or fumes). Any fuel (resin binder or processing oil) that is incorporated into the composite can detract from the favorable fire resistance of the bagasse filler. Additives can be used to upgrade the fire resistance of the composite. However, as in the United States, fire retardant additives can introduce problems of their own in the way of undesirable smoke and fumes - if the materials are burned by a separate source of fuel.

Consequently, a lowest cost" and a "fire retardant" formulation for each of the four candidate roofing products was developed. Interest in the three participating countries has been greatest in the lowest cost product, not the higher cost fire retarded material. As J. V. Cedro, Plant Superintendent at the National

Housing Corporation in the Philippines, expressed it, "People here need first to worry about whether they have a roof over their head, and only much later whether it will burn".

It should be noted, however, that none of the candidate roofing materials presents as great a fire hazard as the asphalt shingles most commonly used for roofing in the U.S. and other developed countries.

3.4.3.2 Use of Water Collected from the Roofs for Drinking

The collection and use of roof water for drinking is undesirable for many reasons. It is also not practiced, to a significant degree, in the major population areas of the three participating countries (other sources of potable water are readily available).

Of the candidate resin binders that are proposed, phenol/formaldehyde has FDA approval for use in water filters in the United States. Natural rubber formulations are used in hoses and kitchenware where water exposed to it may be used for drinking. The thermoplastic resins suggested are also used for cups and glasses where the water will be drunk.

In some of the limited production of roofing material to date, we have used a highly effective water insoluble fungistate as "insurance" against mold growth. This fungistat will be replaced with one having FDA approval for use in foods, or eliminated altogether in any wider scale production.

4. CONCLUSIONS

4.1 ACHIEVEMENT OF PROGRAM OBJECTIVES

- The first program goal was to "match indigenous fillers with low cost binders to produce roofing with a wide range of applicability in developing nations".

This technical approach is also the one recommended by the National Academies of Science in the study they made of the housing problem, in response to UN request, prior to initiation of the US-AID roofing project in May 1973.

This goal has been successfully completed, through research done at MRC's Dayton Laboratory, as well as in facilities made available in the three participating countries. Four different products, and processes to manufacture them, were developed that use a major quantity (70-95%) of the indigenous residue of sugar cane processing (bagasse), along with a minor quantity of natural or synthetic resin (30-5%) to form a strong durable, flat or corrugated, composite panel. Raw material costs for these four composites range from US 6¢-12¢/lb. At the anticipated roofing panel thickness, costs/ft^2 would be in the same range.

- A second goal was to "utilize local labor and resources to manufacture a sufficient quantity of the material to roof four houses in each of the three participating countries (Philippines, Ghana, and Jamaica)".

This goal has also been substantially achieved. Manufacture of at least two of the four types of products developed was demonstrated on a "plant scale" in each of the three countries. Sufficient roofing material was produced to roof four houses in the Philippines, one in Ghana, and eight in Jamaica.

- The third major program goal was to "transfer the necessary technology to qualified organizations in the developing countries".

This objective has also been accomplished. At least one government agency organization, and one private industry firm, has been identified and directly involved in both the experimental and plant scale production in each of the three countries.

4.2 SPECIFIC TECHNICAL CONCLUSIONS

- Out of approximately 50 potential fillers examined, bagasse was easily the best in terms of product properties, cost and availability.

- From at least 10 synthetic and 2 natural rubber binders evaluated, phenol/formaldehyde thermosetting resin was generally best and adopted for use in two of the four roofing products.

- Good alternate binders defined included natural rubber and ABS thermoplastic resin.

- Using the selected fillers and resin binders, four composite roofing materials were developed.

- For each of the four roofing products an economical process, that utilized equipment and facilties available in the developing countries, was defined. The processes are adaptable for mass production of the roofing.

- Bagasse can be readily fibrillated, and depithed, into strong, water resistant, fire retardant fibers. Whole bagasse can be used at abnormally high levels with resin or rubber binders to achieve a durable structural material.

- A process to orient the bagasse fibers to produce panels with desirable directional strength properties was defined.

- The roofing material systems developed probably also have utility as structural and non-structural building materials for all parts of houses.

- Clay, ore tailings or "red mud" can be bonded with thermosetting phenol/formaldehyde resin to form strong, durable composites which, with further development, may be useful in building blocks for walls, floors, etc.

- The bagasse-filled resin bonded composite roofing panels have shown excellent short term resistance to the tropic environment and are expected to have the necessary long-term strength and durability.

- Strength, life, durability, cost, acceptability and installability are important roofing material characteristics (as expected), with cost being of over-riding importance.

- A totally indigenous resin binder system was not achieved in any of the three countries. Even locally grown natural rubber (Philippines, Ghana) required minor percentages of imported vulcanization chemicals, and locally produced phenol/formaldehyde resin (Philippines) requires imported phenol. However, complete "indigenuity," or lack of it, was found to be less important to the project than visualized at the outset.

- Minimizing the foreign exchange requirement was less important than achieving lowest total cost in roofing. There was a willingness to import, necessary ingredients at lower cost; even when a locally manufactured resin was available at higher cost.

- Fire retardance in the roofing was found to be less important than lowest overall cost. "These people need first to have a roof over their heads, then they can begin to worry about fire. After all, there's other things (wood) that will burn in these houses".

- Technology at a high level is available in each of the three participating countries in both government organizations and industry.

- The identification and use of a qualified "Advisory Committee" to make technical expertise available, and lend added credibility to the project was a highly desirable aspect of the methodology.

- The acquisition and use of a participating technical working group was highly beneficial towards implementation of the program and successful completion of the technology transfer.

- Person-to-person contact was found to be essential to efficient technology transfer.

- Locating and utilizing a single, qualified, enthusiastic collaborator to coordinate the effort in each participating country was also essential.

- Technology and enthusiasm, required to further the development effort, was usually available at the highest level in private industry.

- Consulting working visits to each of the three participating countries on a regular periodic schedule maximized the effectiveness of the MRC team with respect to supporting the developing country participants.

- A follow-on or utilization phase is needed in each of the participating countries in order to consolidate the results, to secure continuing plant production of the materials, and to implement large-scale use of the products in housing.

- With a follow-on program of appropriate scope, prospects for commercialization in each of the three participating countries is excellent.

- An initial environmental examination of the processes and products proposed does not reveal any significant environmental threat or hazard to the health of workers or users.

5. RECOMMENDATION

- It is recommended that a follow-on program on an appropriate scale, be implemented in the participating countries to obtain plant scale production, and large-scale sale and use of the composite panels in roofing and other parts of the houses.

- The follow-on work should emphasize developing of process and facilities for manufacture of thin corrugated panels for roofing in order to achieve highest directional strength, longest roof spans, and lowest overall cost.

6. REFERENCES

1. "Roofing in Developing Countries, Research for New Technologies," National Academy of Sciences, National Research Council, Washington, D. C., 1974.

2. "Development of Low-Cost Roofing from Indigenous Materials in Developing Nations," First Annual Report, Contract No. AID/CM/ta-C-73-12, Monsanto Research Corporation, Ival O. Salyer, George L. Ball III, et. al., 30 July 1974.

3. "Development of Low-Cost Roofing from Indigenous Materials in Developing Nations," Second Annual Report, Contract No. AID/CM/ta-C-73-12, Monsanto Research Corporation, George L. Ball III, et. al., 18 December 1975.

APPENDIX A

CONTRACT STATEMENT OF WORK

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CONTRACT STATEMENT OF WORK

The Contractor shall make available and employ its research and development facilities and personnel to carry out a three-year research and development program directed toward developing, testing, and evaluating low-cost binders applicable in meeting DC roofing needs. The experimental program will be conducted in three twelve-month phases as described below.

The binders developed shall be low in cost--particularly in foreign exchange costs, broadly applicable to a variety of locally available cheap fibers and fillers, easy to handle and apply, resistant to wear, and with thermal and other properties suitable to the tropics and socio-economic constraints of developing countries.

Although it is recognized that the bulk of the research will likely be in the field of plastics and resins, the project is also to explore other binding materials, such as rubber, asphalt and cement (especially "ferro-cement"), pursuing them if they appear more advantageous than polymers, etc.

The objective is to provide a key ingredient for DC roofing that can maximize utilization of local natural resources, surplus manpower, and limited manufacturing capabilities, in producing a cheaper and better product than is now available. Targets are DC low-cost housing projects and development of village level industry or self-held methodology.

Phase I - Material and Process Development; and Socio-Economic Base Study

The initial phase will:

(a) involve the selection of three developing countries, one each in Africa, Asia and Latin America (with disparate climatic and roofing problem characteristics), as geographical sites for demonstration purposes;

(b) selection of local personnel and institutions for collaboration;

(c) collection for analytical testing of commonly available native fibers, fillers, or other plentiful and cheap materials, including agricultural wastes, which may be used as a resin source or as fibers, etc.;

(d) collection and study of pertinent literature on DC roofing needs, on existing roofing materials and types in both developed and developing countries, on related projects, experiments and potentials, to avoid duplication and to utilize earlier experience;

(e) study of the building styles, trends, codes, structural characteristics, total costs, foreign currency costs, and the organization and infrastructure controlling new low-cost housing construction, both in larger housing projects and in self-help or village and town-level local construction;

(f) study of the social, cultural, marketing and economic constraints and characteristics which would inhibit or enhance acceptance of new roofing materials and styles;

(g) study of the local labor market pertinent to roofing manufacture, distribution, self-help processes, etc., including quality and trends, and

(h) initiation of processing techniques, testing and preliminary design.

Phase II - Design, Manufacture, Testing and Evaluation of Prototype Roofing

Phase II will incorporate the most promising materials into prototype roofing panels, provide for scaled-up evaluation, testing and environmental exposure, incorporate advanced architectural design responding to strength, longevity, cost, labor and acceptability, and lay the ground work for full-scale construction and demonstration activities in the developing nations.

Phase III - Manufacture and Field Testing of Full-Scale Roofing

Upon acceptance by AID of fully tested and successful prototype(s), in Phase III construct a total of at least 12 full-scale roofs with local manpower, and evaluate in company with local officials. Particular attention will be placed on socio-economic factors in terms of acceptability of the new roofing system, the lack of foreign currency requirements, the total cost, the level of involvement of unskilled and semi-skilled labor, the expected performance characteristics (thermal, acoustic, durability, strength, longevity, etc.), the encouragement of development of local industry, the utilization of cheap and plentiful fibers and fillers, or other local material resources, and the transferability aspects.

APPENDIX B

SELECTED TYPICAL LETTERS OF INTEREST AND/OR INTEREST IN PROGRAM AND MATERIALS IN PHILIPPINES, JAMAICA, AND GHANA

- Letter Standard Building Products Ltd., March 9, 1976
- Letter Standard Building Products Ltd., November 10, 1976
- Letter Ghana Rubber Products Ltd., April 23, 1976
- Telegram USAID Manila, October 1, 1976

STANDARD BUILDING PRODUCTS LTD.
P.O. Box 29, Spanish Town, Jamaica. Telephone: 984-2296. Cables: Stabilprod. Telex: 2269, Codifico, Jamaica, W.I.

March 9, 1976

Mr. George L. Ball III
Project Leader,
US-AID Roofing Programme
Monsanto Research Corporation,
1515 Nicholas Road,
Dayton, Ohio 45407,
U.S.A.

RNC:hg

Dear George:

I am in receipt of your letter of February 23, 1976 regarding Standard Building Products' participation in the Us-AID Roofing Programme, and this letter will serve as our commitment to participate in this programme in accordance with the criteria set forth on pages two, three and four of the above-mentioned letter.

All raw materials to be supplied by Standard Building Products Limited in order to implement this programme are currently in inventory at Standard Building Products Limited and have been reserved for your use. There will be no charge for these raw materials.

It is our intention to locate your wet-depithing, washing, mat-forming and lay-up equipment in our Laminating Plant which is the building that currently houses our single opening daylight 4' x 10' Hot Press. We would further anticipate the preparation of the roofing panels by an application of a preservative (Penta) and the application of the aluminized asphalt paint at our Factory.

Needless to say all laboratory and quality control facilities shall be put at your disposal.

We would be most interested in having, at your earliest convenience, the drawings of the frame and the fabricating mould that will be attached to our 4' x 10' Hot Press so as to ensure the design is in fact compatible with our facility.

Standard Building Products Limited looks forward to working with you and all others involved on this project and promises every co-operation to ensure a successful pilot run.

Yours sincerely,
Standard Building Products Limited

Ralph N. Corning Jr.
President & Chief Executive Officer

cc: I. O. Salyer, MRC, Dayton

Alfrico D. Adams, Douet, Brown, Adams & Partners,
7 Lismore Avenue, Kingston 5, Jamaica.

Technical Director, Scientific Research Council,
P.O. Box 350, Kingston 6, Jamaica.

Dr. Thomas Hughes, Dept. of Physics, UWI, Kgn.6. Jamaica

Mr. Nick J. Mariani, Programme Officer, Us-AID Mission to Jamaica, Duke Street, Kingston, Jamaica.

Mr. Douglas Wynter, Technical Director - R & D, SBP, Jamaica.

November 10, 1976

Mr. Nick J. Marani
Programme Officer
USAID Mission to Jamaica
Duke Street
KINGSTON

Dear Sir:

This letter is to indicate our participation, confidence and interest in the dense phenolic bonded roofing material developed by Monsanto Research Corporation through AID Washington.

First, we well realize the potential of bagasse products for construction in Jamaica to reduce housing costs and minimize foreign exchange requirements. We, infact, manufacture bagasse board that is used for interior construction and furniture. Whereas, there is a broad market for our board, it is not suitable for exterior application on walls, roofing and or fencing. We feel that the dense phenolic bonded roofing panel developed through you offers a way to better utilize our indigenous bagasse in Jamaica.

Our confidence and interest on this product is reflected in our participation in the R & D programme of Monsanto Research Corporation over the past two years. This participation is now reflected in a pilot manufacture of about 6000 square feet of roof shingles for which we are contributing facilities, manpower and the assistance of our technical staff combined (an in kind contribution of approximately $40,000) The roof shingles should all be manufactured by December 15.

As you are probably aware the manufacture of 6000 square feet of shingles is to provide experimental roofs to demonstrate the durability and practicality of the roofing material in Jamaica under our local environmental, weather and use conditions. Needed then is a development programme to define the most reliable and acceptable roofing system for this material.

By means of this letter I am formally requesting that US AID provide assistance to us in the way of technical support from Monsanto Research Corporation, and the Jamaica Scientific Research Council and the necessary materials, tooling, etc. to conduct and complete the development programme.

cont'd...../2

In exchange I offer our enthusiasm, facilities and staff to maximize the results of the development programme and will attempt to make available and commercialize the roofing material once the technical results and economics demonstrate that it is right for Jamaica and Standard Building Products Ltd.

Yours faithfully,
STANDARD BUILDING PRODUCTS LIMITED

JOHN M. CRAFTON
MANAGING DIRECTOR

c.c. Alfrico Adams, Douet, Brown & Adams
Technical Director, Scientific Research Council
Al Richards, Ministry of Housing
George L. Ball, Monsanto Research Corporation

JMC:jmj

GHANA RUBBER PRODUCTS LTD

Tel: 21771
Telex: 2088
Cable: Ghanashoes

P. O. Box 1059
Accra,
Ghana.

Our Ref: 34/2819

23rd April, 1976

Mr. George L. Ball III,
c/o Room 27,
The Ambassador Hotel,
ACCRA.

Dear Mr. Ball,

Following the discussions held in our offices on Thursday, the 15th of April, we wish to confirm our continued interest in the fibre reinforced rubber roofing material project. Our company is willing to participate in the experimental stages of this project and we undertake to mix a trial batch through our banbury and calender during May or whenever the materials can be made available. It is understood that the initial trial batch will be approximately two metric tons.

At the earliest opportunity we will let you have an indication of the approximate costing involved. We wish to place on record that our company is most interested in this project, both in the short term experimental stage and also in the ultimate long term possibilities.

Assuring you of our continued cooperation, we remain.

Yours faithfully,
for GHANA RUBBER PRODUCTS LTD.

P.L. WESTRAY
General Manager

• MONSANTO RESEARCH CORPORATION •

Department of State **TELEGRAM**

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UNCLAS MANILA 16891

AIDAC

E.O. 11652: NA
SUBJ: LOWCOST ROOFING CONTRACT FOLLOW-ON

REF: (A) STATE 260081 (B) MANILA 14923

1. WHILE MISSION UNDERSTANDS AID/W POSITION STATED PARA 4 REFTEL THAT COMMITMENTS NOT POSSIBLE THIS TIME, WE BELIEVE MONSANTO RESEARCH DEVELOPMENT IN PHILIPPINES HAS ACHIEVED PROGRAM GOALS AND BEEN ADEQUATELY DEMONSTRATED TO GOP NATIONAL HOUSING AUTHORITY (NHA) AND NATIONAL SCIENCE AND DEVELOPMENT BOARD (NSDB) REPORTEDLY GENERATING GOP PRESIDENTIAL INTEREST TO BUILD A DEMONSTRATION HOUSE, USING ALREADY DEVELOPED MRC PROCESS MATERIALS, AT NEW INTERNATIONAL CONVENTION CENTER MANILA. WE THEREFORE URGE RECONSIDERATION AVAILABILITY FOLLOW-ON FUNDS AS SOON AS POSSIBLE. RELATED COMMENTS IN PARAS 1-3 OF REFTEL FOLLOW.

2. LOWCOST MONSANTO-PROTOTYPE COMPOSITE ROOFING PANELS NOW BEING INSTALLED ON FOUR DEMONSTRATION HOUSES IN PHILIPPINES USING A [illegible]

OF BAGASSE FILLER BONDED WITH NATURAL RUBBER.

3. BAYER ADVISES THAT ONLY IN JAMAICA IS DEMONSTRATION ROOFING PLANNED USING COMPOSITE OF BAGASSE BONDED WITH PHENOL/FORMALDEHYDE (P/F) THERMOSETTING RESIN.

4. P/F BONDED PRODUCT MAY BE OF INTEREST IN PHILIPPINES FOR INTERIOR WALLS, CEILING, FLOORS, FURNITURE, ETC.

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Department of State **TELEGRAM**

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PAGE 02 MANILA 16891 0209292

5. HE ANTICIPATES NO ADVERSE ENVIRONMENTAL EFFECTS FROM P/F THERMOSETTING RESIN WHICH IS OLDEST SYNTHETIC RESIN, AND IS USED WORLD-WIDE AS BONDING AGENT FOR PLYWOOD AND HARDBOARD. OUTDOOR TYPE, P/F BONDED PLYWOOD NOW BEING USED DIRECTLY ON ROOFS OF HOUSES IN CARRIBEAN AREAS. ALSO THIS RESIN IS ALMOST UNIVERSALLY USED IN PLYWOOD FOR ROOFS IN THE USA WHERE IT IS USUALLY COVERED WITH ASPHALT SHINGLES.

6. SALYER STATES INTEREST NOW HIGH IN BOTH GOVERNMENT AND PRIVATE SECTORS IN ALL THREE TRIAL COUNTRIES. HE BELIEVES DELAYED OR NO FOLLOW-ON COULD BE VERY DELETERIOUS SINCE IT MIGHT LEAD TO DEVELOPING COUNTRIES AID'S LACK OF CONFIDENCE AND CONTINUING INTEREST THIS PROJECT.

7. FROM STANDPOINT GOP INTEREST AND CONTINUED DEVELOPMENT, SCALE-UP, AND UTILIZATION OF RESULTS, EARLY FOLLOW-ON PROGRAM CONSIDERED CRITICAL TO SUCCESSFUL CONCLUSION THIS PROGRAM.
SULLIVAN

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APPENDIX C

REPRESENTATIVE DATA ON BONDED ORIENTED BAGASSE (BOB) SYSTEM GENERATED BY UNIVERSITY OF WASHINGTON

- Section from Master Thesis, Harry Christensen, University of Washington, 1976
- Progress Report, Ben Bryant, September 30, 1975
- Progress Report, S. T. Hsu, October 31, 1975
- Data Tables 53 and 54 from 2nd Annual Report December 18, 1975

ABSTRACT

An innovative roofing product manufactured from agricultural residues is described and analyzed. The analysis is divided into three parts: 1. A brief summary of the housing situation in the modern world, particularly in developing countries. 2. Discussion and description of a roofing product designed for use throughout the developing world as a substitute for the universally used galvanized iron roof. 3. The methods which would best transfer this product and technology for manufacture in the developing world.

In Part I world housing is discussed, particularly the handicap brought on the poor by rising costs, rising middle-class values and the lack of housing available in an affordable price range. A low-cost roof is a needed item in developing countries where the commonly used galvanized iron roof draws into the limited foreign exchange.

Part II summarizes a process through which an inexpensive substitute roofing material can be made. Market comparisons are studied and the cost of setting up a manufacturing plant is included. A simple process is described by which relatively inexpensive sheets of corrugated roofing material can be manufactured in developing countries. The product made from agricultural residues can be made in a low-capital investment operation which is labor intensive. Oriented fiber mats are made in a batch process from a water slurry that contains fibers, phenolic resin binder, and wax. The mats are pressed at relatively low pressure (plywood pressures, up to 250 psi) and then post treated with a water resistant sealant coating in preparation for painting with an aluminized coating. Fire retardants are currently being tested for use in conjunction with the sealant. Analysis of the costs of setting up a pilot plant indicated that the plant equipment might have to be subsidized to produce a product with a price truly affordable by the poor.

The final section of this paper explores the various methods by which a pilot plant could be set up in a developing country and the problems associated with the acceptance of such a facility by the community. A viable alternative appears to be through an already established Christian mission or relief organization. Initial market acceptability could be enhanced by using the product for mission churches, schools, and residences.

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Major advantages of CORB are: local manufacturing, no import costs, indigenous, and, most important, low cost yet good quality. The major disadvantages are: its lack of fire resistance, lack of on-site testing (currently being installed on test houses) as roofing, and lack of acceptance since it is an unknown products. Creating market acceptability will be discussed in Part III.

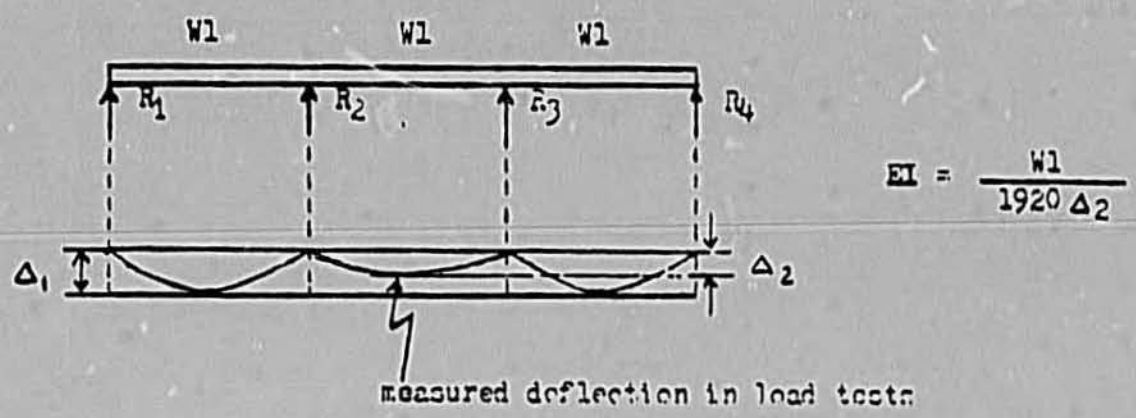
To find out how CORB compared with CGI under loading, some uniform load tests were made. Figure 19 shows the method of loading and the formula for finding EI (modulus of elasticity x moment of inertia - strength measuring indicator). Uniform load tests were made on CORB and CGI as well as on corrugated aluminum and corrugated fiberglass.

Table 6.

Data on comparative uniform load tests

	Bagasse	Steel	Aluminum	Fiberglass
Dimensions of test panel	.109"x21"x72	.031"x21"x72	.038"x21"x72	.034"x21"x72"
Panel weight	5.67 lbs.	11.46 lbs.	6.60 lbs.	2.47 lbs.
Corrugation wavelength	3.00"	3.26"	2.74"	3.26"
Amplitude	0.715"	0.533"	0.978"	0.536"

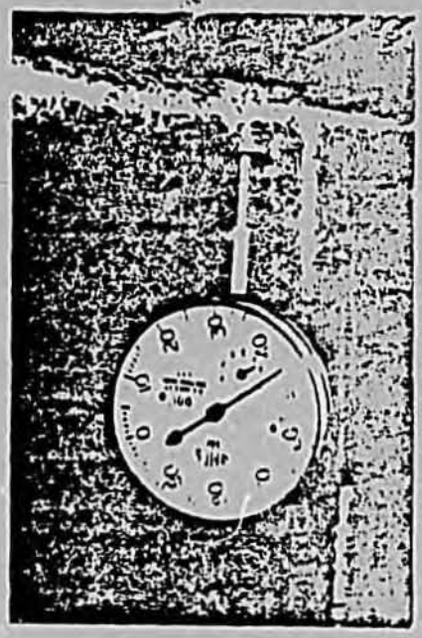
Figure 19. Diagram of uniform load test method[8]



The method of uniformly loading the panels and measuring the resulting deflection is illustrated in Figures 20-25. The fiberglass panel failed under load of 150 lbs./24" span and thereby showed its weakness in relation to the other 3 materials tested. Figures 26 and 27 give evidence to the theory that CORB is comparable to corrugated steel and aluminum under test load conditions. Indeed, the slopes of wt./Δ if multiple tests were done could prove to be statistically equal.

Behavior Characteristics of CORB

> "The product of the wet process, thermoset resin-bonded, depithed, fibrillated, oriented, bagasse is a panel material with excellent directional strength and modulus characteristics. Since surface coating or painting has not been used, it has the appearance of a composition board. Fiber orientation is obvious



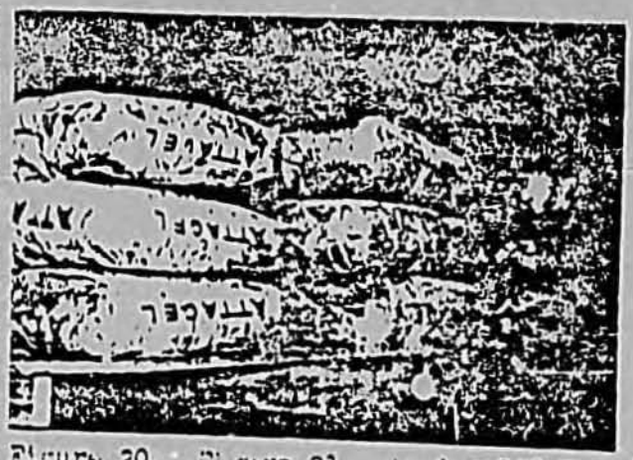


Figure 20. Figure 21. Load = 150 lbs./2 ft. span. Corrugated, oriented bagasse. Deflection = .306" - .200" initial reading = .146".

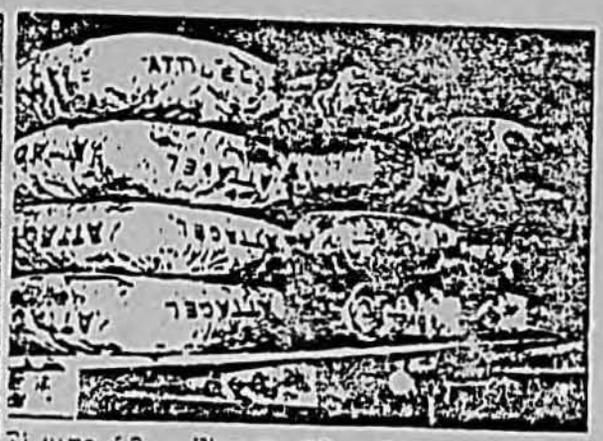


Figure 22. Figure 23. Corrugated aluminum. Load = 200 lbs./2 ft. span (uniform load). Deflection = .285"-0.030" initial reading = .255".

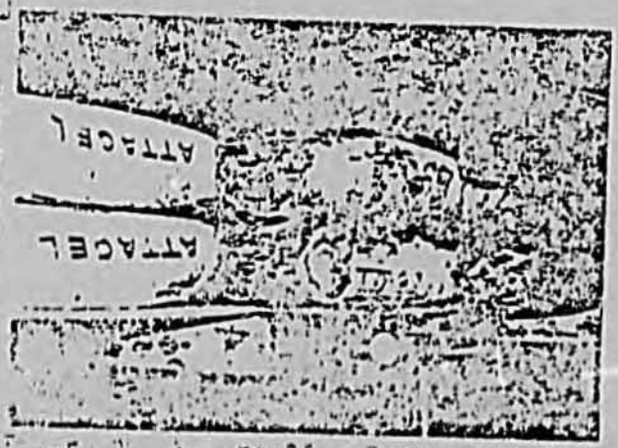


Figure 24. Figure 25. Corrugated fiberglass. Load = 150 lbs./2 ft. span (uniform load). Deflection = .[illegible]" - .150" initial reading = [illegible].

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Figure 26. Comparison of deflection vs. load of four different corrugated materials

Continuous Beam--three equal 2 ft. spans--Uniformly Distributed Load

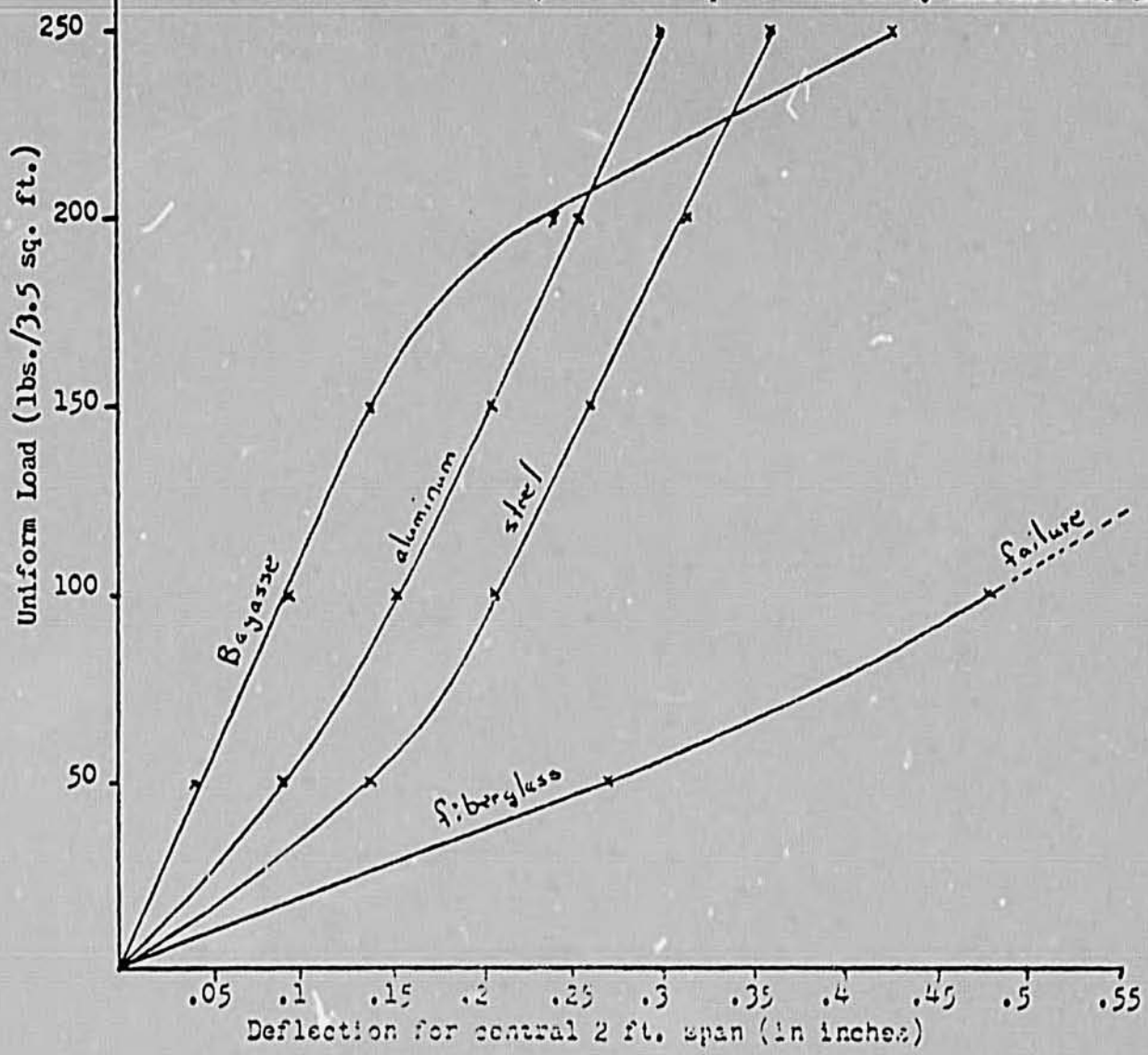
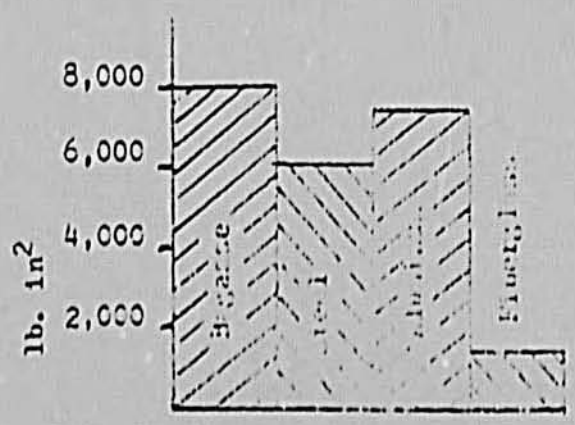


Figure 27. Comparison of EI of four different corrugated materials



ORIENTED HARDBOARD

Progress Report
(September 1 - September 30, 1975)

from

University of Washington
College of Forest Resources
Utilization Research Group

1. Made one oriented bagasse mat; sent to Monsanto Research Corp.
2. Tried out 20% resin addition on bagasse hardboard; tested it's effect on wet-strength (one set of samples sent to M.R.C.).
3. Tested the effect of asphalt on the wet-strength of bagasse hardboard.
4. Prepared linseed oil temperins treatment.

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The Effect of High Level of Resin Addition and Asphalt on the Wet-Strength of Oriented Bagasse Hardboard

Summary

It is important that oriented bagasse hardboard used for exterior type of application such as roofing has high wet-strength. The previous results have shown that bagasse hardboard with 5% resin and 2% wax additions did not meet MRC's required 50% strength-retention objective. To determine the effect of higher levels of resin addition on the wet-strength of bagasse hardboard, in this experiment, 20% resin level was used. The resin was applied by both the precipitating method and the spraying method. Boards were pressed at both wet (200-250 % MC) and damp (20-30 % MC) conditions. The effect of asphalt on the wet-strength of the bagasse hardboard also was explored. The results showed that:

1) With 20% resin addition, the bagasse board had higher wet-strength value than those with 5% resin addition.

2) The pressed damp condition gave higher wet-strength than those pressed in the wet condition.

3) With 20% resin addition the maximum wet-strength (MOE) is 37% in parallel direction and 47% in perpendicular direction of dry-strength value.

4) Both 1% and 2% asphalt additions in the board did not affect its wet-strength.

Conclusion

In spite of the higher cost of resin and process complication, with 20% resin addition the wet-strength of bagasse hardboard still did not reach the target 50% of dry-strength value.

Much resin was squeezed out in pressing in the case of "spraying" method. And resin was lost in mat forming in the case of the precipitate method. New ways of resin application and new types of water-resistant agent will be explored. Our next challenge is to temper the bagasse board with linseed oil to achieve 50% wet-strength targets. This parallels commercial hardboard practice.

Table 1. Test Results of Modulus of Elasticity

Treatment	Before soaking ∥to grain	Before soaking ⊥to grain	After 24 hrs. water soaking ∥to grain	After 24 hrs. water soaking ⊥to grain	% of residue strength ∥to grain	% of residue strength ⊥to grain
Standard	636,000psi	269,000psi	167,000psi	110,000psi	26%	41%
A	654,000	319,000	161,000	52,500	25	16
A'	765,000	431,000	277,000	164,000	36	27
B	598.000	260,000	218,000	130,000	37	50
B'	700,000	477,000	243,000	133,000	35	28
C	598,000	275,000	152,000	83,500	25	30
C'	438,000	275,000	139,000	80,000	32	29

Treatment:

Standard = 5% resin 2% wax

A = 20% resin, 2% wax precipitated: pressed wet

A'= 20% resin, 2% wax precipitated: pressed damp

B = 2% wax and 20% resin sprayed in centrifuge: pressed wet

B'= 2% wax and 20% resin sprayed in centrifuge: pressed damp

C = 5% resin, 2% wax and 2% asphalt pressed wet

C'= 5% resin, 2% wax and 1% asphlat pressed damp

Table 2. Test Results of Modulus of Rupture

Treatment	Before soaking ∥ to grain	Before soaking ⊥ to grain	After 24 hrs. soaking ∥ to grain	After 24 hrs. soaking ⊥ to grain	Remaining strength ∥to grain	Remaining strength ⊥to grain
Standard	5719 psi	2762 psi	1667 psi	418 psi	29%	51%
A	5877	2790	1523	767	26	27
A'	7261	4367	2946	2066	41	48
b	5170	2690	2407	1238	47	49
B'	6262	4189	2585	1784	41	43
C	6024	3155	1396	1237	23	39
C'	4838	3315	1602	1306	33	39

Note: All tested specimen were prepared from 2 boards (one for dry test, one for wet test) only. The low value of treatment A might be counted as experimental error.

Table 3. Linear Expansion and MC Pickup After 24 hrs. Soaking

Treatment	∥ to grain	⊥ to grain	Thickness swelling	Weight increase
Standard	20.12	0.40	18.8%	42%
A	0.31	0.38	12.0	52.2
A'	0.20	0.41	10.5	42.4
B	0.45	0.37	12.5	46
B'	0.1	0.20	24.5	56.5
C	0.20	0.45	19.5	30.5
C'	0.24	0.24	13.7	27.0

Improving the Properties of Bagasse Hardboard by Oil Tempering and Asphalt Coating

ABSTRACT

Oil tempering significantly reduced thickness swelling linear expansion and water pick-up of bagasse hardboard 25-35% on both "dry" and "wet" test. Bagasse hardboard with asphalt tar coating showed the least loss of MOR and MOE compared to oil tempering and control treatments after the 24-hour water soaking test.

Oil tempering is a commercially accepted and widely used process for improving the strength, dimensional stability and durability of hardboard. The purpose of this study was to determine the extent to which these properties of bagasse hardboard could be improved by oil tempering. In addition, since asphalt has also been widely used for roof coating, the water repellent efficiency of asphalt coated bagasse hardboard was also included in this study.

PROCEDURE

Thirty 12" x 12" x 1/8" smooth-two-sides random oriented bagasse hardboard was made*. Each mat contained 5% phenolic resin and 2% wax. These boards were then randomly separated into five groups for different treatments as follows:

Group 1: Control, without any additional treatment

Group 2: 5% linseed oil tempering treatment

*The mechanically dewatered mats were dried under forced, room-temperature air circulation overnight, conditioned at 90° RH for two days and pressed without screen at 280°F under a diminishing pressure (starting at 300 psi) for about 8 minutes.

Group 3: 10% linseed oil tempering treatment

Group 4: Hot asphalt coating treatment

Group 5: Asphalt emulsion coating treatment

After treatments, the boards of each group (except group 4 and 5) were further divided into two sub-groups: one for the "dry" test and another subjected to 24 hours water soaking test to determine the thickness swelling, linear expansion, water pick-up and residue strength of the bagasse hardboards. All boards in group 4 and 5 were for water soaking test only.

In oil tempering treatment, boiled linseed oil was used in this experiment. Two percent of a 12% cobalt octate was added to linseed oil as a drier. The oil was heated to approximately 170°F in a dipping pan and the hardboard was immersed into the heated oil until final oil retention reached to 5% and 10% (air-dry weight basis). After the oil impregnated, the boards were dried in a drying oven at 280°F for 3 hours. The tempered boards were then conditioned at room temperature and ready for further tests.

In asphalt tar coating treatment, the asphalt tar of low melting point (150°F, which is the only type available at the time) was heated in a dipping pan until melted. The bagasse boards were then dipped into the pan and coated with hot asphalt.

For the asphalt emulsion coating, the asphalt emulsion was applied by brush to the bagasse hardboard at room temperature and allowed to dry.

Nine specimens were prepared from each sub-group for the bending test (by Instron testing machine). The linear expansion, water pick-up and thickness swelling were measured from three boards before being cut into smaller specimens for bending test.

RESULTS

The experimental results are in Table 1. Oil tempering was very effective in reducing thickness swelling, linear expansion, and water pick-up in the samples subjected to the 24-hour water soaking test. In the "dry" test, the MOR of oil tempered specimens were 34-35% higher than those without oil tempering (control treatment). The MOE of oil tempered specimens were 20-30% higher than the controls. There was no significant different in the "dry" strength (MOE and MOR) between 5% and 10% oil tempering treatments. However, 10% oil tempered specimens had higher "wet" strength (residue strength) than those with 5% oil tempering after 24 hours water soaking. In both 5% and 10% oil tempering treatments, the "wet" strength was about 50% for MOR and 45% for MOE of the "dry" strength.

The "wet" strength of hot asphlat coated specimen was significantly higher than those of oil tempering treatment. In asphalt emulsion coating treatment, the "wet" strength was even lower than those of control treatment. This showed asphalt emulsion had low water repellent efficiency and due to the fact that the coated specimens were thicker than those of control treatment specimens, the higher I resulted in lower calculated MOR and MOE.

DISCUSSIONS AND CONCLUSIONS

1) Linseed oil tempering treatment increased both "dry" and "wet" strengths and reduced linear expansion, thickness swelling, and water pick-up significantly. The oil tempering treatment could easily be accomplished without sophisticated equipment. The cost of tempering oil was about 0.3¢/ ft^2 for 5% oil tempering treatment. (Boiled linseed oil $0.09/lb in car tank quantity - cost of July, 1973).

2) In this experiment, all bagasse hardboard contained 5% phenolic resin and 2% wax before oil tempering or asphalt coating treatment. Further study is necessary to determine the effect of lower resin level (less than 5%) addition to the properties of the final oil tempered addition to the properties of the final oil tempered bagasse hardboard to reduce the cost of the final product.

3) Inexpensive asphalt tar coating showed good water repellency. Further study on this asphalt tar coating process is also necessary.

4) The results of this experiment showed that the linear expansion after 24 hours water soaking were only 0.38% and 0.41 % for 10% and 5% oil tempering respectively. For a 6' long roof panel, the maximum board expansion will only be 0.3 inches and may be within the tolerance limits as far as roofing material is concerned.* If the EI of the board is sufficient, random oriented bagasse hardboard (with oil tempering or asphalt tar coating) which could be produced in a simple process (i.e. deckle box) could be used for roofing material.

S. T. Hsu
October 31, 1975

*To reduce linear expansion further it is common practice to rehumidify the board to the average level of moisture it will experience in service before shipping.

Table 1

Properties of Bagasse Hardboard Treated with Tempering Oil, Asphalt Coating at Control Test and 24 Hrs Water Soaking Conditions

Treatment	MOR[1] (psi)		MOE[1] (1,000 psi)		Wt[2] increase	Thickness[2] swelling	Linear[2] expansion
	Control	24 hrs soaking	Control	24 hrs soaking	after 24 hrs water soaking		
Control	5,900	2,800	580	243	23.0 %	18.8%	0.46 %
5 % tempering oil	8,000	3,900	745	305	16.5 %	13.4 %	0.41 %
10 % tempering oil	7,900	4,100	690	335	15.8 %	13.7 %	0.38 %
Asphalt Tar coating	----	4,500	---	360			
Asphalt Emulsion coating	--	2,600	---	206			

1. Each value is the average of 9 test specimens

2. Each value is the average of 3 test specimens

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Table 53

EFFECT OF FIBER ORIENTATION AND WATER IMMERSION ON PROPERTIES OF PHENOLIC BONDED DEFIBRILLATED BAGASSE COMPOSITES

Sample ID MBC-DA	Composite Composition: Resin[a] (%)	Bagasse Type[c]	Bagasse content (%)	Montan Wax (%)	Process[d]	Orientation[e]	Flexural[f] Strength Dry (psi)	Flexural Strength Wet (psi)	Flexural Strength W/D (psi)	Flexural Modulus, 10^3 Dry (psi)	Flexural Modulus Wet (psi)	Flexural Modulus W/D (psi)	Tensile[f] Strength Dry (psi)	Tensile Strength Wet (psi)	Tensile Strength W/D (psi)	Tensile Modulus, 10^3 Dry (psi)	Tensile Modulus Wet (psi)	Tensile Modulus W/D (psi)	Water Pickup (%)
184129-6	0.0	UCW	100	-	We	*	2500	Fa	Fa	402	-	-	690	Fa	Fa	1030	-	-	Fa
184129-5	0.0	SCDp	100	-	We	*	1500	Fa	Fa	254	-	-	810	Fa	Fa	1040	-	-	Fa
184129-4	10.0	UCW	90	-	We	*	3700	1400	3400	498	193	460	1520	540	1200	610	140	300	40.0
184129-3	10.0	UCDp	90	-	We	*	3400	850	2400	460	130	300	850	260	470	310	82	560	44.0
184129-2	10.0	SCDp	90	-	We	*	3000	2000	2300	510	250	380	2130	540	1400	710	230	1000	37.0
184129-1	10.0	SCDp	90	-	We	*	2600	1000	3500	430	160	590	1700	710	1400	630	340	540	40.0
184121	10.0[b]	Dp	87.5	2.5[g]	CO	-	4700	1990	5600	600	330	320	5410	1700	3050	910	290	910	33.0
184123	10.0[b]	Dp	87.5	2.5	CO	⊥	1740	520	2020	250	95	170	1130	510	890	365	100	430	34.0

(a) Monsanto PP-588 liquid phenolic resin.
(b) R-7248 (Rhelchhold Chemicals) phenolic resin substituted for PP-588 (Monsanto).
(c) Bagasse and process type identification:
UCW - unscreened, chopped, dry, mechanically whole bagasse.
SC - sieve cut between 10 and 32 mesh of UCW.
UCDp - Unscreened, chopped, depithed by 2% NaOH solution and wash.
SCDp - Screen of 10-32 mesh, mechanically chop, caustic 2% NaOH depith and wash.
(Dp) - Screening type depithing.
(d) CO - Centrifugally oriented.
We - Wet process during molding.
(e) * - Random fiber orientation.
- - Properties measured parallel to the fiber orientation.
⊥ - Properties measured perpendicular to the fiber orientation.
(f) Wet - represents total immersion in water for 72 hours.
W/D - Wet/Dry - represents total immersion in water for 72 hours, followed by 24 hours drying under ambient conditions.
Fa - represents falls apart - meaning no integrity.
(g) Montan (ester type wax) and paraffin wax in a 3:1 ratio; M.P. 69°C.

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Table 54

STRENGTH AND DURABILITY OF CHEMICALLY DEPITHED BAGASSE FIBERS WITH PHENOLIC RESIN

Sample ID MRC-DA	Composition[a] Bagasse[b] Fiber (Wt %)	Phenolic[c] Binder (Wt %)	Wax[d] (Wt %)	Tensile Strength (psi)	Tensile Modulus (psi, 10^3)	Water[e] Absorption	Flexural Test Data in psi: Dry Panels Strength (psi)	Dry Panels Modulus (psi, 10^3)	Soaked Panels[f] Strength (psi)	Soaked Panels[f] Modulus (psi, 10^3)	Wet/Dry Panels[g] Strength (psi)	Wet/Dry Panels[g] Modulus (psi, 10^3)
175482-1	90.0	10.0	-	1170	481	24.0	2500	312	1230	113	1800	218
175482-2	85.0	10.0	5.0	1630	992	19.0	5150	489	3680	229	5610	423
175482-3	90.0	5.0	5.0	2040	654	16.0	5820	517	4280	285	5100	492
175482-4	92.5	5.0	2.5	2690	851	17.0	6990	629	3140	286	5400	536

(a) Molding and Curing Conditions: Cured for 20 minutes under pressure at 350°F.
(b) Fiber prepared by soaking whole bagasse with 2% sodium hydroxide and 800% water for 2 hours, wet blending, washing three times with water, and finally drying in a circulating oven, i.e., pith removed.
(c) PF-588 liquid phenolic resin, Monsanto.
(d) Cascowax E40 EW emulsion, Borden.
(e) Following immersion in water for 24 hours.
(f) Soaking Time - 24 hours immersion in water.
(g) Wet/Dry Specimens dried in air for 24 hours after 24 hours immersion in water.

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APPENDIX D

JAMAICA WORKING GROUP TECHNICAL REPORT
ON BOB ROOFING RESEARCH AT
SCIENTIFIC RESEARCH COUNCIL

. Progress Report No. 2, Scientific Research Council, July 1976

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SCIENTIFIC RESEARCH COUNCIL
KINGSTON, JAMAICA

PROGRESS REPORT NO. 2

DATE: July, 1976

PERSONNEL: G.I.D. Williams

DISTRIBUTION LIST

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4. SELECTED MEMBERS OF ADV. COMMITTEE

   (a) A.A. Adams
   (b) T. Hughes
   (c) G.L. Ball

PROJECT TITLE: USAID/Monsanto Low Cost Roofing Project

PROJECT NO:

SUMMARY

The process for the production of a bagasse based roofing panel on a laboratory scale was outlined in the first Progress Report[1]. The purpose of this report is to present the results of tests performed on some laboratory pressed panels during the period April 1976 - June 1976 and to outline the findings during this period. The objectives during this period were to produce panels whose properties were similar to those produced by Monsanto Research Corporation (MRC) and to investigate the effectiveness of a bituminous aluminium paint as a waterproofing agent for the panels. The results indicated that the size and geometry of the bagasse fibres are critical factors in the production of a panel with properties equivalent to the properties of panels produced by Monsanto Research Corporation (MRC). A panel with suitable waterproofing properties has not been produced.

1. EXPERIMENTAL

Wet pressing of the panels was performed on the laboratory hydraulic press at Standard Building Products. This press does not have a temperature controlling device and the heat input to each platen is not the same. As a result the pressing temperature was nonuniform and could not be maintained at a constant level. The principal function of hot pressing is the application of heat for the polymerisation of the phenolic resin. The pressing temperature recommended by MRC is 163°C. However, the curing temperature for phenolic resins (liquid or powder) ranges from 121°C - 149°C[2] so that the pressing temperature is not critical provided it does not drop below 120°C.

.../2

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There were large fluctuations in the pressing temperature of the various panels produced; the mean temperature of the upper press platen ranged from 118°C 129°C while that of the lower platen ranged from 109°C 146°C. However, it should be noted that the work performed was mainly intended as a preliminary materials development study. A pressure of 245 psi was used during the hot pressing operation, the pressure recommended by Monsanto is 200 psi. The higher pressure used provides better contact of the bagasse particules thus reducing the effect of the low pressing temperature to a certain degree.

2. RESULTS

It was decided to perform preliminary water absorption tests on the first set of samples produced using a bituminous aluminium paint manufactured by Berger Paints Limited as the waterproofing agent. The results of these tests are presented in Table 1. The excessive water absorption resulted in delamination, warping and swelling of the panels. Delamination was particularly severe along the interface of the two layers of mat used in the panel construction.

Tables 2.1 and 2.2 give flexural modulus, tensile strength, water absorption and thickness swelling of panels made using coarsely chopped, unscreened, wet depithed bagasse fibres. The flexural moduli of the three panels produced by Scientific Research Council (SRC) were all appreciably lower than that of the Monsanto Research Corporation (MRC) samples. There appeared to be some loss of strength as a result of wax addition, the wax was added by impregnating the panel in a solution of wax dissolved in mineral spirit.

Table 3.1. and 3.2 give results of flexural modulus, tensile strength and water absorption tests. This set of samples was made using bagasse fibres that had been reduced to a finer particle size. These results were closer to the results obtained for the MRC samples with one exception. This was the result of the increase in thickness of the samples after 24 hours soaking in water followed by 24 hours drying in ambient air (permanent swelling).

3. DISCUSSION

3.1 WATERPROOFING and WAX SIZING

Water repellancy is provided primarily by the reduction of capillary flow in the panels. This capillary flow is a result of voids between the bagasse particles and cell lumen openings[3]. The waterproofing agents used (bituminous asphalt paint and wax) cannot enter the latter. Therefore the action of these agents is restricted to the voids which are composed of small capillaries whose paths are predominantly along the direction of orientation of the panels. The excessive water absorption of the "water proofed" panel that was completely immersed in water is due primarily to insufficient impregnation by the waterproofing agent.

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It will therefore be necessary to incorporate the extra waterproofing step of asphalt impregnation in the process unless Berger is willing to produce a special batch of high asphalt content aluminium paint. Sample 3 indicated that an appreciable amount of water was being absorbed along the edges of the panel. This highlighted the importance of using machining tools which would provide smooth edges during the trimming and cutting of the panels. It will also be necessary to seal the edges with asphalt after cutting.

3.2 PARTICLE SIZE

Particle geometry (shape and size) is an important factor in determining the properties of the panels: it influences the mechanical properties and the surface and edge appearance of the panels. Thin and small particles provide good particle particle contact thus enhancing adhesive bonding. This affects panel strength and is indicated by the results of flexural modulus given in Table 2.1 and Table 3.1.

The response of the panels to water is a vital property affecting such characteristics as water absorption, thickness swelling, strength, warping, delamination and surface appearance. Particle geometry controls this response to an appreciable extent. There were no appreciable differences in the water absorption, swelling and flexural modulus for the two particle sizes used. However, there was considerably more delamination and warping in the panels made using coarsely chopped fibres. Photographs of the bagasse fibres used by MRC and the coarsely chopped fibres used by SRC are shown in Figure 1.

3.3 MAT MOISTURE CONTENT

The high level of mat moisture (approximately 65% based on wet weight) makes the bagasse fibres more pliable, thus producing a more compressible mat for pressing. High moisture content leads to good surface wetting characteristics thus promoting resin flow and transfer. It also provides rapid heat transfer resulting in a more complete cure of the phenolic resin. However, this excessive mat moisture led to long press times due to the necessity to remove all the free water before effecting the final cure; this took up to 8 minutes in some cases. Blisters also resulted in some cases because the moisture content had not been reduced sufficiently before effecting the final cure.

4. RECOMMENDATIONS and CONCLUSIONS

1. Panels with properties similar to the properties of panels produced by MRC can be made, provided that the particle geometry of the fibres used are similar.

2. Effective water proofing cannot be provided by using the bituminous aluminium paint only. It will be necessary to use either an asphalt impregnation step or a high asphalt content aluminium paint if this is available.

3. To effect a meaningful materials and process development programme it will be necessary to acquire a press with good temperature and pressure controls.

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TABLE 1

PRELIMINARY WATERPROOFING TESTS

Sample No.	1	2	3
Wt.% Resin	5	7	5
Wt.% Wax		0.5	
Wt.% Paint*	22.3		22.8
Av. Curing Temperature (°C)	153	138	136
% Water absorption	41+	43+	29°

* Bituminous Aluminium paint used

+ Complete immersion in water for 24 hours

° One end of the panel immersed to a depth of 1 cm for 24 hours.

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TABLE 2.1

PROPERTIES OF DRY PANELS

Sample No.*	Orientation	Flexural Modulus	Tensile Strength (psi)	Density (lb/ft³)	Wt.% Resin	Wt.% Wax	Av. Platen Temperature (°C) Upper	Lower.
S - 1.1	⊥	0.34		59	5	)		
S - 1.2	∥	3.65	417	59	5	)	127	146
S - 1.3	∥	3.16			5	0.5		
S - 2.1	⊥	1.68			5	0.5)	129	146
S - 2.2	⊥		596	61	5	)		
S - 3.1	∥	3.9		58	7	)	129	146
S - 3.2	∥	3.47			7	0.5)		
MR - 1	⊥	1.88		63				
MR - 2	∥	7.28		63				

* Samples labelled S - were made using coarsely chopped, unscreened, wet depithed fibres, MR - denotes Monsanto samples.
∥ Strip of material parallel to fibre orientation.
⊥ Strip of material perpendicular to fibre orientation.

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TABLE 2.2

RESULTS OF WATER ABSORPTION TESTS

	24 Hours Immersion in Water.		24 Hours Immersion in Water/24 Hours Drying in Ambient Air.		
Sample No.	% Water Absorption	% Swelling	% Permanent Swelling	Flexural Modulus (x 10^5 p.s.i.)	% Strength Retention
S - 1.1	49.8	36.9	21.4	0.34	40.5
S - 1.2	47.6	40.1	26.6	1.2	32.9
S - 1.3	50.4	40.1	26.5	0.73	23.1
S - 2.1	48.1	46.3	28.3	0.34	20.2
S - 2.2	41.7	39.7	24.9	0.35	
S - 3.1	48.3	29.9	22.7	0.91	23.3
S - 3.2	42.1	29.7	15.6	1.5	43.2

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TABLE 3.1

PROPERTIES OF DMT PANELS

Sample No.	Orientation	Bagasse Type	Wt.% Resin	Density (lb/ft^3)	Flexural Modulus (x 10-5 p.s.i.)	Tensile Strength (psi)	Average Platen Temperature (°C) Upper	Lower
MR - 3	‖	SWD	5	47.8	4.75	1142 (1)		
MR - 4	‖	S	5	52.1	3.82	1295 (1)		
MR - 5.1	‖	S	5	44.5	4.57	1689		
MR - 5.2	⊥	S	5	44.5	2.45			
S - 4	*	UWD	7	57.2	2.93	1079	118	109
S - 5	*	UWD	5	57.2	2.52	730	124	121
S - 6.1	‖	UWD	7	59.6	4.8		) 125	129
S - 6.2	⊥	UWD	7	59.6	2.2		)	
S - 7.1	‖	UWD	5	61.6	6.38	836	) 128	138
S - 7.2	⊥	UWD	5	61.6	2.27			

SWD Screened and wet depithed fibres
S Screened fibres
UWD Finely chopped unscreened, wet depithed fibres
* No fibre orientation.

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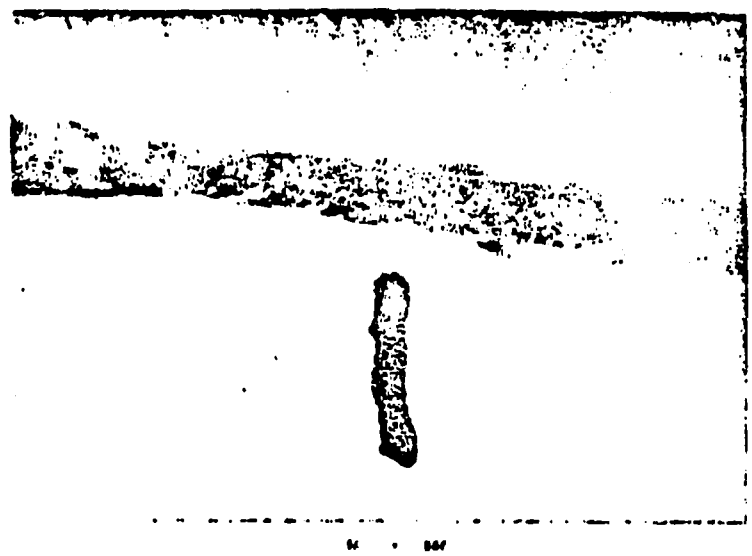
TABLE 3.2

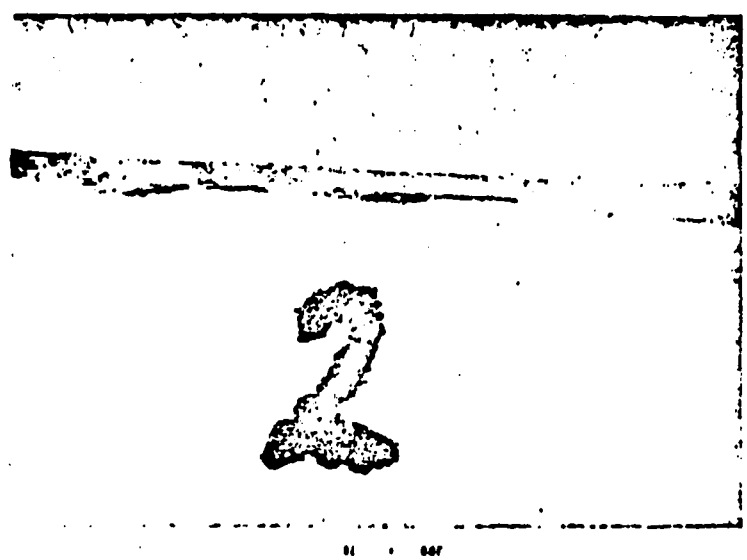
RESULTS OF WATER ABSORPTION TESTS

	24 Hours Immersion in H_2O		24 Hours Immersion in H_2O/24 Hours Drying in Air.		
Sample No.	% H_2O Absorption	% Swelling	% Permanent Swelling	Flexural Modulus (x 10^{-5} p.s.i.)	% Strength Retention
MR - 3	48.5	22.0	6.5	2.41	50.7
MR - 4	46.8	38.8	6.2	2.62	[illegible]
MR - 5.1	50.6	22.9	7.7	2.08	45.5
MR - 5.2	50.5	22.0	5.4	1.	40.8
S - 4	48.1	36.7	22.7	0.87	29.7
S - 5	51.6	36.9	22.7	0.58	23.0
S - 6.1	47.0	35.8	19.1	1.33	27.7
S - 6.2	45.2	38.3	26.6	0.44	20.
S - 7.1	46.1	38.6	21.5	1.70	26.6
S - 7.2	44.2	38.6	22.2	0.76	33.5

FIGURE 1 PHOTOGRAPHS OF THE TWO TYPES OF BAGASSE FIBRES USED.



(i) FIBRE USED BY SCIENTIFIC RESEARCH COUNCIL (SRC)



(ii) FIBRE USED BY MONSANTO RESEARCH CORPORATION (MRC)

...../10

REFERENCE

1. USAID/Monsanto Low Cost Roofing Project "Progress Report No.1", April, 1976

2. Spencer, A.G. & Lay, J.A. "Wood and Wood Products", Charles Merril Publishing Co. 1975.

3. Moslein, A.A. "Particleboard" Vol. 1. Southern Illinois University Press.

Prepared by: _____
G.I.D. Williams

Supervised by: _____

Approved by: _____
Technical Director

Date: 28/7/76

APPENDIX E

JAMAICA ADVISORY COMMITTEE TYPICAL REPORTS ON COMMITTEE ACTIONS, HOUSE SELECTION, AND ROOF CRITERIA

- Report on Selection and Analysis of Criteria for roofing materials, A. D. Adams: January 7, 1976
- Comments on Selection and Analysis of Criteria for roofing materials, A. D. Adams, July 16, 1976
- Letter A. D. Adams to Ministry of Housing, Roof Site Selection, July 16, 1976
- Letter Ministry of Housing to A. D. Adams, Roof Site Selection, July 21, 1976
- Advisory Committee Progress Report, December 10, 1976

DOUET BROWN ADAMS & PARTNERS

LOW-COST ROOFING STUDY FOR USAID

REPORT ON SELECTION AND ANALYSIS
OF CRITERIA FOR ROOFING MATERIALS

January 7, 1976

1.0 SCOPE OF THE REPORT

This report is intended to deal with the following:-

(a) Identify and discuss the basic requirements of a Roofing System in Jamaica, i.e. those requirements, which, if not met, would make the material quite unsuitable for the purpose, or those necessary to the basic function of a roof.

(b) Identify "Highly Desirable Characteristics" of a Roofing System and assign a weighting to each such characteristic.

The "highly desirable" characteristics would not necessarily be basic or essential requirements.

The weighting (marks out of 100) assigned to such a characteristic would fall between 60 and 100%.

(c) Identify, generally "Desirable Characteristics" for a Roofing System and assign weighting to each such characteristic.

These characteristics, though desirable, may also not necessarily be essential in a roof, especially a low-cost roof.

2.0 ROOFING CRITERIA

Basic Requirements

2.1 To Keep Off Rain

This is the basic function of deflecting rain water from the interior of a building. All candidate materials which are impervious will achieve this without difficulty.

2.2 To Prevent Leakage

This is the function of preventing seepage of water through cracks, laps, nailholes, etc.

To achieve this, the material must not be prone to cracking.

Nail holes should be self-sealing i.e. a driven nail should not create a hole which is larger than the nail's diameter, but should wedge its way through the material.

This latter problem can, however, be circumvented by the use of washers or gaskets.

2.3 To Resist Water

The material should not erode or become water-logged under the effects of rain.

2.4 To Resist Wind

It is essential that it should be able to resist frequently occurring winds and gusts, say based on at least five year recurrence interval.

It is, of course, 'highly desirable' to resist winds up to hurricane speeds, but it is often argued that this is not essential.

Wind resistance, of course, depends not only on the roofing material, but also on the spacing and strength of the support system. These can generally be adjusted at an increased cost to achieve the necessary wind resistance.

2.0 ROOFING CRITERIA CONTD.

2.5 Resist Incidental Loads

Here in the tropics, the main cause of super-imposed loading on pitched roofs is that caused by workmen during erection and maintenance.

The ability to support the weight of a man (plus some excess for dynamic effect) without failure or excessive deflection, is therefore essential.

It should be noted however, that this can sometimes be achieved with the help of temporary boards, etc. to spread such loads to supporting members.

2.6 Keep Out Direct Sun

The main requirement is opacity which is easily achieved.

2.7 Minimum Life

The importance of minimum life of the roofing material cannot be separated from that of cost; e.g. a life of two years might not be unacceptable, if the roofing material is of negligible cost e.g. thatch.

2.8 Availability

Obviously, availability in sufficient quantities is an essential requirement.

3.0 HIGHLY DESIRABLE CHARACTERISTICS

As mentioned before, the following characteristics are not essential to the function of a roofing material. However, the absence of any of these characteristics, would tend to make the material a poor candidate for selection.

The following is a discussion of such characteristics:-

3.0 HIGHLY DESIRABLE CHARACTERISTICS CONTD.

3.1 Acceptability to User

Although this is a somewhat subjective characteristic, it is fundamental and is assigned a weighting of 100%.

In Jamaica, the optimum material for this characteristic would be wooden shingles.

3.2 Low Cost

This is relative and an acceptable level of cost will often vary with other characteristics e.g. with long life, a higher level of initial cost can be accepted. A weighting of 90% is assigned to this characteristic. An optimum material for low-cost characteristics on initial cost would for example be thatch made of cane leaves.

3.3 Reasonable Life (5 year minimum)

For a commercially produced roofing material it is clearly desirable to achieve a reasonable life of the order of five years. However, as mentioned at item 2.7, where cost is negligible, for example, for a roof made by self help, and using very cheap, abundant materials which are available locally, a minimum life of less than five years might well be acceptable.

The optimum material for a long life would probably be aluminium sheeting.

A weighting of 90% is assigned to the characteristic of a 5-year minimum life.

All candidate materials, with estimated life of five years or over will be given full marks of this assigned weighting.

3.0 HIGHLY DESIRABLE CHARACTERISTICS CONTD.

3.4 Indigenous Material (>50%)

This is an economic and trade benefit, but it should be noted that if a large proportion of the "value added" to the basic raw material is derived in Jamaica, then an indigenous raw material content, of less than 50% might be acceptable.

For this characteristic, a weighting of 80% is assigned.

An optimum material for this characteristic would be say thatch, involving little processing and clay tile involving some processing.

3.5 Acceptability to Government

Although also vital, this is somewhat more objective and is a function of certain other characteristics such as indigenous content, load resistance, wind resistance, etc.

It is therefore assigned a weighting of 80%.

3.6 Fire Resistance

This is a desirable characteristic, but many traditional materials are poor performers in this respect; e.g. thatch and dry wood shingles will burn readily. Galvanised iron and aluminium will buckle under heat.

An optimum material for this characteristic would be clay tiles.

A weighting of 70% is assigned to fire resistance.

3.7 Easy Installation

Lightness, nailability, a minimum of fixings, large panel size, ease of cutting, resistance to breakage, stiffness to support workmen, are all characteristics which contribute to easy installation.

3.0 HIGHLY DESIRABLE CHARACTERISTICS CONTD.

3.7 contd.

An optimum roofing material for these considerations would be galvanised iron sheets.

A weighting of 70% is assigned to this characteristic.

3.8 Labour Intensive Manufacturing

This has a socio-economic benefit which is valuable for Jamaica. However, in aiming for "low-cost" houses, production on a "commercial scale" may be necessary and might demand the use of a mechanised manufacturing process.

An optimum material for this aspect would be clay tiles made by hand-operated moulds.

A weighting of 60% is assigned to this characteristic.

3.9 Dimensional Stability

It is highly desirable that a roofing material should be dimensionally stable under exposed weather conditions.

Excessive temperature and moisture movement will generally cause cracking - failure of the material at fixings.

However, it is often possible to solve this problem by the proper design of the profile and panel size and detailing of fixings and connections.

Optimum materials for dimensional stability would be metal sheets for moisture and a built-up felt roofing for temperature.

A weighting of 60% is assigned to this characteristic.

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS

4.1 Basic Requirements

(a) Must Keep Off Rain

(b) Must Not Leak

(c) Must Resist Water (i.e. Non-Absorbent)

(d) Must Resist Wind (Up to 70 M.P.H. Minimum)

(e) Must Resist Incidental Loads e.g. During Construction, Maintenance

(f) Must Keep Out Direct Sun

(g) Must Have a Minimum Life

(h) Must Be Readily Available.

4.2 Highly Desirable Characteristics

Item	Characteristic	Assigned Weighting
1	Acceptability to User	100
2	Low Cost	90
3	Reasonable Life (5 year minimum)	90
4	Indigenous Material (i.e. Indigenous Content $\geq$ 50%)	80
5	Acceptability to Government	80
6	Fire Resistance	70
7	Easy Installation	70
8	Labour Intensive Manufacturing	60
9	Dimensional Stability	60
	TOTAL	700

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS CONTD.

4.3 Desirable Characteristics of a Roofing Material

4.3.1 Roofing Material: Desirable Characteristics - Mechanical

Characteristic	Weighting Assigned to This Characteristic	Example of Rf. Material Securing Full Marks	Relevant Test Standard Where Applicable
1. Support a Person	100	-	
2. Hurricane Resistance	55	Depends on supporting structure	
3. Impact Resistance	50	Concrete Slab	
4. Provide Security and Protection	50	Concrete Slab	
5. Minimum Truss and Purlin Requirement	50	Corrugated Aluminium Sheeting	
6. Strength ($f_y Z$) (See also 2,3 and 4)	40	-	
7. Rigidity (EI) (See also 3)	40	-	
8. Resist Abrasion	40	Galvanised Iron	
9. Resist Earthquakes	40	Depends on roof arrangement	
10. Hold House Together	30	Concrete Slab Other Materials Depend on Framing	
TOTAL	495		

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS CONTD.

4.3 Desirable Characteristics of a Roofing Material contd.

4.3.2 Roofing Material: Desirable Characteristics - Environmental and Life

Characteristic	Weighting Assigned to This Characteristic	Example of Rf. Material Securing Full Marks	Relevant Test Standard Where Applicable
1. No maintenance within 5 years	70	Aluminium Sheets	-
2. Easy maintenance	80		-
3. Ability to nail, seal and cut	90	Bitumastic Tiles	
4. Lightweight	40	Aluminium Sheeting	-
5. No Toxicity during	50		
6. 10 Year minimum Life	80	Aluminium Sheeting	
7. Use of Simple Tools and equipment for Manufacture	50	Concrete Slab	
8. Resistant to Insects, Water and UV	100	Aluminium Sheeting	
9. Vapour impermeable	50	Metal Sheeting	
10. Re-usable	40	Metal sheeting	
11. Availability	100	G.I. or Alum. Sheeting	
TOTAL	750		

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS CONTD.

4.3 Desirable Characteristics of a Roofing Material contd.

Roofing Material: Desirable Characteristics - Optical

Characteristic	Weighting Assigned to This Characteristic	Example of Rf. Material Securing Full Marks	Relevant Test Standard Where Applicable
1. Keep out Sun	80	Coloured Aluminium Sheeting	
2. Opaque	80	- do -	
3. Attractive	40	- do -	
4. Shine	40	- do -	
5. Color	40	- do -	
TOTAL	280		

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS CONT'D.

4.3 Desirable Characteristics of a Roofing Material contd.

Roofing Material: Desirable Characteristics - Thermal

Characteristic	Weighting Assigned to This Characteristic	Example of Rf. Material Securing Full Marks	Relevant Test Where Applicable
1. Keep off Sun	100		
2. Resist Heat	100		
3. Ventilation	50	Wooden Shingles	
4. Thermal Control: retain heat reflect heat keep in heat keep out heat keep out cold keep in cold	90	Concrete Slab or timber boarding	
TOTAL	340		

4.0 SUMMARY OF SELECTION AND RANKING OF CRITERIA FOR ROOFING MATERIALS CONTD.

4.3 Desirable Characteristics of a Roofing Material contd.

Roofing Material: Desirable Characteristics - Acoustic

Characteristic	Weighting Assigned to This Characteristic	Example of Rf. Material Securing Full Marks	Relevant Test Standard Where Applicable
1. Not noisy in Wind or Rain	40	Concrete Slab	
2. Sound Absorbing	40	- do -	
3. Poor Sound Transmission	40	- do -	
4. Damping	40	- do -	
TOTAL	160		

A. D. Adams

DOUET BROWN ADAMS CONSULTANTS LTD.
CONSULTING ENGINEERS

7 LISMORE AVENUE, KINGSTON 5, JAMAICA, W.I.
TELEPHONE: 926-3485; 926-0046
CABLES: 'DOUETBRAD' KINGSTON

OUR REF:

YOUR REF:

July 16, 1976

Mr. George Ball,
Monsanto Research Corporation,
Box 8, Station B,
Dayton, Ohio 45407,
U. S. A.

Dear George,

Re: Low Cost Roofing Study for USAID

Further to my Draft Report "Selection and Analysis of Criteria for Roofing Materials", I have noticed from my files, that I failed to forward comments on my draft report, as requested from Fred Campbell and Ken Espeut. I had selected these two as I guessed that they were the ones most likely to spare the meticulous attention necessary for such detailed considerations.

I enclose a copy of the comments from SRC which were apparently prepared by Denny Williams. This is for your records as this aspect is somewhat superseded now.

One important point on which they both seemed to differ from me, is on my example of the optimum material for acceptability to user. You will recall that at Clause 3.1 I suggested "wooden shingles". I can also remember your surprise at this.

Well, both Fred Campbell and Ken Espeut disagreed. Ken suggested coloured aluminium. Fred did not identify an alternative. I maintain my original view. However, I admit that the lower permitted slopes and definite cost savings, has inexorably imposed the aluminium choice on house-builders against their own traditional preference.

Yours truly,
DOUET BROWN ADAMS CONSULTANTS LTD.

A. D. Adams

ADA/hb

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SCIENTIFIC RESEARCH COUNCIL
(Established and Maintained by the Government of Jamaica)

CABLE ADDRESS "SCIENTIST"
TELEPHONE: 937-0031-3

P.O. BOX 350
KINGSTON 6
JAMAICA, W.I.

YOUR REF.
OUR REF. 22/4 - 2

31st March, 1976

RECEIVED

Mr. A. Adams
Douet Brown Adams and Partners
7, Lismore Ave.
KINGSTON 5

Dear Al:

Thanks for the copy of your report on Criteria for Roofing Materials. Please accept my apologies for the delay in getting SRC's comments on the report to you.

I have enclosed a list of tables giving our values for the characteristics on which we are not in agreement.

Yours very truly,
SCIENTIFIC RESEARCH COUNCIL

G.I.D. Williams
Scientific Officer.

ATTCH.

GID/bb.

SCIENTIFIC RESEARCH COUNCIL

TABLE I

Highly Desirable Characteristics

Characteristic	Assigned Weightings	
	A.A.	SRC
Acceptability to User	100	
Low Cost	90	
Reasonable Life (5 Year Minimum)	90	
Indigenous Materials (50%)	80	90
Acceptability to Government	80	60
Fire Resistance	70	60
Easy Installation	70	80
Labour Intensive Manufacture	60	
Dimensional Stability	60	80

TABLE 2

Desirable Characteristics - Mechanical

Characteristic	Assigned Weightings	
	A.A.	SRC
Support A Person	100	
Hurricane Resistance	55	
Impact Resistance	50	
Provide Security and Protection	50	70
Minimum Truss and Purlin Requirement	50	80
Strength	40	
Rigidity	40	
Resist Abrasion	40	
Resist Earthquakes	40	
Hold House Together	30	

TABLE 3

Desirable Characteristics - Environmental and Life

Characteristic	Assigned Weightings	
	A.A.	SRC
No Maintainance Within 5 Years	70	80
Easy Maintainance	80	
Ability to Nail, Seal and Cut	90	
Lightweight	40	
No Toxicity During Manufacture	50	
10 Year Minimum Life	60	
Use of Simple Tools and Equipment for Manufacture	50	
Resistant to Insects, Water and U.V.	100	
Vapor Impermeable	50	
Re-Usable	40	60
Availability	100	

TABLE 4

Desirable Characteristics - Optical

Characteristic	Assigned Weightings	
	A.A.	SRC
Keep out Sun	80	90
Opaque	80	
Attractive	40	
Shine	40	
Colour	40	

July 16, 1976

Sites & Services Project,
Ministry of Housing,
2 Hagley Park Road,
KINGSTON 10.

Attention: Mr. Al Richards

Dear Sirs,

Re: Low Cost Roofing Study for U. S. A. I. D.
Experimental Roofs - Hunts Bay

Further to our recent meeting and exchanges, I confirm the following:

1. It had originally been decided to provide and fix roofing panels to four of the housing units which would be occupied by purchasers.

2. We had before considered it unwise to roof your model house with our experimental panels. This was on the grounds that prospective purchasers should preferably be able to view the typical roofing material for the project (i.e. the aluminium roof), on a model house.

   However, as you pointed out, for housing at this price level, this is unlikely to be an important consideration. Furthermore, one advantage would be to make the experiment more acceptable to house owners, who would subsequently be having a similar proto type roof.

3. With this in view, we have reproduced roof support details which are identical to those proposed by you for the conventional roofs. Only the panels will differ.

We enclose one copy of our drawings Nos. J43/1-4 which show Site Plan, Floor Plan, Roof Plan and Sections respectively.

.....2/

Ministry of Housing,
KINGSTON 10.

July 16, 1976

One of our main concerns at the moment is the fact that, although we were aiming for construction of the roofs in this month (July), this is no longer possible owing to delays in the program.

I would now consider that the earliest that these panels can be manufactured for erection is in late August to Mid September. I would suggest therefore, that if this delay will affect your programme, we could revert to our original plan to omit the model house from the experimental roofing program and select instead four other units in the project. We have marked a suggested location for these four houses on the Site Plan.

Finally, I invite your comments on our details, to ensure that it is in accordance with your own requirements. You will note that the roof slope which we have preserved could be considered shallow (1 in 12) for this type of lapped material. However, we feel that if the panels nest well, with the natural "bedding in" action caused by tight connections, the tendency to leak will be offset.

I look forward to your reply.

Yours truly,
DOUCET BROWN ADAMS CONSULTANTS LTD.

A. D. Adams

ADA/hb
encls.
c.c.: Mr. George Hall, Monsanto Research Corporation
Ms. Nadine Isaacs, Ministry of Housing
Mr. G. McLaughlin, Ministry of Housing
Mr. C. Laidley, Ministry of Housing

DOUET BROWN ADAMS
CONSULTANTS LTD.
CONSULTING ENGINEERS

7 LISMORE AVENUE, KINGSTON 5, JAMAICA, W.I.
TELEPHONE: 926-3486; 926-0048
CABLES: 'DOUETBRAD' KINGSTON

OUR REF:

YOUR REF:

Rcd 8/8/76

26th July, 1976

Mr. George Ball,
Monsanto Research Corporation,
Box 8, Station B,
Dayton, Ohio 45407,
U.S.A.

Dear George,

Re: Low Cost Roofing Study for U.S.A.I.D.
Experimental Roofs - Hunts Bay,

I enclose a photocopy of a letter received from Mr. Al Richards of the Ministry of Housing on the above subject. It is self explanatory.

Yours sincerely,

.....
Alfrico D. Adams
Douet Brown Adams Consultants
Limited.

ADA/cf

Encl.

DIRECTORS
A.D. ADAMS, C. ENG; M.I. STRUCT. E. • E.O. BROWN, C. ENG; M.I.C.E., M.I. STRUCTE. E. • L.M. DOUET, C. ENG. M.I. STRUCT. E.
A.A. DOVE, B.Sc., C.ENG. M.I.C.E. • C.D. WALLACE, C. ENG. M.I.C.E. M.I. STRUCT. E.
MEMBERS, INSTITUTION OF ENGINEERS, JAMAICA

ANY REPLY OR ENDORSEMENT REFERENCE TO THIS COMMUNICATION SHOULD BE ADDRESSED TO THE PERMANENT SECRETARY AND THE FOLLOWING REFERENCE QUOTED:-

No.

MINISTRY OF HOUSING
P.O. BOX 397,
KINGSTON 10,
JAMAICA

21st July, 19 76

Douet Brown Adams & Partners,
Consulting Engineers,
7 Lismore Avenue,
Kingston 5.

Attention: Mr. A.D. Adams

Dear Sirs,

Re: Low Cost Roofing Study U.S.A.I.D.
Experimental Roofs - Hunts Bay

We are in receipt of your letter dated July 16th, and drawings Nos. J43/1-4. Your letter indicated some misunderstanding of our project and I would like, at this time, to clarify those areas.

1. Except for a model house which we intend to build, we will not construct any completed units. Approx. 50% of the units will have a completed bathroom. Your roofing material can, therefore, only be applied to the model house or to some bathroom roofs.

ADA to clarify intended that material could be applied to roofs only on extension

2. The drawings that we supplied to you were done for our Camplands project and were meant only to be used as a guide, until such time that we had prepared a complete set of drawings for our Hunts Bay project. Although the concept is similar, some detailing changes have been made. In particular, the ridge detailing has been revised.

3. We note the preferred location for experimental purposes. However, we have not yet selected the location for our model house, but will nonetheless try to at least maintain the preferred orientation.

4. The delays in your programme is not likely to impede our programme at the moment. The project is due to be completed in March 1977, so that our model house need not be completed before that time. We believe that both units could be completed in 6 weeks barring all unforseen circumstances.

We thank you for your involvement in our project and look forward to hearing from you.

Yours truly,

Al Richards
Project Architect

RECEIVED

M E M O R A N D U M

TO: Members of Advisory Committee

DATE: December 21, 1976

FROM: A. D. Adams

RE: Alternative Roofing Material with Economic and Trade Benefits to Jamaica (Low Cost Roofing Study for USAID)

Enclosed is our latest progress report on the above.

A meeting of the Advisory Committee on the above is being held on Monday, January 24, 1977 at 10:00 a.m. in the Conference Room of the Scientific Research Council, Hope Road. I hope you will find it possible to attend.

Signed:.....
A. D. Adams
DOUET BROWN ADAMS CONSULTANTS LTD.

ADA/hb
encl.

IMPROVED ROOFING MATERIALS WITH

ECONOMIC TRADE BENEFITS TO JAMAICA

LOW COST ROOFING STUDY FOR USAID

PROGRESS REPORT TO ADVISORY COMMITTEE MEMBERS

DECEMBER 10, 1976

SCOPE OF THE REPORT

This report covers the period since the last Progress Report dated July 14, 1976.

It is intended to bring all members of the Advisory Committee up-to-date. There has been no meeting during this period although the Working Group has been involved in the day to day activities of the project.

Activities under the various "Program Tasks" as set out in the Advisory Committee Information Leaflet dated July, 1975 are summarised as follows:-

Tasks 1 and 2:	Organise Committee - Review R and D Work
Task Completed:	Mr. E. G. Gabay, member of the Incorporated Masterbuilders has been invited to serve on the Advisory Committee at this stage.
Task 3	Conduct Cost Analysis
Task Completed:	Note however, that Cost Analyses done so far, applied only to basic raw material costs for the purpose of comparisons at the stage of making a selection from candidate materials. The basic material cost of the selected material is estimated at 11 J¢ - 12 J¢ per sq. ft. (See Task 6). Approaches have been made to one of the Advisory Committee members, Mr. Roderick Rainford of the Ministry of Tourism and Foreign Trade to initiate an economic assessment of the proposed material from the perspective of net trade benefits to Jamaica.

SCOPE OF THE REPORT CONTD.

Task 3 — Conduct Cost Analysis contd.

This is necessary as at first glance a large proportion of the basic raw material cost (as opposed to volume) is in imported resins and although processing will represent considerable local "value added" this must be compared with existing competitive materials.

Task 4 — Conduct Exposure Analysis

This is a continuing process of observation on samples on the exposure-rack at Berger Ltd. The detailed exposure-monitoring methods of Berger Ltd. have provided invaluable assistance in this during the past eighteen months.

Tasks 5 and 6 — Conduct R and D Program and Optimise Process Techniques

Since the July report, work has continued in both the Scientific Research Council, Jamaica and Monsanto Research Corporation, U. S. A.

In September, 1976, Mr. George Ball of M.R.C. announced that further work on the "Oriented Bagasse Fibre" panels had prompted a change from the selection of the OBF panels to the Dry Blended Phenolic-Bonded Bagasse.

It was found that the fire-resistance criteria set could not be met with the OBF panels without additional fireproofing and waterproofing which would push the price up to a level equivalent to the previously discarded candidate materials.

Monsanto had decided that in view of the naturally superior appearance and fire and water-resistant properties of the Phenolic Bonded Alternative, it was [illegible] this change.

Task [illegible] — [illegible]

SCOPE OF THE REPORT CONTD.

Task 8 — Design Roof and Product

It is generally accepted that the corrugated sheet form of any of the materials will give the best strength to weight ratio. However, in the case of the Dry Blended phenolic-bonded material, there are certain technical difficulties in moulding to a corrugated form due to the dry powdered state of the material before pressing.

It was decided by Monsanto therefore, that in order to meet the deadline of getting some samples up mainly for weathering and durability purposes in a pilot demonstration programme, flat sheets would be produced for laying as large shingles. This is definitely not the optimum design of this product from a cost or performance point of view.

Collaboration between MRC and the University of Seatle, Washington, established a 4.0 ft. x 2.0 ft. x 0.08 inch sheet as a unit size with a material density of 85 lbs per cu. ft.

However, for practical reasons to do with the local make-shift moulding arrangements, etc, this was changed to 4'-0" x 2'-2" x 0.11 inch by our Local Working Group.

Task 9 — Define Construction Details

Arising from work done by Washington University, the proposal was to lay the 4 ft. x 2 ft. shingles with a 50% lap on to purlins or laths spaced at 11.0 inch centres. However, in order to improve the simplicity of the setting out on site, panels were changed from 2'-0" to 2'-2" wide to permit lath centres of 12".

SCOPE OF THE REPORT CONTD.

Task 9 — Define Construction Details contd.

Each tile is fixed by two rows of nails with the rows 12" apart. Nails are driven at 6" centres. The intention was that the downslope edge of each shingle would be unfixed and would just cover the row of nails below. However, as the roof design selected was that of an existing design with a very shallow slope it was necessary to consider fixing this lower edge also.

Flashing, ridge caps, etc. were similar to the Hunts Bay Sites and Services design.

Advisory Committee members who wish illustrations or drawings showing the actual details used, may apply to Douet Brown Adams Consultants Ltd.

It should be noted once again that the above would be misleading in considering the long-term economics of the material, as a final corrugated version would aim for very similar fixing and support details to conventional corrugated metal roofing.

Task 11 — Determine Criteria and Select Site for Experimental Roofs

Completed — The site selected was the Hunts Bay Sites and Services Project of the Ministry of Housing. The proposal is to construct approximately 3,000 sq.ft. of roofing on that project.

Task 12 — Fabricate Roofing Product

The major inputs on this have come from SRC, SBP, Goodyear and Monsanto for this stage.

SCOPE OF THE REPORT CONTD.

Task 12 — Fabricate Roofing Product contd.

The Scientific Research Council has provided technical personnel and laboratory facilities throughout. Goodyear has provided processing facilities consisting of two eight-hour shifts of Banbury processing of the whole bagasse and pigment:

(1) Monsanto has provided materials, technical direction and funding as main contractors on the project.

(2) Standard Building Products Ltd. have provided technical personnel, plant and space for the final pressing and finishing of the product.

The final quantities of shingle at this date are still being pressed.

Task 13 — Construct Four Roofs

It was decided to proceed by roofing a number of bathroom spaces on these units in perfecting the construction details.

We would then proceed to roof the proposed model house which was planned for construction in January/February, 1977.

To date eight such bathroom spaces have been roofed in two clusters of four spaces each.

The first four units are numbered 65-68 (not 95-98).

MONITOR PERFORMANCE

The finished appearance and effectiveness of the first two spaces roofed proved less than satisfactory. The material exhibited a tendency to warp and to curl at the corners and this would definitely tend to effect the roofs overall ability to prevent leaking.
A number of devices were tried to minimise this effect for the remaining roofs done so far and some improvement has been effected.

However, it should be noted that these effects should be eliminated almost entirely in the final corrugated version of the product.

Monitoring will be undertaken on a continuing basis in the years ahead by Berger Paints Ltd. who have indicated their willingness to continue to provide their expert monitoring on the exposure samples and periodic inspection on any painted full-scale roofs.

CONCLUSION

We are at the end of this phase of the project and thanks to the tremendous efforts and co-operation of most members of the Working Group and Advisory Committee the following benefits have been gained:

1. The know how and technology of producing composite materials of the type considered here, has been largely transferred to our own Jamaican Sciantific Research Council and to a lesser extent to other co-operating firms.

2. Some of the products considered, have good possibilities for application as building and other materials, for purposes other than roofing in the future.

3. The principal objective to produce an "alternative roofing, material, with economic trade benefits", is not completely realised as there is still some further technical development work to be done. However, enough has been done to make it clear that this can and will be achieved.

One point that may be noted is that the words "low cost roofing" were the main motivating force in obtaining the active co-operation of many local participants and as the present selected product appears more to be "an equal cost alternative", there is a certain sense of having missed our objective.

CONCLUSION CONTD.

It remains for our local economic and trade administrators to confirm the value of this alternative and if necessary for the Scientific Research Council to press on with further development in an effort to produce a "low cost" version among the various formulations studied. MRC have also reported that further funding for the next phase should become available from USAID by mid 1977.

In short, in a very real sense, this should not be the end of the project but simply the end of one stage.

Signed:.....
A. D. Adams
DOUET BROWN ADAMS CONSULTANTS LTD.

ADA/hb

APPENDIX F

JAMAICA WORKING GROUP DEMONSTRATION PLANS, RESULTS AND FUTURES REPORT

- Jamaican Roofing Material Pilot Demonstration Program Details, September 6, 1976
- Jamaican Roofing Material Pilot Demonstration Program Details, November 12, 1976
- Kingston, Jamaica Roofing Demonstration Program Details; October 26, 1977
- Scientific Research Council News Release, October 24, 1977
- Test Report, Jamaica Bureau of Standards, November 24, 1976
- Letters and Photographs, A. D. Adams on Drewsland roof, December 1977

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DOUET BROWN ADAMS
CONSULTANTS LTD.
CONSULTING ENGINEERS

7 LISMORE AVENUE, KINGSTON 5, JAMAICA, W.I.
TELEPHONE: 926-3465; 926-0048
CABLES: 'DOUETBRAD' KINGSTON

OUR REF:

YOUR REF:

24th September, 1976

Monsanto Research Corporation,
P.O. Box 8, Station B,
Dayton, Ohio 45407,
U.S.A.

Attention: Mr. George Ball

Dear George,

Re: Low Cost Roofing Study
for U.S.A.I.D.

Enclosed is a copy of the program circulated to all participants listed on page 1 as you requested.

Denny Williams and I have visited Goodyear to discuss arrangements and things are well in hand. I will send you a resume of arrangements made, in time for your return to your Ohio Office in mid October.

Please note that Goodyear prefers to do the Banbury processing on Friday, 29th October, at 7:a.m. However, they are prepared to continue beyond the eight hour day if it is necessary.

Yours truly,
DOUET BROWN ADAMS CONSULTANTS LTD.

A. D. Adams

A. D. Adams

ADA/cf

Encl.

c.c. Mr. Ival Salyer, Monsanto.

DIRECTORS
A.D. ADAMS, C. ENG. M.I. STRUCT. E. • E.O. BROWN, C. ENG. M.I.C.E., M.I. STRUCT. E. • L.M. DOUET, C. ENG. M.I. STRUCT. E.
A.A. DOVE, B.Sc., C.ENG. M.I.C.E. • C.D. WALLACE, C. ENG. M.I.C.E. M.I. STRUCT. E.
MEMBERS, INSTITUTION OF ENGINEERS, JAMAICA

JAMAICA

ROOFING MATERIAL

PILOT DEMONSTRATION PROGRAM

(Revised 6th September, 1976)

1. FIBER REINFORCED PHENOLIC DRY BLEND ROOFING MATERIAL

(a) Pilot Run - Compounding: 25-29 October 1976 (Morant Bay)
(b) Pilot Run - Molding 1-30 November 1976 (Spanish Town)
(c) Roof Fabrication: 15-30 November 1976 (Hunts Bay STS)
(d) Experimental process studies: 1 September - 25 October 1976 (SRC)

1.1 PARTICIPANTS

1.1.1 Douet Brown Adams Consultants Ltd. 926-3485
Alfrice T. Adams, Roofing Project Coordinator

1.1.2
1.1.2 Scientific Research Council 937-9931
Technical Director
Fred E. Campbell, Senior Principal Scientific Officer
Uran Bowen, Scientific Officer
G.I.D. Williams, Scientific Officer

1.1.3 Standard Building Products 984-2295
Ralph N. Corning, Jr., President
Douglas Wynter, Technical Director

1.1.4. Goodyear Jamaica Ltd.
William R. McKenzie, Managing Director 926-8018
Richard R. Greene, Production Director 982-2353

Helmut Schueller, Technical Superintendent

1.1.5 Ministry of Housing 936-1590
Rev. Gerald L. Mclaughlin, Special Adviser to the Minister.

Ms. Nadine Isaacs, Architect
Al Richards, Hunts Bay Sites & Service Supervisor 923-6226

1.1.6 Berger Paints
Dervin R. Brown, Technical Manager
Ken Espeut,

1.1.7 University of the West Indies (Physics Department) 927-0751
Dr. Thomas Hughes, Professor of Materials Science

1.1.8 Bureau of Standards 926-3140
Dr. A.S. Henry, Director
Mr. Campbell, Head, Materials.

...../2

1.1.9 U.S.A.I.D. Mission to Jamaica 932-6340
Nick J. Mariani, Program Officer

1.1.10 Monsanto Research Corporation (USA) 513-268-3411
TWX 810-459-1681
George L. Ball III, Project Leader USAID Roofing
Ival O. Salyer, Program Manager

1.1.11 Jamaica School of Agriculture
Dr. Aston Wood, Principal
Mr. Lee-Sang, Supervisor

1.2 SOURCE OF MATERIALS

1.2.1	Whole Bagasse (20% water)	) Std. Building Products
1.2.2	Baled Bagasse	) School of Agriculture
1.2.3	Phenolic Molding Power	)
1.2.4	Iron Oxide Pigment	) Monsanto Via
		) Scientific Research Council
1.2.5	Penta Stabilizer	)
1.2.6	Poly bags	) Standard Building Products
1.2.7	Mylar Sheet	) Monsanto via SRC
1.2.8	Aluminum plates (3 ft. x 10 ft.)	Std. Bldg Products

IDENTIFICATION (PREFERRED MATERIALS OR EQUIVALENTS)

1.2.1 Bagasse sun and air dried to 20% moisture, unprocessed
1.2.2 Bagasse baled and tied into hay blades (~25 lb/cu. ft.)
1.2.3 PR 736 dry molding power, Monsanto Co.
1.2.4 Mapico# 477 Iron Oxide red or equivalent
1.2.5 Technical grade pentachlorophenol, Monsanto Penta
1.2.6 ~55 gallon size PE or PVC bags
1.2.7 Heavy duty Mylar sheet (42 in. wide)

1.3. MATERIAL REQUIREMENTS

		Weight Parts	%	Banbury lbs.	Final lbs.
1.3.1	Baled whole bagasse(dry weight)	203	63	3100	2835
1.3.2	Phenolic power	100	31	x	1395
1.3.3	Iron Oxide Pigment	19.4	6	300	270
1.3.4	Penta stabilizer	0.16	0.05	2.5	2.25
1.3.5	Process water	40	-	620	x
	TOTAL	362.56	100	4023	4502.25

4.2 lb packages PR736

Basis

4 houses x 750 sq. ft.	=	3000 sq. ft.
Double coverage (x 2)	=	6000 sq. ft.
Area utilization	=	46% (2 ft. x 4 ft. panel)
Minimum area needed	=	6522 sq. ft.
Assume ~20% losses	=	7800 sq. ft.
7800 sq. ft. x 0. 58 lb/sq. ft.	=	4500 lbs of material for panels
Actual use	=	3800 lbs.
Density	=	1.36 (85 lb/cu. ft.)
Thickness	=	0.08 in.
Panel size (finished)	=	2 ft x 4 ft
Areal density	=	0.57 lb/sq. ft.

1.4 PROCESS STEPS

1.4.1 Have all materials designated in 1.3 available

1.4.2 Air dry bagasse to 20% moisture content from the 50% as it comes from the sugar mill.

1.4.3 Transport dryed bagasse (ca. 5000 lbs wet weight) to baler at School of Agriculture.

1.4.4 Bale whole low moisture bagasse into "hay bales" of ca. 1. ft. x 1.ft. x 3. ft.

1.4.5 Transport baled bagasse to Standard Building Products for dry storage.

1.4.6 Five to seven days before processing of bagasse at Goodyear Morant Bay sample at least 10 bales (handful from each from center), weigh each sample, dry overnight at 100°C, then re-weigh immediately upon removal from oven. Calculate % moisture $\left(\frac{Wt._{initial} - Wt._{final} \times 100}{Wt._{initial}}\right)$ of each sample and report individual and average results.

1.4.7 Three to Five days prior to run at Goodyear deliver the baled bagasse (item 1.3.1, c.a. 4500 lbs), pigment (1.3.3) and penta (1.3.4) to receiving at the Goodyear Plant, Morant Bay and notify H. Schueller, Technical Superintendent.

Banbury 1.4.8 Goodyear is to put together a process based on their best judgement for handling the system and is to set up to handle the bagasse and powdered products, i.e. chute, bags, drums, etc.

1.4.9 The following are process steps proven to work on small equipment.

1.4.9.1 Use water jacketed and cooled banbury intensive mixer (assume 440 lbs size but start with a 300 lb charge).

1.4.9.2 Clear banbury of excessive residue.

1.4.9.3 Turn on banbury

1.4.9.4 Add 150 lbs of baled bagasse (180 lbs wet) to banbury (item 1.3.1) and pressurize to compact.

1.4.9.5 Add slightly pre-blended iron oxide (1.3.3) 28.6 lbs, and penta (1.3.4) 0.25lbs. (Caution: handle penta with care, it is highly toxic if ingested).

1.4.9.6 Mix in banbury until volume reduced (1 to 2 minutes). Determine if additional water needed.

1.4.9.7 Add additional 150 lbs of baled bagasse (180 lbs wet) to banbury.

1.4.9.8 Continue mixing for additional 1 to 2 minutes.

1.4.9.9. Drop banbury charge through chute to poly bags (100 lb each) and tie.

1.4.9.10 Check processed material for fineness of fibers and degree of mix. Fibers small and red.

1.4.9.11 Repeat steps 1.4.9.3 through 1.4.9.10 until 4000 lbs of bagasse and pigment have been processed.

1.4.9.12 Repeat steps 1.4.9.3 through 1.4.9.10 omitting step 1.4.9.5 (pigment addition) until 1000lbs of bagasse have been processed.

1.4.9.13 Make sure all poly bags are sealed by ties to prevent moisture pick up.

1.4.10 Transport processed bagasse to Standard Building Products, Spanish Town for dry storage. Identify as "Banbury Bagasse Pigmented" and "Banbury Bagasse".

1.4.11 Sample 10 bags at random and determine moisture content as in item 1.4.6

7. Drying — 1.4.12 If moisture content is greater than 3%, dry all material in ovens at 75-100°C for 8 to 16 hours until moisture content is reduced to less than 1%. Sample and test to validate.

1.4.13 Bag dryed Banbury bagasse to keep out moisture and keep sealed.

Dry blend 1.4.14 The next part of the process includes the dry blending with a phenolic resin and molding into 2 ft. x 8 ft. x 0.08 in panels (to be cut to 2 ft. x 4 ft. panels and drilled).

1.4.14.1 Make available low speed bulk mixer.

1.4.14.2 Weigh out a convenient quantity of the banbury bagasse (pigmented) for the mixer to be used, correcting weight for moisture content (if any.)

1.4.14.3 Weigh out the equivalent amount of phenolic powder (Item 1.3.2), i.e. 31 lbs in 69 lbs of 1.4.14.2

Note: Since the actual molding is to be 2.5 ft. x 9 ft. x 0.08 in, which should weigh 12.75 lbs, the initial charge to the mold should be 14 lbs (110%). Thus blends having integral sizes would be desirable and convenient.

1.4.14.4 Add 1.4.14.2 and 1.4.14.3 to blender and mix thoroughly. Should require only a few minutes.

Note: This should not be done more than 2 hours ahead of molding unless blend is put back into bags to eliminate moisture pick up.

1.4.14.5 Weigh out portion for 1 - 2 x 8 ft. panel, i.e. 14 lbs.

Molding

1.4.14.6 Prepare "dry casting" mold consisting of a supporting layer of aluminium (3 ft. x 10 ft.), a sheet of heavy duty mylar (42" x 10 ft.), a box frame with an inside dimension of 2.5 ft. x 9 ft. and a thickness of 0.24 in.

Note: A release agent (Mold Wiz E-6) should be sprayed onto the Mylar Sheets.

1.4.14.7 Distribute 1.4.14.5 around inside "dry casting mold. Rake level and fine level with thin traversing sheet.

Note: This step is one of the most critical in the process, especially since it must be done manually. Great care should be used to ensure an even density distribution over the entire mold. Low density areas will not mold properly resulting in a reject part.

1.4.14.8 Remove thick (0.24") box frame and replace with thinner stop frame (0.08 in x 2.5 ft. x 9 ft. inside).

1.4.14.9 Cover mold with second sheet of Mylar (42" x 10 ft.) and aluminium sheet (if this seems desirable)

1.4.14.10 Transfer mold VERY CAREFULLY to the [illegible] of the [illegible] press and line up for insertion.

1.4.14.11 Preheat press to 275°F and adjust pressure for 3 ft. x 10 ft. area to be at least 300 psi.

1.4.14.12 Shuttle filled mold into press and immediately apply pressure.

1.4.14.13 Hold pressure for 2 minutes (time to be adjusted as results dictate) then drop to near zero (50 psi) to vent water and volatiles for 30 seconds, then reapply full pressure for additional 10 minutes. (First time hold for 25 minutes to assure molding then with experience decrease to 10 minutes).

1.4.14.14 Release pressure, open mold and have vacuum shuttle pick up mold and part (if possible all at once).

1.4.14.15 Transfer part from press, strip away mylar and inspect.

Sizing

1.4.14.16 Trim part into 2-2.0 x 4.0 ft. panels. Sand if necessary for smooth edges.

Best Available Document

1.4.14.17 Drill holes into panels in number and spacing according to drawings to be provided by Alfrico Adams.

1.4.14.18 Repeat 1.4.14.2 through 1.4.14.17 until 850 - 2 ft. x 4 ft. panels have been prepared (~425 cycles).

1.4.14.19 Cut a to be specified quantity of panels into 2 ft. x 2 ft. and 1 ft. x 4 ft. pieces to be used at roof transitions.

1.4.14.20 Stack and store panels in a dry area until Ministry of Housing is ready for them.

1.4.14.21 SRC is to take 10 - 2 ft. x 4 ft. panels for evaluation at SRC, UWI, JBS, Berger and MRC.

1.5 ROOF INSTALLATION

1.5.1 Select specific house and substructure that is to be roofed.

1.5.2 Get detailed drawings for house.

1.5.3 Modify drawings to incorporate roof consisting of 2 x 4 ft. flat panels.

1.5.4 List changes, additions and possible problem areas such as transitions. Indicate how ridge, edges, etc. are to be handled being very specific.

1.5.5 Get Ministry of Housing approval for design.

1.5.6 Determine dates construction at stage where roof can be installed.

1.5.7 Set necessary details into motion to have roof installed.

(a) order components for transitions
(b) order nails
(c) order other materials
(d) make labor available
(e) discuss details with job supervisor and emphasize importance of project and results.

1.5.8 Have roof or roofs installed with detailed supervision at all times and recording of results onto 35 mm slide film.

1.6 METHODOLOGY

1.6.1 Alfrico Adams of DBA is to co-ordinate the entire project and is to handle the specific details of the actual roofing job (item 1.5).

1.6.2 G.I. Denny Williams of SRC is to co-ordinate all aspects of the Material and Process requirements described in items 1.2, 1.3, 1.4 and to finally assist in item 1.5.

1.6.3 George Ball of MRC has gotten agreement from all participants and co-ordinators to co-operate in their various tasks provided we are able to minimize individuals problems and keep resonable schedules.

1.6.4 It is anticipated that the banbury work will take (including getting ready) one week, the molding 1 month, and the construction 2 to 3 weeks for a total elapsed time of 6 to 8 weeks.

1.6.5 Standard Building Products will handle transport and supply of all bagasse. They will provide facilities and manpower for all aspects of the process items in 1.4.14. Will provide aluminium sheets and box and step frames for pressing.

1.6.6 Goodyear is to provide all aspects of process items 1.4.8 through 1.4.9.13

1.6.7 SRC is to provide analytical testing support for moisture content, preliminary blending and molding of panels in the lab, technical support, drying, (item 1.4.12) if necessary and supporting labor to assist in the overall process implementation.

1.6.8 George Ball will be available for supervision to cover process steps 1.4.8 through 1.4.14.17 and thereafter within reason. Hopefully time and scheduling will also permit supervision on the roofing construction itself (1.5).

1.6.9 The School of Agriculture, near Spanish Town, has agreed to bale the necessary bagasse in their Massey-Ferguson hay baler. SBP will take bagasse to them for baling

1.6.10 Alfrico Adams is to co-ordinate and implement all aspects of the roofing construction (1.5). He will work through Al Richards at the Ministry of Housing.

1.6.11 George Ball is to have items 1.3.2, 1.3.3 and 1.3.4 shipped to SRC for future transfer to Goodyear and SBP. Actual quantities will be respectively 1600 lbs, 300 lbs, and 10 lbs. Also to provide a roll of 42". Wide heavy duty Mylar sheet, Mold Wiz E-6 Release Agent and 50 lbs. of Magnesium Oxide Pigment.

2. <u>ORIENTED FIBER COMPOSITE PROCESS</u>

2.1 Since the OFC still looks promising, whether for roofing or interior panelling, it should be further explored at SRC with assistance from SBP and residual bagasse from Goodyear.

2.2 All necessary equipment for a laboratory run now exists and will soon be operable at SRC, i.e. extractor, defibrillator, press and miscellaneous accessories.

2.3 With the processing of bagasse (item 1.4.9.12) properly defibrillated bagasse will be available. It will need to be screened and/or washed to be readied for further processing.

2.4 A large quantity of PA-2 liquid phenolic resin is on the way to SRC.

2.5 George Ball will assist in making large flat oriented panels at SRC and SBP if all equipment is in working order and as time allows during items 1.2. through 1.5 It is expected future AID funding may also allow further work on this process, but nothing can yet be committed.

JAMAICA

ROOFING MATERIAL

PILOT DEMONSTRATION PROGRAM

(12 November 1976)

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1. This information updates the information distributed 6 September 1976 concerning the roofing development project. It incorporates the events during the visit of George Ball 28 October thru 12 November and includes the critical plans to complete the roofing demonstration.

1.1 The only change in participants is that John Crafton is now Managing Director at Standard Building Products.

1.2 The key particpants for the final stage of the demonstration are:

Alfrico Adams, Douet Brown Adams Consultants
Douglas Wynter, Standard Building Products
Denny Williams, Scientific Research Council
Al Richards, Ministry of Housing
Ken Espeut, Berger Paints
Tom Hughes, U.W.I.
James Campbell, J.B.S.

1.3 Status

1.3.1 Summary

Briefly, to date all has gone as planned with a few minor problems. All bagasse has been processed in the banbury. A portion has been dryed and a molding process worked out at Standard Building Products. 26 in. x 48 in. x 0.1 in. shingles are being molded. A quantity of shingles to roof 100 sq ft were manufactured and a roof installed at the Hunts Bay Site and Service project. Thus an exposure study was initiated 11 November 1976 on a practical scale.

1.3 Status contd.

1.3.2 Fiber Preparation

An estimated 3,700 pounds of pigmented bagasse (on a dry-weight basis) was processed at Goodyear Jamaica, Morant Bay. The product is a mixture of bagasse/oil/pigment/penta (87/5.6/7.3/0.07) processed in a banbury. The oil is distributed over the defilbrillated fibers and the pigment and penta are also distributed and stick to the oil.

Batch size was 300 pounds (wet) 240 pounds dry) with a cycle time of 15 minutes. 15 good batches were prepared. Fiber bundle size reduction was less than desired with ca. 15% being too large, but in general a usable product was made.

1.3.3 Transport, Sizing, Drying and Blending

All usable material was transported to SRC, Old Hope Road. Bulk density estimated at 20 lb/ft^3 (dry basis).

A coarse fraction of fibers and agglomerates were observed in the banburyed product. Thus all material is to be sized through a 3/16 inch mesh metal screen at SRC. The agglomerates are groups of good pigment coated fibers that were formed due to pressure on wet hot product. The mechanical action of screening should break these up and make them usable. A 3 x 6 ft box frame has been fitted at SRC for this purpose. Initial observations indicated the coarse fraction to be about 15% by volume of our product. Probably a 10% weight loss reducing our yield to 3,300 pounds.

The drying procedure is exactly as used in the laboratory and is being conducted at SRC. The process consists of heating at 85°C in an air-circulating oven overnight. With only one oven our yield is 90 dry pounds per day which will provide material for 9-2.5 ft x 9 ft panels (18 - 26 in. x 48 in. x 0.1 in. shingles). This is presently the limiting step in our process (would require 30 days).

1.3 Status contd.

1.3.3 Transport, Sizing, Drying and Blending contd.

Blending with phenolic resin is conducted in a polyethylene bag by simple manual tumbling. The sticky fibers readily pick up the resin. Batch size is 14 pounds (9.8 pound pigmented bagasse/4.2 pound phenolic powder which is the charge size for one molding. The bag is sealed to prevent moisture pick-up. Sealed bags are delivered to Standard Building Products for molding.

1.3.4 Molding

Molding also is a direct scale up of the MRC-Dayton Lab procedure. The dry blend is first "cast" into a 2.5 ft x 9 ft x 0.25 in bagasse board frame that is laid flat on a 3 ft. x 10 ft. 18 ga (0.055 in.) aluminum sheet. The aluminum sheet is first treated with the EQ-6 Mold Wiz release agent. The "casting" procedure consists of dumping the 14 pounds of powder into the frame, distributing with metal spatulas until level, then packing with a draftsman's straight edge. This takes care and is tedious, but works and can be done in 20 minutes. After casting, the 0.25 in. frame is removed, an identical release agent coated plate is put on top, the plates are taped together and the package is sent into the press.

Actual thermal molding is done in SBP's 5 ft. x 11 ft. laminating press. Molding temperature is 135°C and pressure is 200 kp/cm^2 gage (estimated at 700 psi on the part). Total molding time is 17 minutes. The press is first closed (requiring 45 seconds), held at pressure for 30 seconds, then bumped open and closed (requring 50 seconds), and finally held at pressure for 15 minutes.

(If advantageous 5 minutes could be taken off the last 15 to reduce total time to 12 minutes.)

1.3 Status contd.

1.3.4 Molding contd.

A good molding is produced with a glossy surface on the bottom platen. Two inches around the circumference is low density and must be removed (potential 83% yield).

To minimize warping the newly molded parts are plyed between bagasse board until cooled. Some minor warping, however, remains a problem.

A 4 to 5-man team is needed for the molding operation.

1.3.5 Trimming to Shingles

Shingles are prepared by sawing two 26 in. x 48 in. plates from each molded panel (this is a yield of 77% based on molding powder cast). An 8 in. x 26 in. panel also results that can be used for testing and sampling. To trim, a straight line is drawn about 2 in. from the edge on a long side. A square is used to mark an end cut and center (48 in.) cut. The panel is first cut in two by hand, then machine cut to size.

1.3.6 Shingle Installation on Roof

The 26 in. width accommodates a 12 in. lath spacing of 1 x 3's. Thus the substructure consists of 1 x 3's running horizontally on 12 in. centres.

The shingles are nailable with galvanized clout-head 1.25 in. long nails. They are first nailed along a centre line (at 13 in.) using 4 nails equally spaced (none in centre). The top (at 1 in. down) is nailed after the nail first goes through another shingle at its centre line. 12 in. of shingle is exposed. Shingles are staggered so no edges line up. A regular 24 in. pattern side to side is used.

1.3 Status contd.

1.3.6 Shingle Installation on Roof contd.

Because the pitch of the roof was derived for continuous corrugated Al, it is much lower than desired for a shingle roof. Thus sealing will be used to prevent ingress of water due to wind and rain. This is achieved by trowelling a thin layer of Sealastic caulk over the nailed centre line before applying the next covering shingle. Slight pressure should be applied to form the seal.

Transitions and flashing are to be achieved with standard aluminum pieces. Painting red will be done for appearance.

1.4 Project Plans

1.4.1 Denny Williams is to supervise all drying, blending, molding and trimming.

1.4.2 Drying and blending is to be conducted at SRC.

1.4.3 Molding and trimming is to be conducted at SBP.

1.4.4 Denny Williams is to co-ordinate a molding schedule for the SBP laminating press with Doug Wynter to minimize the days required for molding of the roofing panels. Estimates now are for 200-250 moldings. A rate of 15-30 per day should be practical. Thus 15-20 days will be required. See item 1.4.2.4.

1.4.5 Denny Williams is to co-ordinate the drying process to maximize output from this limiting step. Since 30 days (nights) will be required, weekends should be utilized if at all possible. Alternatively, additional oven space could be used if found.

1.4.6 All panels should be molded by 17 December with partial deliveries for roofs as they can be made available. There are 25 week-days available between now and 17 December (35 calendar days). See item 1.4.14 and 1.4.24.

1.4 Project Plans contd.

1.4.7 The possibility of using 52 in. wide panels instead of 48 in. should be considered to increase yield from 77 to 83%. Alternatively, after sufficient 8 in. x 26 in. samples are made (40) the casting frame could be reduced to 2.5 ft x 8 ft 4 inches.

Alfrico Adams should resolve this.

1.4.8 Alfrico Adams is to draw and itemize simple roof shingle details for a typical roof.

1.4.9 Review and analysis of the first roof at 95-97 Hunts Bay Site and Service is to be set up with SRC, Berger and Richards at M of H participating.

1.4.10 Possibility of covering 2 or 3 4-bathroom sets (each totalling approximately 200 ft^2) is to be considered by Adams and Richards to facilitate getting maximum exposure time from panels.

1.4.11 Roofing of one (1-1/2) model house is to be planned for but will probably occur in late January or early February 1977.

Assumption is that this will require 1,000 ft^2 of roof (2,200 ft^2 of shingles) or 260 shingles.

1.4.12 Roof plans should be based on availability of 500 shingles (until better estimates can be made). See item 1.4.24.

1.4 Project Plans contd.

1.4.13 Based on the roofing installation conducted 11 November at 95-97 Hunts Bay 24 shingles are required per 90 sq ft of roof area (i.e. a good conservative estimate is a yield of 3.75 sq ft per shingle). This includes trim losses, breakage, etc. since the shingle is 26 in. x 48 in. (8.67 sq ft) we achieved a 43% shingle area utilization (3% short of a caluclated 46% yield).

1.4.14 Referring to 1.4.10 covering 2 4-bathroom sets should require 3 x 50 = 150 shingles. This is 75 moldings. Producing panels at the intial start up rate (9 per day) Denny Williams should be able to have these panels made by 26 November (2 weeks). Assuming additional time for trimming, etc. they could be delivered to M of H by 1 December. This is to be the major number 1 goal.

[By producing 15 panels per day only 5 molding days should be required which should fit in with SBP other requirements for the laminating press.]

1.4.15 Alfrico Adams should coordinate and provide information and supervision (Earl the carpenter) for installation of the roofs at Hunts Bay.

1.4.16 Ken Espeut of Berger Paints is to be notified by Alfrico Adams when the third roof is completed. Ken is to then proceed to plan the painting on this one roof. Ken is to select the paint preferably a light color with high relfectivity. Berger will install the paint, keep records and evaluate results periodically. Treatment of and/or weathering of the roof for 30 days should be conducted to remove release agent from the molded shingle surface.

1.4 Project Plans contd.

1.4.17 Ken Espeut should arrange to evaluate all installed roofs at least once montly for the first 4 months then quarterly to the first year and finally annually. Comparison to the phenolic bonded bagasse samples that have been on exposure at Berger should be made and especially any deviations noted. [The fence panels do not contain penta.] Of primary interest is surface durability, distortion, swelling, mold growth (inside and outside), cracking, warping and otherwise general performance. Evaluation should be tailored to roof rather than just "coating" performance. Records should be kept by Berger and copies mailed to Alfrico Adams and George Ball. Any severe problems should be noted immediately and results sent to George Ball for review.

1.4.18 The M of H personnel should also review performance and pass on comments, either positive or negative to Alfrico Adams.

1.4.19 Alfrico Adams should request financial assistance from USAID Jamaica to conduct the review coordination for a period of years.

1.4.20 Denny Williams is to install a simple outdoor thermometer on a rafter in each of the "house sets" and as well in one "house" covered with corrugated aluminum. Enough measurements (daily for 1 month) are to be made to establish a comparison. Hopefully site supervisors could record these on a record sheet provided by Denny. This information is to be passed on to Alfrico Adams.

1.4.21 Copies of this entire document are to be sent to all participants by Alfrico Adams by 19 November.

1.4.22 A cover letter and Sections 1.1, 1.2 and 1.3 of this document are to be sent to all committee members by Alfrico Adams. The fact that we are moving from a research into a development stage should be noted and their future participation for review is requested.

1.4 Project Plans contd.

1.4.23 Sample roof shingles are to be delivered to Ken Espeut by George Ball for their evaluation with paints and fence exposure (by 12 November).

1.4.24 After completing item 1.4.14 Denny Williams is to concentrate on providing shingles for the Hunts Bay Model House (item 1.4.11). Depending on the roof area (1000 to 1200 ft^2) this will require 260 to 320 shingles (this is a project total of 470 shingles - 1800 sq ft of roof covered, 235 moldings, 3290 pounds of molding powder and 2310 pounds of screened dryed pigmented bagasse. Referring to items 1.3.2 and 1.3.3 just enough material should be available.)

1.4.25 M of H should be encouraged to provide the labor for installation of the roof on the Hunts Bay Model House with support via item 1.4.15 included as an additional charge.

1.4.26 The Hunts Bay Model House roof should be designed to maximize the performance and beauty of the flat shingle. Consideration should be given to using 13 in. x 24 in. shingles on 6 in. lath centers and increasing the roof pitch to let the roof be seen and reduce possibility of water ingress.

1.4.27 The demonstration panel fabricated by Earl for Alfrico Adams should be reconstructed with good shingles. This display should be presented to Al Richards at M of H for the purpose of demonstrating the roofing material to future potential users.

1.4 Project Plans contd.

1.4.28 Five tin trim panels are to be given to Tom Hughes at UWI and Jimmy Campbell at JBS for mechanical testing of flexural modulus, strength, etc. Properties are to be measured from both the bottom and top of the panel. Performance after immersion in water (24 hours and 170 hours) both wet and following drying are to be determined. This data should be sent to SRC, Alfrico Adams and George Ball Results would be appreciated by 6 December. In water immersion tests weighing should be conducted to determine actual weight percent moisture pick up based on the panel as received (probably with some level of moisture already in it).

1.4.29 Other tin trim panels are to be retained by SRC for possible future analysis.

1.4.30 SBP is to retain any panels, shingles, etc. that would be of value to future production, marketing, etc. plans. They have invested heavily in the pilot production and should have immediate advantage of results and conclusions. They should contact Bill McKenzie of Goodyear direct for assistance in future planning or production.

1.4.31 In discussion of the roofing product the word bagasse should not be used since it has a very negative connotation in Jamaica (about as bad as cou-dung). Giving the product a name that indicates it is a surable roofing product should be done. It is in fact (as hopefully time will show) a fiber-toughened phenolic high performance composite roofing material. Initial stress should also not be on low cost since it is more of an equal cost alternative roofing with primary advantage to reduced foreign exchange requirements. Names like Duraroof, Tough Cover, etc. should be considered.

1.4 Project Plans contd.

1.4.32 Sometime in November or December a press conference and/or release should be conducted - probably through the M of H staff. Suggested is the turning over of the experimental roof from Alfrico Adams, coordinator of the project, to Al Richards and Nadine Isaacs M of H architects for ministry evaluation. Included also, and credit should be given to SBP, Berger, SRC, UWI, Goodyear, Monsanto Research Corporation and USAID. Jamaican participation and involvement should be emphasized. That further development needs to be done should be included to indicate it is not yet available commercially. Item 1.4.31 should also be recognized.

Listing of items by particpant (primary) action.

Alfrico Adams - All

Denny Williams, SRC - All

Doug Wynter, SBP - 3, 4, 6, 14, 24, 30, 31, 32

Al Richards, M of H - 6, 7, 8, 9, 10, 11, 12, 14, 15, 18, 20, 24, 25, 26, 27, 31, 32

Ken Espeut, Berger - 14, 16, 17, 20, 23, 31, 32

Tom Hughes, UWI - 14, 20, 28, 29, 30, 31, 32

KINGSTON - JAMAICA

Roofing Demonstration Program
(26 October 1977)

1. This information updates the information distributed 12 November 1976, concerning the Low-Cost Roofing Demonstration. It incorporates the events during the visit of George Ball 17 through 26 October.

1.1 The objective of the visit was to (a) review the performance of the BRP roofs installed at Hunts Bay in November and December 1976, (b) construct, if possible, another roof from the BRP panels made in December 1976, (c) construct a roof from BOB corrugated panels made at Seattle, and (d) determine degree of interest and capabilities to proceed with a product development stage.

1.2 Participants - A number of key personnel have left Jamaica. However, active participants are still available and enthusiastic. They are:

Alfrico Adams - SMADA Ltd., 9260331

John Crofton - Std. Bldg. Products

Denny Williams - Scientific Research Council

Dr. Arnoldo Ventura - Technical Director/Chairman SRC

Ms. Nadine Isaacs - Ministry of Housing

Ken Espeut - Berger Paints

James Campbell - J. Bureau of Standards

J. A. (Tony) Blackwood - Thermoset Ltd.

Bob Tait - UWI

Bill McKenzie - Goodyear-Jamaica, Ltd.

2. STATUS

2.1 SUMMARY

2.1.1 The BRP reinforced phenolic roofing shingles installed at the Hunts Bay Site and Service housing project on 8 roofs (ca. 400 sq ft total) are performing well. No deterioration, other than an expected surface chalking, has occured. There is no visible mold, warpage, mechanical failure, swelling, water pick up or leakage (except where nails later added for flashing introduced unsealed holes).

2.1.2 Exposure samples at Berger Paints that have been outdoors since May 1975 continue to perform well. Only slight mold growth is observed on a few worn surfaces (none of these panels contain a fungistat).

2.1.3 Tests at SRC and Jamaica Bureau of Standards on the BRP shingles confirm the strength and water resistance. Accelerated aging results also were positive. Data is attached.

2.1.4 Another ca. 500 sq ft high pitch roof is to be constructed in the Kingston area (probably Central Village) within the next three weeks. Shingle size is to be 13 in. x 26 in. (1/4 that used at Hunts Bay) and lay up is to be like wood shingles (60% overlap). These BRP panels were manufactured at Std. Building in December 1976 under the supervision of Denny Williams, SRC.

2.1.5 A ca. 100 sq ft roof was fabricated at SRC on a shed using Roof Maker painted, oriented fiber (BOB) corrugated panels (6'10"x2'2"). Installation proceeded like any other roofing material using five nails for attachment and two period overlaps. (5 full and 5 half panels were required). This represents the lowest cost alternative available from this research program.

2.1.6 Considerable interest and enthusiasm exists in furthering the program to make either or both (BRP and BOB, of the roofing materials commercially available. Interest also exists in pursuing other applications for the materials.

2.1.7 Those organizations and individuals listed in Section 1.2 all agreed to participate in any future effort. Importantly, major commitments will be made when an AID-sponsored program is implemented. Assumed needed is product definition and development, process refinement, cost reduction and plant definition.

2.1.8 A press release was issued from SRC to the Agency for Public Information and the Daily Gleaner indicating the end of a successful phase. (See attached).

3. PLANS

A few items remain to be completed for the existing program. These will be coordinated by Alfrico Adams with SRC, SBP, M of H, and Berger.

3.1 A house needing a roof will be selected by Nadine Isaacs. A size of approximately 500 sq ft is desired to accomodate the remaining BRP shingles.

3.2 Denny Williams, SRC, is to ship the existing 26 in. x 52 in. shingles to Std. Bldg. Products.

3.3 John Crofton, SBP, is to see that the panels are cut into 4 - 13 in. x 26 in. shingles. The shingles can be stored at SBP or returned to SRC.

3.4 Having defined a house, Alfrico Adams is to rough a design using the shingles and a pitch of at least 1 ft in 4 ft. Double overlap is not required, but at least a 60% overlap is suggested and shingles should be staggered. (Average ~5.2 in. x 26 in.; thus ~600 shingles needed for 500 sq ft roof, or ~250 sq ft floor space house).

3.5 Alfrico Adams is to organize the construction of the roof and supply funds for materials and one carpenter. A second carpenter is to be provided at no cost by SRC. Denny Williams at SRC is to supervise the construction.

3.6 A press release is to be prepared and submitted by SRC promoting the installation of the new proven roofing material consisting of the cane fiber toughened plastic composite (bagasse should not be mentioned). Berger's excellent participation in providing exposure analysis should be included in this release. Photos should be taken and also sent to Monsanto.

3.7 Denny Williams, SRC, is to see that the BOB roof at SRC is repainted, the bottom 6 inches, the bottom edges, and the bottom side up 6 inches with the "Roof Maker" paint. This is to prevent wicking of water that hangs on the lower edge during a rain.

3.8 The carpenter at SRC is to finish off the roofing job by closing in the sides with BRP panels. The wood should then be painted to match the rest of the shed.

3.9 A. Adams should send any published information to G. Ball, Monsanto. Mission Director Lion at AID should also be made aware of any publicity.

3.10 A. Adams is to arrange a meeting between Dr. Ventura, SRC, and Tony Blackwood, David O'Keefe, and Carol Morin of Thermoset Ltd. to provide an interchange of interest. This will have to be after 7 November. Thermoset should have a preliminary proposal. Thermoset is at 67A Halfway Tree - Phone 92-96951.

4. THANKS

I wish to express my gratitude to a host of diligent and enthusiastic workers who made the roofing development project a success. The cooperation was unquestionable. I hope we can continue to work together for the betterment of Jamaica in 1978.

My sincerest regards.

George L. Ball

NEWS RELEASE

SRC passes milestone in developing roofing materials

Dr. Arnoldo Ventura, Chairman/Director of the Scientific Research Council today announced the successful completion of the research stages of a joint SRC/Jamaican Industry/USAID/Monsanto Research Corporation programme to develop alternative roofing materials and processes that utilize abundant Jamaican resources. Experimental roofing panels and roofs manufactured and installed in the Kingston/Spanish Town area passed their initial two-year outdoor exposure testing.

Two candidate roofing material systems were developed in the four-year programme. They are also projected to be useful for other areas of construction including wall and ceiling panels, table and counter tops, shutters and doors. These materials that range in indigenous content from 70 to 96 percent are tough, durable, colourful, water and fire resistant and have the potential for use both in very low cost and high performance roofing applications. Roof coverings anywhere from small individual wood-like shingles to large efficient corrogated sheets can be fabricated.

The materials consist of fibre-toughened durable resins that also have been proven in similar ventures in Ghana and the Philippines.

Two roofs were installed at the Hunts Bay World Bank Sites and Services Project in November 1976, and/a third was just installed at SRC under the supervision of SRC personnel and with technical support from Monsanto Research Corporation. A fourth larger roof is planned for the Kingston area later this month.

/....

The materials and roof panels were manufactered jointly at Goodyear Jamaica Limited, Morant Bay; the SRC Laboratories, Hope Road and Standard Building Products, Spanish Town under the supervision of SRC personnel with G. Denny Williams as the project technical supervisor. Roof sites were selected and provided through the Ministry of Housing by Nadine Isaacs and Al Richard, Architect.

Overall coordination of the roofing development programme was provided by Alfrico D. Adams of SMADA Limited, who tied together the various necessary local technical disciplines, industries and government agencies in support of a Monsanto Research Corporation, Dayton, Ohio, Contract to the US Agency for International Development, Washington, D.C.

George Ball, the Project Leader for Monsanto Research Corporation, stated in reviewing the results in Kingston this past week that " the successful completion of the research stage and the performance of the roofs, will provide the basis for recommending to USAID a further effort to include product development and process and performance optimisation. This effort, projected for 1978-79 would culminate in making a roofing product available to Jamaica that would benefit its economic position and create jobs."

Dr. Arnoldo Ventura also added that "the results of the programme illustrated very well the role that SRC has been playing and is amplifying with respect to increasing Jamaica's self-reliance. The fact that this programme is in its fourth year also illustrates that there is a finite, but foreseeable term in achieving the desired benefits."

Scientific Research Council
October 24, 1977

JAMAICAN BUREAU OF STANDARDS
CALIBRATION CERTIFICATE
TEST REPORT
NO (47) NJ-1

6 Winchester Road
P O Box 113
Kingston 10
Jamaica W I
Tel 926 3140

Sheet 1 of 2 sheets

This certificate/report is a correct record of the measurements and observations made. [illegible] information of those for whom the work was done and must not be used in whole or in part in any other way except with the [illegible] val of the Director of Standards. Misuse may lead to the penalties [illegible] the Standards Act 1968 [illegible] responsibility for any loss or damage which may be sustained as a result [illegible]

Tested for: SCIENTIFIC RESEARCH COUNCIL	Reference: BeAelle 852 Date Submitted: 24. 11. 76
Manufacturer: SCIENTIFIC RESEARCH COUNCIL	Serial No:
Product: Fibrous Building Boards	Specification:
Test Method: BS 4305 Appendix D BS 1811: P t 2: 1963	Ambient Conditions: 23°C 60% RelH. Test Laboratory: N/A

SUMMARY OF RESULTS

The above mentioned samples were tested to determine the following:

1) Mechanical properties

2) Physical properties

3) Accelerated ageing

The results of these tests are shown on sheet attached.

The sample was tested to BS 4305, Appendix D to determine its resistance to accelerated ageing. There were no visible cracks or defects as specified.

Copies: Library Lab. File ✓ Dept.Head Scientific Research Council.	Remarks:	Signed: [illegible] Position: [illegible] Date:

BUREAU OF STANDARDS

Fibrous Roofing Material

Scientific Research Council

BAN # 852 Test Sample	Mechanical Properties (Parallel to direction of orientation) Tensile Strength		Physical Properties						
			Density		Moisture Content	Water Absorption after 24 hours immersion	Swelling after 24 hours soaking	Water retention after 24 hours soaking and 24 hours drying	Linear expansion after 24 hours soaking and 24 hours drying
	psi	N/cm²	lb/ft³	kg/m³	%	%	%	%	ins
A	1702	12	74.91	1200	3	9.6	3	7.7	.030
B	1375	10	76.78	1229	0	9.6	6	6.8	0
C	2241	16	84.90	1360	3.4	9.0	4	7.4	005
D	2250	16	74.13	1187	3.3	8.8	6	9.2	0
E	2770	19	88.02	1410	0	6.5	4	12.7	0
F	2119	15	83.65	1340	1.9	9.4	2	7.0	0
Average	2075	14.5	80.[illegible]	1287	1.93	8.2	4	8.6	.007

SMADA CO., LTD.

(Wang Computers & Processing)
8 HOPE ROAD, KINGSTON 10, JAMAICA, WEST INDIES
TELEPHONE: 926-0331 • CABLES: ALADAMS KINGSTON

OUR REF.

YOUR REF.

30th November, 1977.

Monsanto Research Corporation,
1515 Nicholas Road,
Dayton, Ohio 45418
U. S. A.

Attention: Mr. George Ball

Dear George,

Re: Low Cost Roofing Study.

I enclose a couple of clippings of interest.

We have installed 450 sq. ft. of roof at Drewsland as arranged.

The community self-help workers asked for the remaining panels to extend this to another 200 sq. ft. on the remaining half of the building extension.

The final roof will probably look rather like a patch work quilt as at least half of one slope will be of some other material. However, we can make a virtue of necessity by considering such an area as a control for comparison of durability.etc.

I will send pictures when they are developed.

As we expected, your allocation of funds for materials etc. was exceeded but Denny Williams managed to arrange help from SRC.

The roof at SRC has performed very badly. The paint is very inadequate as waterproofing. Water soaks right through.

Ken Espeut confirms that the paint was mainly created for insulative and reflective properties and I am now about to advise Denny Williams to use the original bituminous aluminium paint which is a stock item at Berger.

Ken Espeut has indicated his preference for this latter paint in the light of the performance of a similar paint on the exposure fence.

/2.....

STRUCTURAL & CIVIL ENGINEERING ANALYSIS • PROJECT MANAGEMENT ANALYSIS

DIRECTORS: ALFRICO O. ADAMS, M.I. Struct. E., M.I.E.J., CHARTERED ENGINEER • SLATEL J. ADAMS

(2)

30th November, 1977.

Monsanto Research Corporation,

It is my view that the roof will deteriorate rapidly unless we improve its imperviousness.

Yours truly,

Alfrico D. Adams.
SMAMA CO. LTD.

AMA/sc.
Encls.

c.c. Mr. K. Espeut, Berger Paints Jamaica Ltd.
Mr. D. Williams, Scientific Research Council.

With the Compliments

of

SMADA CO., LTD.

Wang Computers & Processing

8 Hope Road
Kingston 10, Jamaica, W.I.

Cables:
Aladams Kingston

Telephone:
926-0331

New building products created here

BY C. ROY REYNOLDS

There has been a big breakthrough in the development of building materials from local raw materials. It involves the creation of products that have 60 to 96 percent local materials.

The Daily News has been informed that the products came after a four-year research programme carried out at the Scientific Research Council, with collaboration of local industry, USAID and Monsanto Research Corporation.

The new products have already been field tested and can be used in roofing, walls, ceiling panels, table and counter tops, shutters and doors.

Experimental roofing panels and roofs manufactured from the new materials were installed at Berger Park in Kingston and have passed the initial outdoor exposure tests.

The Daily News understands that bagasse is one of the chief components of the new materials. They are reported to be tough, durable, colourful, water and fire resistant, with potential for use "in very low cost and high performance roofing applications".

The material can be prepared in individual wood-like shingles, or in large corrogated sheetings.

Other installations of the materials have been carried out at the Hunt's Bay World Bank Sites and Services project in November last year, and at the Scientific Research Council at Hope. A fourth and large installation is due shortly.

The products themselves were manufactured jointly at Goodyear Jamaica Limited, Morant Bay; the Scientific Research Council laboratories at Hope, and the Standard Building Products plant at Spanish Town. Roof sites were selected and provided through the Ministry of Housing.

Commenting on the development, Scientific Research Council Chairman-Director, Dr. Arnoldo Ventura said "the results of the programme illustrated very well the role that the SRC has been playing and is amplifying with respect to increasing Jamaica's self-reliance".

Kingston Daily News Nov 22, 1977

SMADA CO., LTD.

(Wang Computers & Processing)
8 HOPE ROAD, KINGSTON 10, JAMAICA, WEST INDIES
TELEPHONE: 926-0331 • CABLES: ALADAMS KINGSTON

OUR REF.

YOUR REF.

8th December, 1977.

Monsanto Research Corporation,
1515 Nicholas Road,
Dayton, Ohio 45418
U. S. A.

Attention: Mr. George Ball

Dear George,

Re: Experimental Roof
Davidson Crescent,
Drewsland, Kingston

I enclose some unmounted transparencies of the experimental roof under construction. Due to our usual import problems there are no card mounts to be had in Jamaica at the moment.

They are somewhat over exposed due to my inexperience with the camera but some are usable.

Rafters are 2" x 4" pitch pine at 2 ft. crs. Laths are 1" x 2" at 6" crs.

Due to the elevated site it proved difficult to get view on the full roof. The couple of half hidden shots from a distance are unfortunately the worst.

On completion of the finishes etc. we will arrange to take another few more shots.

Yours sincerely,

Al Adams.

P.S. Could you send me back a print of these ?

AA.

ADA/sc.
encls.

STRUCTURAL & CIVIL ENGINEERING ANALYSIS • PROJECT MANAGEMENT ANALYSIS

DIRECTORS: ALFRICO D. ADAMS, M.I. Struct. E., M.I.E.J., CHARTERED ENGINEER • SLATEL J. ADAMS

Figure F-1. A house at Davidson Crescent, Drewsland, Kingston was roofed in November 1977 with 13 in. x 26 in. BRP shingles manufactured at Standard Building Products in December 1976 under the supervision of Scientific Research Council personnel.

APPENDIX G

GHANA WORKING GROUP DEMONSTRATION PLANS

- Ghana roofing material pilot demonstration program details, August 12, 1976
- Ghana roofing material pilot demonstration program details, October 25, 1976
- Ghana roofing material pilot demonstration program details, November 11, 1977

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GHANA
ROOFING MATERIAL
PILOT DEMONSTRATION PROGRAM
(Revised 12 August 1976)

1. FIBER REINFORCED NATURAL RUBBER ROOFING MATERIAL

(A) Experimental run Saturday, July 1976 (Accra)
(B) Pilot run - September 1976 (Accra)
(C) Experimental process May-July, 1976 (Kumasi)
(D) Roof fabrication - September 1976 (Kumasi)

1.1 PARTICIPANTS

1.1.1 Building and Road Research Institute, Kumasi — 4221/2

Kofi Obeng, Roofing Project Co-ordinator
J.W.S. de-Graft Johnson, Director
A. K. Chatterjee, Head Materials Division
Professor Kuffour, Chemistry, UST

1.1.2 Ghana Rubber Products, Industrial Area, Accra — 21771

Phil Westray, General Manager — Telex 2088

1.1.3 Ghana Sugar Estates Ltd. — 63424

Accra Office - Dim Vander Heeden, Managing Director

1.1.4 Reiss and Company (Importers), Accra — 65105

N.B.X.P.M. Meijer (to August 1976) — Telex 2040
J. Assenberg (after August 1976)

1.1.5 Forest Products Research Institute, Kumasi — 5770

F. W. Addo-Ashong, Director

1.1.6 Monsanto Research Corporation (MRC), Dayton, Ohio — 513-268-3411, TWX 810-459-1681

Ival O. Salyer, Program Manager
George L. Ball III, Project Leader, USAID Roofing

$\delta = 1.344 g/cc = 83.9 lb/ft^3$
$.01 in = 0.56 lb/ft^2$

1.2 Source of Materials

1.2.1	Natural Rubber	Ghana Rubber Products (G.R.P.) Accra
1.2.2	Sulfur	
1.2.4	Stearic Acid	
1.2.5	Zinc Oxide	
1.2.7	Pigment - Iron Oxide Red	
1.2.8	Magnesium Oxide	
1.2.6	Whole Bagasse	GHASEL
1.2.6a	Drying of Bagasse	BRRI
1.2.12	Antimony Oxide	
1.2.13	Aluminum Paint	
1.2.3	Chlorinated Paraffin	Monsanto via Reiss & Company - Mr. J. Assenberg
1.2.9	Flectol H	
1.2.10	A100 Accelerator	
1.2.11	Penta Stabilizer	

Identification (preferred materials or equivalents)

1.2.7 - Mapico #477 Iron Oxide red or equivalent
1.2.8 - Rubber grade magnesium oxide scavenger
1.2.6a - Baled clean dry (<0.1% moisture) sugar cane bagasse
1.2.12 - Ground Antimony Oxide fire retardant, KRLTS
1.2.13 - Acrylic or oil-based, aluminum flake commercial paint
1.2.3 - Chlorowax 40, Diamond Shamrock Company, 40% Cl.
1.2.9 - Flectol H powder or flakes, Monsanto antioxidant
1.2.10 - A100, Monsanto aldehyde amine accelerator
1.2.11 - Technical grade Pentachlorophenol, Monsanto Penta

1.3 MATERIAL REQUIREMENTS Formula 198015-1

			Wt Parts	Wt (%)	Mid-Aug (lb)	Mid-Sept (lb)
1.3.1	Natural Rubber	20	100	20.5	61.5	1642
1.3.2	Sulfur	5	46	9.4	28.2	752
1.3.3	Chlorinated Paraffin	30	42	8.6	25.8	688
1.3.4	Stearic Acid	30	1	0.20	0.60	16
1.3.5	Zinc Oxide	40	1	0.20	0.60	16
1.3.6	Dry Whole Bagasse	1	265	54.2	162.6	4343
1.3.7	Iron Oxide Pigment	50	15	3.0	9.0	240
1.3.8	Magnesium Oxide	20	15	3.0	9.0	240
1.3.9	Flectol H Stabilizer	95	.25	0.05	0.15	4
1.3.10	A100 Accelerator	65	1.5	0.31	0.9	25
1.3.11	Pentachlorophenol	42	0.1	0.02	0.06	1.6
1.3.12	Antimony Oxide	165	2.5	0.51	1.53	41
		Total	489.35	100	300	8009

Rubber @ 20¢ .08 = 6¢/ft² .16 = 12¢/ft² .12 = 9¢/ft² 353

1.3.13 Aluminum Paint ~250*
*quantity to cover 10,000 sq ft of surface

1.3.14 Antimony Oxide (to flame retard paint) 5

1.4 PROCESS

1.4.1 Have all materials available. Bagasse dryed to moisture content of less than 0.1%. Bagasse stored in plastic bags after drying to prevent moisture pick up.

1.4.2 Compound ingredients in the following order using a water-cooled banbury.

1.4.2.1 Turn on banbury.
1.4.2.2 Add 1/2 of the dry bagasse (1.3.6) to the banbury.
1.4.2.3 Add iron oxide and magnesium oxide pigments (1.3.7 and 1.3.8).
1.4.2.4 Mix penta (1.3.11) into chlorinated paraffin (1.3.3) in separate container.
1.4.2.5 Add paraffin and penta mixture to banbury [CAUTION: Penta is highly toxic].
1.4.2.6 Mix in banbury until volume reduced (~3 minutes).
1.4.2.7 Add remainder of dry bagasse (1.3.6).
1.4.2.8 Mix in banbury additional 3-5 minutes.
1.4.2.9 Add rubber (1.3.1), stearic acid (1.3.4), zinc oxide (1.3.5), Flectol H (1.3.9) and antimony oxide (1.3.12).

1.4.2.10 Mix for 3-5 minutes until well compounded and fibers not visible. May heat to 100°C and expel steam. Best to let the steam boil out.

1.4.2.11 Cool banbury to less than 125°C (preferably 100°C).

1.4.2.12 Add sulfur (1.3.2) and A100 (1.3.10).

1.4.2.13 Mix 2 minutes (or optimum mixing time for banbury).

1.4.2.14 Dump to holding mill and sheet off material to feed calender.

1.4.3 Calender compound into sheet of ~0.09 inches thickness (preferred but may skip if residual strain minimized).

1.4.4 Mold panels of appropriate size (minimum 30" x 40") in thickness of 0.08 inches ±0.01 at 160°C ± 3°C for 30 minutes (-0, +5 minutes).

1.4.5 Postcure panels at 90°C for 4 hours minimum (18 hour max.) on flat shelves.

1.4.6 If desired paint top (one) surface and edges with acrylic based flaking grade aluminum paint to which 2% by weight of solids of Antimony Oxide has been added. Thin-sprayed coat only.

1.5 ROOF INSTALLATION

1.5.1 Panels are to be nailed as a minumum to purlins with spiral aluminum nails with rubber seals. If desired, J bolts can be used but drilling of holes is then recommended.

1.5.2 Purlin spacing to be adjusted to maximize use of the 30" x 40" panel.

1.5.3 Panels to be laid up as shingles with complete overlap (double roof). Half panels will need to be used at ends.

1.5.4 Other details shown in attached 3 pages (JPRF-a,b,c) and to be worked out at time of installation.

1.6 METHODOLOGY

1.6.1 Kofi Obeng of Building and Road Research Institute is to coorindate entire project, assuring all materials are properly handled and get to appropriate places well on schedule. All (See 1.1) concerned are to be notified of expected schedule.

1.6.2 George Ball of MRC has gotten preliminary agreement from all participants to cooperate in their various tasks. G.R.P. has agreed to make July run at no cost and is estimating costs, if any, for September run (molding separate).

1.6.3 Obeng must arrange for availability of all bagasse by 29 April thru Ghasel and see that it is shipped to BRRI Kumasi for drying.

1.6.4 Obeng is to arrange to have bagasse dryed and stored in appropriate plastic bags. He is also to arrange for shipment to G.R.P., Accra.

1.6.5 George Ball will see that Monsanto items are shipped to Accra and Meijer will facilitate entry and get to G.R.P.

1.6.6 Obeng is to visit GIHOC, Footware Division, Kumasi to observe compounding and molding by 30 April.

1.6.7 Obeng is to set up with G.R.P. a time, before 10 May to observe compounding of rubber in banbury, calendering and molding at Accra plant to become familiar with process.

1.6.8 Obeng to make sure material is at G.R.P. for July run and is to be there to observe the entire process through molding.

1.6.9 Obeng is to keep ~50 lbs of calendered flexible sheet for curing studies at Building and Road Research Institute or F.P.R.I.

1.6.10 Panels molded at G.R.P. are to be placed outside on exposure fence at Building and Road Research Institute.

1.6.11 Obeng is to conduct curing studies on calendered sheet using temperatures of 150, 160, 170° C, times of 15, 30 and 45 minutes, and pressures of 200, 400 and 600 psi. Post-curing at 90°C for 30, 60 and 90 minutes is also to be examined. Samples of minimum 12 in. x 17 in. should be prepared in above tests (~0.10 in. thick).

1.6.12 Simple flexural specimens (0.1 in. x 0.5 in. x 6.0 in.) should be cut from molded samples of 1.6.11 and tested for flexural strength (and modulus) if possible.

1.6.13 Obeng is to arrange for all materials for run in September to also be observed by George Ball.

1.6.14 By June 15 Obeng is to see that 4 houses will be ready in Kumasi area on which roofs are to be constructed. Houses to be supplied through BRRI at no cost to roofing program.

1.6.15 Obeng is to see that proper roof substructure is constructed so that roofs can be installed in September.

1.6.16 Obeng is to get costs for all materials used and idea of conversion costs from G.R.P.

1.6.17 Acrylic paint is to be selected by consulting with qualified paint company.

1.6.18 de-Graft Johnson to inform appropriate government officials of plan, especially for roof installation in September.

1.7 MATERIALS SHIPPED

	Item	From	Quantity, lbs (sent)	Quantity, lbs (needed)	Date	To
1.7.1	A100 (1.2.10)	Akron	50	26	30 May 1976	Reiss-Accra
1.7.2	Flectol H (1.2.9)	Akron	50	5	30 May 1976	Reiss-Accra
1.7.3	Sunolite 240 (-)	Dayton	50	0*	18 June 1976	Reiss-Accra
1.7.4	Penta (1.2.11)	Dayton	25	3**	18 June 1976	Reiss-Accra
1.7.5	Chlorowax 40 (1.2.3)	Clev.	1000	715	3 Aug 1976	Reiss-Accra

*discontinued from product 26 July 1976
**remainder to be used in oriented bagasse product

MONSANTO RESEARCH CORPORATION *Inter-Office Correspondence*

FROM LOCATION : Dayton Laboratory CC :

DATE : 26 October 1976

SUBJECT :

REFERENCE :

TO : Ghana Roofing Demonstration Participants

Attached is a slightly revised information and action agenda for the roofing program, based on the one you received dated 1 October 1976. Will you please read through it to make sure you agree with it in all respects relating to your participation?

If there are any problems, please let me know directly through Louanne Douris at the AID Mission on Reng Road, Accra.

Regards,

George L. Ball III

dmt
Attch.

GHANA
ROOFING MATERIAL
PILOT DEMONSTRATION PROGRAM
(Revised 25 October 1976)

1. FIBER REINFORCED NATURAL RUBBER ROOFING MATERIAL

(A) Experimental run - 22-30 September 1976 (Accra)
(B) Pilot run - October-November 1976 (Accra)
(C) Experimental process - May-September 1976 (Kumasi)
(D) Roof fabrication - November 1976 (Kumasi)

1.1 PARTICIPANTS

1.1.1 Building and Road Research Institute, Kumasi — 4221/2

Kofi Obeng, Roofing Project Co-ordinator
J.W.S. de-Graft Johnson, Director
A. K. Chatterjeee, Head Materials Division
Professor Kuffour, Chemistry, UST

1.1.2 Ghana Rubber Products, Industrial Area, Accra — 21771

Phil Westray, General Manager — Telex 2088
Jiri Subert, Technical Manager

1.1.3 Ghana Sugar Estates Ltd. — 63424

Accra Office - Dim Vander Heeden, Managing Director

1.1.4 Reiss and Company (Importers), Accra — 65105
Telex 2040

Jan Assenberg

1.1.5 Forest Products Research Institute, Kumasi — 5770

F. W. Addo-Ashong, Director

1.1.6 Monsanto Research Corporation (MRC), Dayton, Ohio — 513-268-3411
TWX 810-459-1681

Ival O. Salyer, Program Manager
George L. Ball III, Project Leader, USAID Roofing

1.2 SOURCE OF MATERIALS

1.2.1	Natural Rubber	Ghana Rubber Products G.R.P.) Accra
1.2.2	Sulfur	
1.2.4	Stearic Acid	
1.2.5	Zinc Oxide	
1.2.7	Pigment - Iron Oxide Red	
1.2.6	Whole Bagasse	GHASEL
1.2.6a	Drying of Bagasse	BRRI or local company
1.2.3	Chlorinated Paraffin	
1.2.9	Flectol H	
1.2.10	A100 Accelerator	Monsanto via Reiss & Company - Mr. J. Assenberg
1.2.11	Penta Stabilizer	
1.2.8	Magnesium Oxide	
1.2.12	Antimony Oxide	

Identification (preferred materials or equivalents)

1.2.7 - Mapico #477 Iron Oxide Red or equivalent
1.2.8 - Rubber grade magnesium oxide scavenger
1.2.6a- Baled clean dry (<0.1% moisture) sugar cane bagasse
1.2.12- Ground Antimony Oxide fire retardant, KRLTS
1.2.13- Acrylic or oil-based, aluminum flake commercial paint
1.2.3 - Chlorowax 40, Diamond Shamrock Compamy, 40% Cl.
1.2.9 - Flectol H powder or flakes, Monsanto antioxidant
1.2.10- A100, Monsanto aldehyde amine accelerator
1.2.11- Technical grade Pentachlorophenol, Monsanto Penta

1.3 MATERIAL REQUIREMENTS [Formula 198015-1A]

		Weight Parts	Weight (%)	23 Sept (lb)	Oct-Nov (lb)
1.3.1	Natural Rubber	100	20.5	61.5	1230
1.3.2	Sulfur	46	9.4	28.2	564
1.3.3	Chlorinated Paraffin	42	8.6	25.8	516
1.3.4	Stearic Acid	1	0.20	0.60	12
1.3.5	Zinc Oxide	1	0.20	0.60	12
1.3.6	Dry whole bagasse	265	54.2	162.6	3252
1.3.7	Iron Oxide Pigment	23.8	4.75	14.25	285
1.3.8	Magnesium Oxide	6.2	1.25	3.75	75
1.3.9	Flectol H Stabilizer	.25	0.05	0.15	3
1.3.10	A100 Accelerator	1.5	0.31	0.9	19
1.3.11	Pentachlorophenol	0.1	0.02	0.06	1.2
1.3.12	Antimony Oxide	2.5	0.51	1.53	31
	Total	489.35	100	300	6000

1.5 MATERIALS SHIPPED

	Item	From	Quantity, lbs (sent)	Quantity, lbs (needed)	Date	To
1.5.1	A100 (1.2.10)	Akron	50	26	30 May 1976	Reiss-Accra
1.5.2	Flectol H (1.2.9)	Akron	50	5	30 May 1976	Reiss-Accra
1.5.3	Sunolite 240 (-)	Dayton	50	0*	18 June 1976	Reiss-Accra
1.5.4	Penta (1.2.11)	Dayton	25	3**	18 June 1976	Reiss-Accra
1.5.5	Chlorowax 40 (1.2.3)	Clev.	1000	715	3 Aug 1976	Reiss-Accra
1.5.6	Magnesium Oxide	Dayton	100	75	22 Oct 1976†	GRC-Accra
1.5.7	Antimony Oxide	Dayton	50	31	22 Oct 1976†	GRC-Accra

*discontinued from product 26 July 1976
**remainder to be used in oriented bagasse product
†Originally shipped 24 September, but refused by Pan Am in New York without notification to Monsanto.

1.6 ACTION ITEMS - October 1, 1976)

1.6.1 Ghana Rubber Company (GRC) is to banbury, sheet and mold one 40 kg. experimental batch of formula 198015-1 identical in Section 1.3 of the 12th August letter. [Done 23 September].

1.6.2 Based on results of 1. GRC is to process additional batches of the extent of available bagasse during the week of 27th September, 1976. [Done 1 October].

1.6.3 Panels 2 ft x 2 ft x 0.08 in. (61 cm x 61 cm x 2 mm) are to be molded by GRC and molds for the 6 daylight press are to be fabricated to allow this. [Done 30 September].

1.6.4 George Ball is to assist GRC in 1, 2 and 3. [Done 1 October].

1.6.5 R. Heirman of the Ghasel Sugar Mill at Asutsuare is to bag all processable bagasse available (approximately 125 bags) at mill and transport to GRC-Accra. [Done 29 September].

1.6.6 R. Heirman is to contact the Ghasel Mill at Komenda to determine if additional bagasse may now be available and to also have it bagged and shipped to GRC.

1.6.7 In October 4000 pounds (dry) or 8000 pounds (wet) of bagasse are needed. If 5 and 6 do not satisfy this need, program may need to be delayed until mills start in November.

1.6.8 If 7 is necessary, Phil Westray of GRC should contact Dim Vander Heeden of Ghasel, Accra to work out details and earliest delivery.

1.6.9 George Ball is to have shipped from USA, 50 pounds Antimony Oxide and 100 pounds Magnesium Oxide direct to GRC by 24 September. [See 1.5.6 and 1.5.7].

1.6.10 For next and larger production the Formula 198015-1 shall be revised as follows: Item 1.3.7 Iron Oxide Pigment is to be 4.75% (23.8 parts) and item 1.3.8 MgO is to be 1.25% (6.2 parts). [Done - See Section 1.3. Formula is now 198015-1A].

1.6.11 GRC is to process (banbury) 6000 pounds (2700 kg) of 10 and sheet ready for molding. Bagasse will be dried at kiln of local factory.

1.6.12 GRC is to mold at least 1950, 2 ft x 2 ft x 0.08 inch, panels from 11. This should total 7800 sq ft. Molding is to be at 160°C for 30 minutes.

1.6.13 Kofi Obeng of BRRI is to stay in contact with GRC to determine when panels are ready. Positive contact at least once a week.

1.6.14 At least 10 of the completed panels are to be shipped by air to George Ball at MRC for testing and analysis.

1.6.15 Unmolded sheets (at least 5) are also to be shipped to George Ball for molding into demonstration corrugated panels. One large rolled sheet 30 in. x 80 in. is also be be shipped for similar treatment.

1.6.16 Phil Westray, GRC is to report to George Ball any problem and/or the ease with which processing was accomplished and delivery dates. [See 1.6.17].

1.6.17 Communication to George Ball will be expedited by the USAID Mission to Ghana, Ring Road, Ms Louanne Douris or her staff through AID Washington, OST, Merrill Conitz.

1.6.18 26 molded panels are to be delivered to Kofi Obeng (or Mr. Chatterjee) at BRRI, Kumasi at the earliest possible time. One panel is for physical tests.

1.6.19 Item 18 is to be used to prototype a roof section, work out detailing, and provide an exposure panel to be placed at the exposure sight of BRRI. this should provide a 10 ft wide by 4.5 ft high roof section. One panel should be used to measure tensile, flexural, water pick up, etc at BRRI and U.S.T.

1.6.20 BRRI is responsible for designing a roof based on the 2 ft x 2 ft panels. Panels are to be drilled. 8 holes each 6 inches apart and 3 inches from each side. 4 holes on top are to be 1 inch down and the other 4 on center line. Panels are to be laid up as shingles in a staggered pattern so holes <u>must</u> match.

1.6.21 Having achieved a proper design (20) and demonstrated it (19) BRRI is to determine the best method for drilling holes using a pattern frame.

1.6.22 The remaining 1915 panels are to be shipped to BRRI-Kumasi. Transport is to be worked out between GRC and BRRI. The panels are to be stored inside at BRRI and protected.

1.6.23 BRRI is to drill the holes in the panels to make them ready for roof installation. NOTE - once the holes are drilled the panels cannot be repaired. Thus make sure all designs are correct before proceeding.

1.6.24 BRRI (Chatterjee, Okyere, Obeng, de-Graft Johnson, Neutsugah, Afele) are to select the houses on which the roofs are to be installed.

1.6.25 Strong consideration for houses is to be given to the Rural Housing Scheme of Mr. Afele discussed with George Ball, Okyere and Obeng on 27 th September. The whole houses and/or kitchen areas may be considered. Roof area should be less than 750 sq ft per house.

1.6.26 The equivalent of 4 houses are to be selected for roofing by BRRI.

1.6.27 BRRI is to construct the houses and install the roofing using the 2 ft x 2 ft panels making sure extreme care is taken to assure proper workmanship. Where transitions are required, aluminum fittings are to be used, but transitions should be minimized by design. Nails are to be flat head type at least 1.5 inches long and spiral grooved to prevent creepout. All nail heads are to be covered by overlapping panels.

1.6.28 BRRI (de-Graft Johnson) is to report all findings concerning roof construction, both favorable and unfavorable to George Ball at MRC. [See item 1.6.17].

1.6.29 George Ball is to be notified by de-Graft Johnson through AID (1.6.17) as to the schedule for construction of the roofs. This should take place in November 1976.

1.6.30 George Ball is to be in Kumasi during 1.6.29 to observe and assist, if schedules permit. The first roof should be fabricated before his arrival.

1.6.31 Kofi Obeng is to put together the elements for at least 2 displays showing the use of indigenous materials in roofing panels in Ghana. To be included are raw materials (small samples), banbury product, milled sheet, molded part, drilled part, etc. One display is to be used at exhibition in Accra (early 1977) to be put on by BRRI. Other for AID Washington. George Ball or AID will transport.

1.6.32 Display something like this:

Additives Pigment Bagasse Rubber	from Ghana
Banbury Product Milled Sheet Molded Panel Finished Panel	all manufacturing done in Ghana

Drawing and/or
photos of house

1.6.33 Phil Westray, GRC is to estimate the sales price of the panels as they were made. This information is to go to George Ball who will estimate cost of corrugated sheets and final roof. Prices are to be estimated and quotes are to be reserved for specific cases.

1.6.34 Dr. B. Biswas, Department of Chemistry, UST is to observe and provide support when necessary in his areas of expertise.

1.6.35 Kofi Obeng of BRRI is to get from FPRI (or other good source) wood shavings or sawdust (hardwood) to be processed by GRC. At least 200 pounds dry weight is to be made available. The wood residue is to be representative of Ghana sources, is to be well defined so more can be procured, and is to be reasonably fresh.

1.6.36 GRC is to process the wood residue into formula 198015-1A substituting it for the bagasse (item 1.3.6). But first instead of using 265 parts (54.2%) use 150 parts then proceed to use 265 parts if it seems possible. Mold 2 ft x 2 ft panels.

1.6.37 BRRI is to put a number of the 1.6.36 panels on outdoor exposure to determine their future potentials.

1.7 NEW ACTION ITEMS (25 October 1976)

1.7.1 George Ball is to have 100 pounds of Borden dry powder phenolic resin (Thor MD-820-92) shipped to BRRI. This will be sent as a sample through Swiss African Trading, P.O. Box 897, Accra (Mr. M. O. Afful).

1.7.2 Ghana Rubber Company processed approximately 30 kg of bagasse, pigment and penta on 1 October, identified as Formula 10176-B. This is to be used with item 1.7.1 in experimental work at BRRI on the phenolic bonded dry blend [31% 1.7.1 with 69% pigmented banburied bagasse].

1.7.3 Kofi Obeng is to experiment with molding of the phenolic bonded dry blend at BRRI. Molding is to be at 275°F (135°C) and mold release EQ-6 must be used.

1.7.4 Kofi Obeng is to report at least once every 10 days between 1 October and 15 December to George Ball through the AID Mission to Ghana (See 1.6. 17). Reporting is to be done to include work done or not done.

1.7.5 J.W.S. de-Graft Johnson is to confirm that house and roof plans are complete and that houses are under construction to be roofed. He is to notify George Ball of expected completion dates.

1.7.6 Items 1.5.6 and 1.5.7 were delayed by the airlines. Their lack of availability in Ghana may require rescheduling of some of the work.

1.7.7 As an immediate goal we should plan to have at least one roof up and complete by 15 November.

Ref: Ghana 11-11-77
Edited 12-28-77

GHANA ROOFING MATERIAL
PILOT DEMONSTRATION PROGRAM

Participant Information Memo

by

George L. Ball III

1. INTRODUCTION

This information updates the information distributed 25 October, 1976 concerning the Low-Cost Roofing Demonstration in Ghana. It incorporates the new events since that time, and those during the visit of George Ball, October 31 through November 12, 1977.

1.1 OBJECTIVES

The objectives of the visit by Mr. Ball were to (a) review the performance of the outdoor samples at Kumasi, (b) manufacture Bagasse Reinforced Phenolic (BRP) shingles at Ghana Rubber Products (as indicated in items 1.7.2 and 1.7.3 of the 25 October 1976 memo), (c) install at least one roof using the BRP shingles on a structure selected by BRRI, (d) examine use of wood residues in BRP shingles (item 1.6.35), (e) determine needs and timing to reactivate the Bagasse Reinforced Rubber (BRR) roofing shingle demonstration, and (f) define any continuing interest, future program, and the possible or probable participants.

1.2 PARTICIPANTS

Mr. Jeri Subert, Technical Manager at Ghana Rubber, who was a key participant involved in the past, has been replaced with Mr. Ivo Caganek. He is a well qualified rubber expert.

MRC's contact at the AID Mission now is John Cooper, Chief, Office of Science and Technology.

2. SUMMARY

Good results were achieved over the past year in Ghana, in spite of a massive fire in a warehouse at Ghana Rubber Products that disrupted their normal business and destroyed all raw materials that had been sent to them, and all BRR product produced in October 1976.

A 100 sq ft roof was installed at the Council for Scientific Industrial Research (C.S.I.R.) Secretariet grounds (ACCRA) on 9-11 November. The roof consisted of BRP shingles (10 in. x 20 in.) that were manufactured and finished entirely at and by Ghana Rubber Products between 3rd and 8th November 1977.

THE BRP shingle formulation was slightly modified from the standard by substituting mahogany wood shavings for 25% of the bagasse. A 50% level was also examined. Where flexural strength and toughness are required, such a substitution is not recommended. The fibrous bagasse performed best. No fiber character was retained in the wood because it was ground to dust. Borden's Thor Phenolic powder was used in the experiment.

The outdoor exposure samples at BRRI, Kumasi still are performing well. The BRR, BOB (painted) and phenolic clay - are all excellent. They show little wear and no mold growth. The BRP is showing mold growth, especially on the bottom side. A biostat will be needed. A corrugated unprotected BOB has been virtually destroyed through outdoor exposure.

Strong interest in the BRR system still exists at GRP and they will pursue it as soon as their new boiler is installed.

Availability of bagasse is a continuing problem that needs to be resolved.

Work will continue in Ghana during at least the next 6 to 12 months based on the interests at GRP and BRRI. The future cause of action will then depend on the results of this work.

3. ACTION ITEMS

3.1 GRP will conduct another small plant run to manufacture BRP shingles using 100 pounds of phenolic resin shipped from MRC. This should occur within the next four weeks and formulation A, only bagasse, should be used.

3.2 BRRI is to construct a second roof from the panels produced in 3.1 in the Kumasi area. Mr. Obeng is to coordinate with GRP and plan for a 100-120 sq ft roof.

3.3 BRRI/FPRI, in Kumasi, is to install their 4 ft x 4 ft hydraulic press and have it operating by 15th January, 1978. Steam heat to 160°C desired.

3.4 Once 3.3 is complete, Mr. Obeng is to experiment with BRP material from October 1976.

3.5 Mr. Obeng is to examine roof number 1 - BRP at CSIR, Accra; record comments in notebook, and re-examine monthly for one year.

3.6 Mr. Obeng is to establish and keep records on outdoor exposure samples at BRRI, Kumasi. He is to wire down these samples and add the new shingles.

3.7 Mr. Obeng is to determine the physical properties of the shingles made in November 1977, and to report the data to GRP and MRC.

3.8 Messrs. John Cooper and Phil Westray are to meet to discuss the program.

3.9 MRC will provide GRP proforma invoices for materials needed to make both the BRP and BRR materials. The amounts for 1 and 10 ton lots will be used.

3.10 GRP will compound more of the BRR system once a press is available to mold at either GRP or BRRI. The October 1976 formula will be used.

3.11 GRP and BRRI should obtain a supply of bagasse as soon as the sugar mills start operating. 5 to 10 tons should be stored and dried.

3.12 Mr. Obeng is to report by letter to Mr. Ball-MRC via Mr. Cooper, AID/Accra, as each of the above events occur, but at least once every two months.

3.13 Mr. Ball will notify all parties involved if and when funds are made available by AID/Washington for any future development effort.

4. DETAILS

4.1 BRP MOLDING POWDER MANUFACTURE

First, it was determined that the materials necessary to make panels to cover at least 100 sq ft of roof were available. Critical was bagasse (that had not been destroyed in the GRP fire), since the sugar mills were not operating, and the phenolic powder (100 pounds). The phenolic powder (Borden Thor MD-820-92, MRC P.O. D89680) was at BRRI, Mahogany wood shavings (hardwood residues) were found in a furniture plant next to GRP.

Three molding powder formulations were planned. They were designated (less resin): GH11477 -

	A	B	C	D
		(weight, Kg.)		
Wet Whole Bagasse*	36	-	18	27
Wet Wood Shavings*	-	36	18	9
Processing Oil-Light	1.6	1.6	1.6	1.6
Red Pigment	2.1	2.1	2.1	2.1
Pentachlorophenol	0.02	0.02	0.02	0.02
Total	39.7	39.7	39.7	39.7
Dry Wt.	28.9	28.9	28.9	28.9

*Assumes 30% by weight water

The above listed materials were processed in a 45-liter Banbury mixer. Compound A processing proceeded as expected taking a total of about 20 minutes. Compound C was then processed, but it was observed that refining of the wood required much more energy and time such that 30-40 minutes was used.

Compound A had intact, long bagasse fibers (even though a few percentage were a little large), whereas Compound C consisted of all finely ground bagasse and wood. Compound C would be easier to cast, but would not have the tensile strength of A. Accordingly, Compound B was not made and all but material for one molding of A and C were mixed together to form Compound D. They were mixed after large bagasse pieces were screened from Compound A.

The banburied Compounds A and C (two batches each) totaling 160 Kg were dried overnight (12 hours) in the steam heated oven at GRP. This oven was at 85°C and some steam leaks were evident. Problems with water were not observed except with the larger pieces of bagasse that were removed.

The banburied bagasse/wood Compound D (70 parts by weight) was dry blended with 30 parts of phenolic powder. This was done in a ~40 gallon drum partially filled with 10 Kg of compound (actually 3500 g Compound A, 3500 g Compound C, and 300 g Phenolic Powder).

4.2 MOLDING AND FINISHING OF BRP SHINGLES

The molding techniques and conditions were identical to those used in the MRC lab and production in Jamaica with the exception that curing times were decreased significantly.

The molds consisted of pairs of aluminum caul plates (1/8 in. thick x 28 in. x 28 in.). The casting frames were 28 in. x 28 in. x 0.38 in. plywood with 21 in. x 21 in. cavities cut into them. Only three sets of molds were used since this small amount of aluminum cost approximately $400.00.

The six caul sheets allowed two parts (four cauls) to be in the press curing while two were being cast on the remaining cauls. This proved to be most efficient resulting in a five minute total cycle time for a yield of 24 panels per hour (24 panels make 48 shingles).

A key to the relatively short total cycle time was the ability to reduce the press cure time to 1.5 minutes. This was achieved by incrementally reducing cure time from a proposed 15 minutes. Shorter times were not used only because they were impractical to time in the manual operation.

The caul sheets were first seasoned with Mold Wiz EQ-6 release agent. Before each casting they were wiped clean and sprayed with an EQ-6/alcohol (5/95) mixture (ethyl alchol from sugar cane).

The molding powder was weighed into polyethylene bags, each containing 1 Kg. This was the charge for one mold.

The molding powder was dumped onto the caul sheets with the wood frames and leveled by hand with straight edges. A crew of four did two of these every four minutes.

The panels were cured at 140°C for 1.5 minutes at 50 atmosphere pressure. A single molding each of Compound A and C were made which showed C to lack resistance to breaking by hand, whereupon Compound D was selected as the best compromise.

At least 140 panels were manufactured. Some of these were experimented with in reducing cure time. One hundred and twenty good panels were produced (333 sq ft). Thickness varied from 2.6 to 3.1 mm (0.10 to 0.12 in.). Panel weights were 0.7 lb/sq ft.

Molded panels were turned into shingles by first trimming to a 20 in. x 20 in. dimension with a circular saw and then cutting into two 10 in. x 20 in. pieces. Cutting was done after the panels were stacked into two piles and left to cool overnight. Some severe warpage of the panels was observed which may be due to a differential thermal contraction. Each panel warped in an identical manner implying a built in constant strain. This problem will not manifest itself when corrugated panels are made.

Wood type saws should be used for cutting since fine teeth cut very slowly. Trimming was actually done in the Modern Furniture, Ltd. plant adjacent to GRP, which was also the source of the wood shavings.

Cutting the panels into two pieces lessened the warping problem but did not eliminate it. The center of the parts were flatter and also seemed a bit thicker. More uniform mixing and molding may help reduce this problem.

4.3 ROOF SELECTION AND INSTALLATION

A site for an experimental roof was discussed with Dr. J.W.S. deGraft Johnson. Because available material was limited, the area of the roof could not exceed ~100 sq ft. By chance, the carpenters at the C.S.I.R. Secretariet, Accra, where Messrs. Ball and deGraft-Johnson met, were in the process of constructing a new security house to provide more room and reduce the high interior temperature, due to the corrugated iron used on the existing building. The building was 6 ft x 10 ft with a roof of 8 ft x 12 ft, with a pitch of 1 in 4.

Since the building needed the anticipated quantity and type of roofing shingles to be produced, Dr. deGraft-Johnson agreed to include it in the project, and arrangements were made to roof the building the week of 7 November after the shingles were manufactured. This roof being in Accra was highly advantageous vis-a-vis transport of shingles since transportation to Kumasi is most difficult. The only disadvantage of the Accra location is that it is not a place where BRRI personnel can see it every day. However, they should examine it at least monthly for the first year and record any obvious changes - and also its continued performance.

The building to be roofed was of wood frame structure with corrugated iron sheet siding. The new building is in the sun whereas the old one was shaded by a tree a good part of the day. Therefore, inside temperatures will be high.

The roofing system was to consist of ~10 in. x 20 in. shingles (to be known after finishing on 7 November). Accordingly, a staggered overlapped configuration was to be used. The shingles were to be nailed to purlins (battons) which were to be connected to rafters which were to be connected to two horizontal wood supporting beams.

Construction of the roof finally started November 9th. By 2:00 PM that day the rafters were installed and battons were being attached.

The rafters were rough sawn actual 2 in. x 4 in. hardwood spaced at 2 ft centers. Seven rafters were added for the 12.5 ft width, including a 3 in. overhang at each end. The purlins were rough sawn 0.5 in. x 2 in., selected by Mr. Ball, to be as uniform in thickness and as straight as possible. The purlins were spaced at 3.5 in. centers except that two were placed side by side at the bottom and top.

On future roofs at least 3/4 in. and preferably 1 in. purlins should be used. Additionally, 4.5 to 4.7 in. spacing can be used (just enough to cover the nail heads on the center line) with this size shingle.

Mr. George Ball supervised the installation of the first three rows of shingles. In the first row, a complete double coverage was used to force rain to drip from the furthest surface and not run down between the butted shingles.

The installation went without incident with attachment by 1.5 inch smooth surfaced large head nails. Actual roofing nails that are textured to prevent pull out are suggested but could not be found in Accra.

One very important consideration that was required to produce an attractive roof was to turn the mid-section cut of the shingle downward. The edges of the shingles were warped, whereas the center was not. Thus, the exposed flat side looked good when the warped side was nailed flat. If this was not done, some curling of panels was noted giving a "rustic" but for now a less desirable appearance. Attempts to explain this problem and its solution were generally unsuccessful. As soon as direct supervision by Mr. Ball stopped, the panels were installed mostly upside down. A shortage of shingles negated reinstalling improperly installed ones.

The installation of the roof was nearly completed by C.S.I.R. carpenters on November 11th. Each row required 7.5 shingles and there were 27 rows. This equalled some 206 shingles at a 35% utilization (intentionally low for the demonstration). The roof looks acceptable and should perform for at least ten years. The only problem foreseen is the possible pull out of the nails upon normal thermal cycling. Bending over the exposed nails would be preferred.

4.4 PERFORMANCE OF THE OUTDOOR EXPOSURE SAMPLES

Samples of BRP, BRR, BRT and BOB have been on outdoor exposure racks at BRRI, Kumasi, since April 1975. The panels are installed at a 10° pitch for maximum water and humidity exposure. A control bagasse PVC sample has completely deteriorated in the first year of exposure and has turned black with mold.

Mr. Ball inspected the samples on November 10, 1977. They all appear to be as in good a shape as a year ago, even the PVC has gotten no worse. The BOB and phenolic clay look excellent with no apparent mold growth and no surface deterioration, except a slight fading of the red color. The BRP is getting a fair amount of mold on the backside. The BRR has bent down between the supports, has no more surface abrasion than last year, and little apparent mold on the top side. The BRT are also not changed from a year ago - still having an excellent appearance. A corrugated BOB has swollen to where it is useless.

4.5 STATUS OF A BRR ROOFING DEMONSTRATION

All raw materials for the BRR system were destroyed in a fire at Ghana Rubber Products (GRP) in August 1977. Mr. Phil Westray said that GRP would buy these materials if MRC would supply Proforma invoices showing sources, costs, etc.

GRP's new higher temperature steam boiler has not yet arrived from Glasgow. It should be installed and operational in the first quarter of 1978. New, larger (102 cm x 102 cm) presses has been installed at GRP giving them added capability. GRP has also acquired a new Wabash press with electric heat for their lab. It has 18 in. x 18 in. platens and thus The BRR material can now be molded on a laboratory scale.

Support had been expected from BRRI and FPRI in Kumasi to mold BRR panels through their installing a two daylight 4 ft x 4 ft press (a new half size plywood press). BRRI and FPRI agreed to install the press two years ago and nothing has yet been done. Commitments to install the press within the next two months were again given to Mr. Ball by Messrs. deGraft-Johnson and Addo-Ashong. Mr. Ball said it must be done or any future effort at BRRI would not appear to benefit the overall program and its future.

4.6 BAGASSE AVAILABILITY

There is a lot of concern over the non-availability of bagasse from the sugar mills for this product. However, the bagasse is superior to all other candidates (including the wood as discussed in 4.1 and 4.2).

Presently, all bagasse is burned as fuel for the sugar mills. Some low grade fuel oils can be used to compliment the bagasse, but the boilers are not designed to take the rates and temperatures of burning associated with oil.

A possible alternative fuel is based on another AID-sponsored program to make charcoal from sawdust residues using pyrolysis. This charcoal could be used to fire the boilers, thus saving the bagasse for the roofing material. There is no good alternative to bagasse for the roofing and thus this problem must be resolved. However, it should not hinder progress on the project with respect to refinement of the processes and definition of viable roof material products.

4.7 GENERAL INFORMATION

A press release appeared in the Ghana Daily Graphic on Monday, October 31, reporting on the existence of the roofing project. This was issued by BRRI.

Mr. Ball met with Professor A. N. Tackie, Executive Chairman of C.S.I.R. and discussed the roofing program in detail. Mr. John Cooper, US-AID, set up this meeting especially since Mr. Tackie was going to a developing nation scientists meeting in the U.S. He seemed most interested and pleased, but he had no previous knowledge of the project (except for the press release he saw the day before the meeting).

Inflation in Ghana has increased greatly since the last visit a year ago. In any future project, this will have to be taken into account.

The Resinox 736 shipped from Dayton did not arrive, or was not found, before Mr. Ball left Accra.

Mr. Jan Assenberg, Reiss and Company, could supply phenolic resin and hardener (glue used in the plywood industry). This is worthwhile investigating to reduce resin costs.

Mr. Phil Westray may be able to assist BRRI in getting samples, etc. to Kumasi, via Mr. Taylor at G.I.H.O.C.

The Komenda sugar mill seems to be about the same size as Asustare, but I expect runs a longer season, thus has a greater potential for supplying bagasse.

[This memo to the Ghana participants was edited specifically for clarity by the author to be included in the final report without changing any technical content, and thus differs slightly from the 11 November version.]

APPENDIX H

PHILIPPINE WORKING GROUP DEMONSTRATION PLANS AND TYPICAL SUMMARY REPORT

- Philippine roofing material pilot demonstration program details, August 12, 1976
- Interim Project Report, National Housing Corporation, Caloocan City, October 30, 1976
- Interim Project Report, Low Cost Building Panels, National Housing Corporation, July 9, 1977

PHILIPPINE
ROOFING MATERIAL
PILOT DEMONSTRATION PROGRAM
(Revised 12 August 1976)

1. FIBER REINFORCED NATURAL RUBBER ROOFING MATERIAL

(A) Preliminary Experimental Run, 8 April, 1976 (Latex City)
(B) Experimental Run, Mid-August 1976
(C) Pilot Run, Mid-September 1976
(D) Experimental Laboratory Work, April-August 1976
(E) Roof Fabrication, late September 1976

1.1 PARTICIPANTS

1.1.1 National Housing Corporation (NHC), Tala, Caloocan City, Ph: 90-10-08
90-16-36
Jose Victor L. Cedro, Roofing Project Coordinator 90-16-37
General Guadencio V. Tobias, Executive V.P.
Colonel Alejandro R. Kibiling 90-16-30

1.1.2 Jardine Davies (JD), 222 Bundia Ave., Makati, Rizal 89-30-61
A. Gordon Westly, V.P.
Andrew W. Russel, Manager

(a) Hawaiian - Philippine Sugar Co., Negros
George D. Gordon, Managing Director

1.1.3 Manila Rubber Corporation (MaRuC), 50 J Ramoy Rd., Caloocan City 90-12-27
90-13-09
Rufino Tan, Plant Manager

1.1.4 Latex Products Co., (LPC) Inc., Las Penas, Rizal 83-18-36
83-27-87
Kong Kuan, Chairman of the Board

1.1.5 Forest Products Research and Industrial Development Commission (FPC), 872 Isabel Bldg., Isabel St., Espana, Manila 27-26-52
Laboratory - Los Banos 23-60
23-77
Dr. Francisco U. Tamolang, Commissioner
Joaquin O. Siopongco, Engineer
Arthuro A. Pablo, Scientific Research Associate and Project Leader

1.1.6 USAID/Philippines (AID/P), 1680 Roxas Blvd. Manila 59-80-11
A. S. (Bert) Fraleigh, Asst. Director - Food for Peace
Bob Halligan, Asst. Program Officer
Maurice J. Hyder

1.1.7 Monsanto Company (MC) 6778 Ayala Ave., Makati — 88-41-05, 88-91-12

R. K. Louis, Regional Business Director

1.1.8 Monsanto Research Corporation (MRC), Dayton, Ohio, USA — 513-268-3411

Ival O. Salyer, Program Manager
George L. Ball III, Project Leader, USAID Roofing

1.2 SOURCE OF MATERIALS

1.2.1	Natural Rubber	Selected Rubber Processor
1.2.2	Sulfur	
1.2.4	Stearic Acid	
1.2.5	Zinc Oxide	
1.2.7	Pigment-Iron Oxide Red	
1.2.8	Magnesium Oxide	
1.2.6	Dry Whole Bagasse	National Housing Corp.
1.2.6a	Whole Bagasse (baled) from Jardine-Davies	
1.2.12	Antimony Oxide	
1.2.13	Aluminum Paint	
1.2.3	Chlorinated Paraffin	Monsanto Research Corp.
1.2.9	Flectol H	
1.2.10	A100	
1.2.11	Penta	

Idenfification (preferred materials or equivalents)

1.2.7 - Mapico #477 Iron Oxide red or equivalent
1.2.8 - Rubber grade magnesium oxide scavenger
1.2.6 - Baled clean dry (<0.1% moisture) sugar cane bagasse
1.2.12 - Ground Antimony Oxide fire retardant
1.2.13 - Acrylic or oil-based, aluminum flake commercial paint
1.2.3 - Chlorowax 40, Diamond Shamrock Company, 40% Cl.
1.2.9 - Flectol H powder or flakes, Monsanto antioxidant
1.2.10 - A100, Monsanto aldehyde amine accelerator
1.2.11 - Technical grade Pentachlorophenol, Monsanto Penta

1.3 MATERIAL REQUIREMENTS

		Wt Parts	Wt (%)	Mid-Aug (lb)	Mid-Sept (lb)
1.3.1	Natural Rubber	100	20.5	61.5	1642
1.3.2	Sulfur	46	9.4	28.2	752
1.3.3	Chlorinated Paraffin	42	8.6	25.8	688
1.3.4	Stearic Acid	1	0.20	0.60	16
1.3.5	Zinc Oxide	1	0.20	0.60	16
1.3.6	Dry Whole Bagasse	265	54.2	162.6	4343
1.3.7	Iron Oxide Pigment	15	3.0	9.0	240
1.3.8	Magnesium Oxide	15	3.0	9.0	240
1.3.9	Flectol H Stabilizer	.25	0.05	0.15	4
1.3.10	A100 Accelerator	1.5	0.31	0.9	25
1.3.11	Pentachlorophenol	0.1	0.02	0.06	1.6
1.3.12	Antimony Oxide	2.5	0.51	1.53	41
	Total	489.35	100	300	8009
1.3.13	Aluminun Paint				~250*
	*quantity to cover 10,000 sq ft of surface				
1.3.14	Antimony Oxide				5

1.4 PROCESS

1.4.1 Have all materials available. Bagasse dryed to moisture content of less than 0.1%. Bagasse stored in plastic bags after drying to prevent moisture pick up.

1.4.2 Compound ingredients in the <u>following order</u> using a water-cooled banbury.

1.4.2.1 Turn on banbury.
1.4.2.2 Add 1/2 of the dry bagasse (1.3.6) to the banbury.
1.4.2.3 Add iron oxide and magnesium oxide pigments (1.3.7 and 1.3.8).
1.4.2.4 Mix penta (1.3.11) into chlorinated paraffin (1.3.3) in separate container.
1.4.2.5 Add paraffin and penta mixture to banbury [CAUTION: Penta is highly toxic]
1.4.2.6 Mix in banbury until volume reduced (~3 minutes).
1.4.2.7 Add remainder of dry bagasse (1.3.6).
1.4.2.8 Mix in banbury additional 3-5 minutes.
1.4.2.9 Add rubber (1.3.1), stearic acid (1.3.4), zinc oxide (1.3.5), Flectol H (1.3.9) and antimony oxide (1.3.12).

1.4.2.10 Mix for 3-5 minutes until well compounded and fibers not visible. May heat to 100°C and expel steam. Best to let the steam boil out.

1.4.2.11 Cool banbury to less than 125°C (preferably 100°C).

1.4.2.12 Add sulfur (1.3.2) and A100 (1.3.10).

1.4.2.13 Mix 2 minutes (or optimum mixing time for banbury).

1.4.2.14 Dump to holding mill and sheet off material to feed calender.

1.4.3 Calender compound into sheet of ~0.09 inches thickness (preferred but may skip if residual strain minimized).

1.4.4 Mold panels of appropriate size (minimum 30" x 40") in thickness of 0.08 inches ±0.01 at 160°C ± 3°C for 30 minutes (-0, +5 minutes).

1.4.5 Postcure panels at 90°C for 4 hours minimum (18 hour max.) on flat shelves.

1.4.6 If desired paint top (one) surface and edges with acrylic based flaking grade aluminum paint to which 2% by weight of solids of Antimony Oxide has been added. Thin-sprayed coat only.

1.5 ROOF INSTALLATION

1.5.1 Panels are to be nailed as a minumum to purlins with spiral aluminum nails with rubber seals. If desired, J bolts can be used but drilling of holes is then recommended.

1.5.2 Purlin spacing to be adjusted to maximize use of the 30" x 40" panel.

1.5.3 Panels to be laid up as shingles with complete overlap (double roof). Half panels will need to be used at ends.

1.5.4 Other details shown in attached 3 pages (JPRF-a,b,c) and to be worked out at time of installation.

1.6 METHODOLOGY

1.6.1 Victor Cedro of National Housing Corporation to coordinate entire project, confirming all schedules and assuring all materials are properly handled and get to appropriate places well on schedule. All (see 1.1) concerned are to be notified of expected schedule.

1.6.2 George Ball and Ival Salyer of M.R.C. have gotten preliminary agreement from all participants to cooperate in their various tasks.

1.6.3 Cedro must arrange for availability of all bagasse by 1 June thru Jardine-Davies and see that it is shipped to NHC, Caloocan City, in time for drying.

1.6.4 Cedro is to arrange to have bagasse dryed and stored in appropriate plastic bags. He is also to arrange for further shipment to the selected rubber processor.

1.6.5 George Ball will see that Monsanto items are shipped to R. K. Louis of Monsanto-Philippines, who will facilitate entry and notify NHC or processor. E. C. Yu will assist when possible.

1.6.6 Cedro, with Ball or Salyer of MRC, is to select the best rubber processor and set up an appropriate schedule for (a) the experimental run and (b) the pilot run.

1.6.7 Cedro is to go over the requirements for materials, processing, and product quality with the selected processor to assure a complete understanding of the intent and expected results in the experimental and pilot runs.

1.6.8 Cedro is to coordinate the anticipated panel design with the appropriate individuals in NHC to assure that they are compatible with existing roof substructures.

1.6.9 Cedro is to coordinate the panel manufacture with the availability of at least 4 houses on which roofs are to be applied.

1.6.10 Cedro is to keep ~200 pounds of calendered flexible sheet from the pilot run for curing studies at NHC in a 4 ft x 8 ft press.

1.6.11 Panels molded in the preliminary experimental and experimental runs are to be placed outside on exposure fences at NHC and Jardine-Davies.

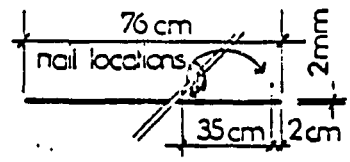
1.7 MATERIALS SHIPPED

	Item	From	Quantity, lbs (sent)	Quantity, lbs (needed)	Date	To
1.7.1	A100 (1.2.10)	Akron	50	26	30 May 1976	MC-Manila
1.7.2	Flectol H (1.2.9)	Akron	50	5	30 May 1976	MC-Manila
1.7.3	Sunolite 240 (-)	Dayton	50	0*	18 June 1976	MC-Manila
1.7.4	Penta (1.2.11)	Dayton	25	3**	18 June 1976	MC-Manila
1.7.5	Chlorowax 40 (1.2.3)	S.Fran.	1000	715	3 Aug 1976	MC-Manila

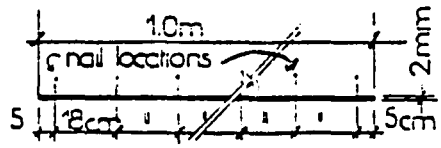
*discontinued from product 26 July 1976
**remainder to be used in oriented bagasse product.

Material:

NR



Cross Section Detail



Longitudinal Section Detail

Cross Section :

E/shingle

Reference Chart:

Cross Section	Dimension	Slope	Joints	Fastening	Substrate
A·Crenellated	1	2	3	4	5
B·V-Beam	1	2	3	4	5
C·Corrugated	1	2	3	4	5
D·Flat with shaped edges	1	2	3	4	5
E·Flat	1	2	3	4	5

1.
DIMENSION: Immediate program constraints, while not developed fully enough to give precise dimensional criteria, indicate that a 'shingle' roof element may be appropriate. For purposes of initial field tests, a shingle measuring 100cm x 76cm (40" x 30") is chosen.

Long term recommendations for roof element dimensions should be related to advances in production processes and other criteria discussed elsewhere.

SURFACE AREA: The surface area of one 100cm x 76cm shingle is 7600cm^2. Exposed surface area as shown in the attached drawings is 3500cm^2, or 46%. The surface area of 'shingle' in a roof area of 1m^2 = 1.71m^2.

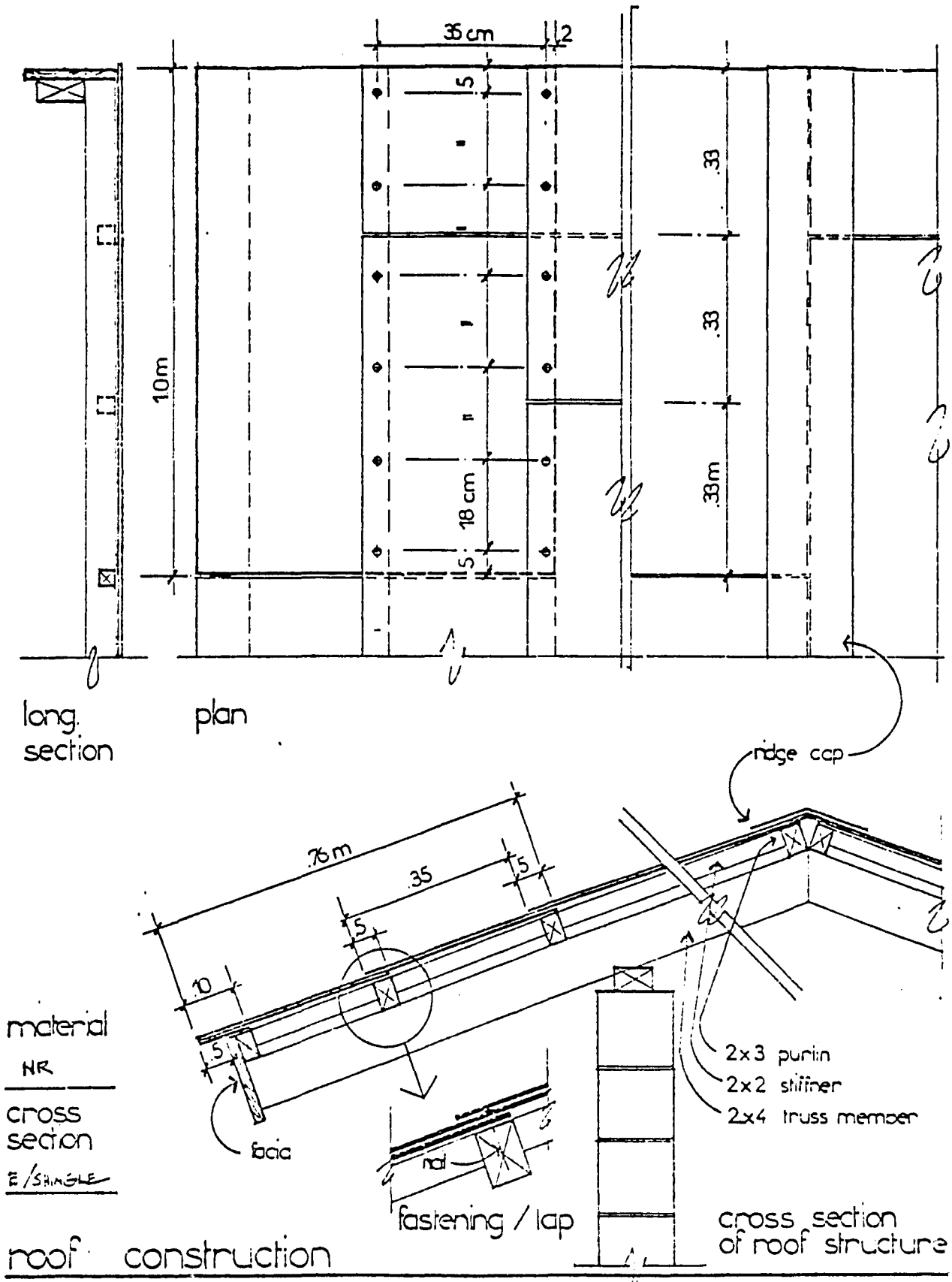
2.
SLOPE: In general, lower slopes are possible when there are fewer joints in the roof plane; higher slopes are necessary as more joints are introduced. One variable is the amount of overlap. Final recommendations should follow field tests of alternative application designs.

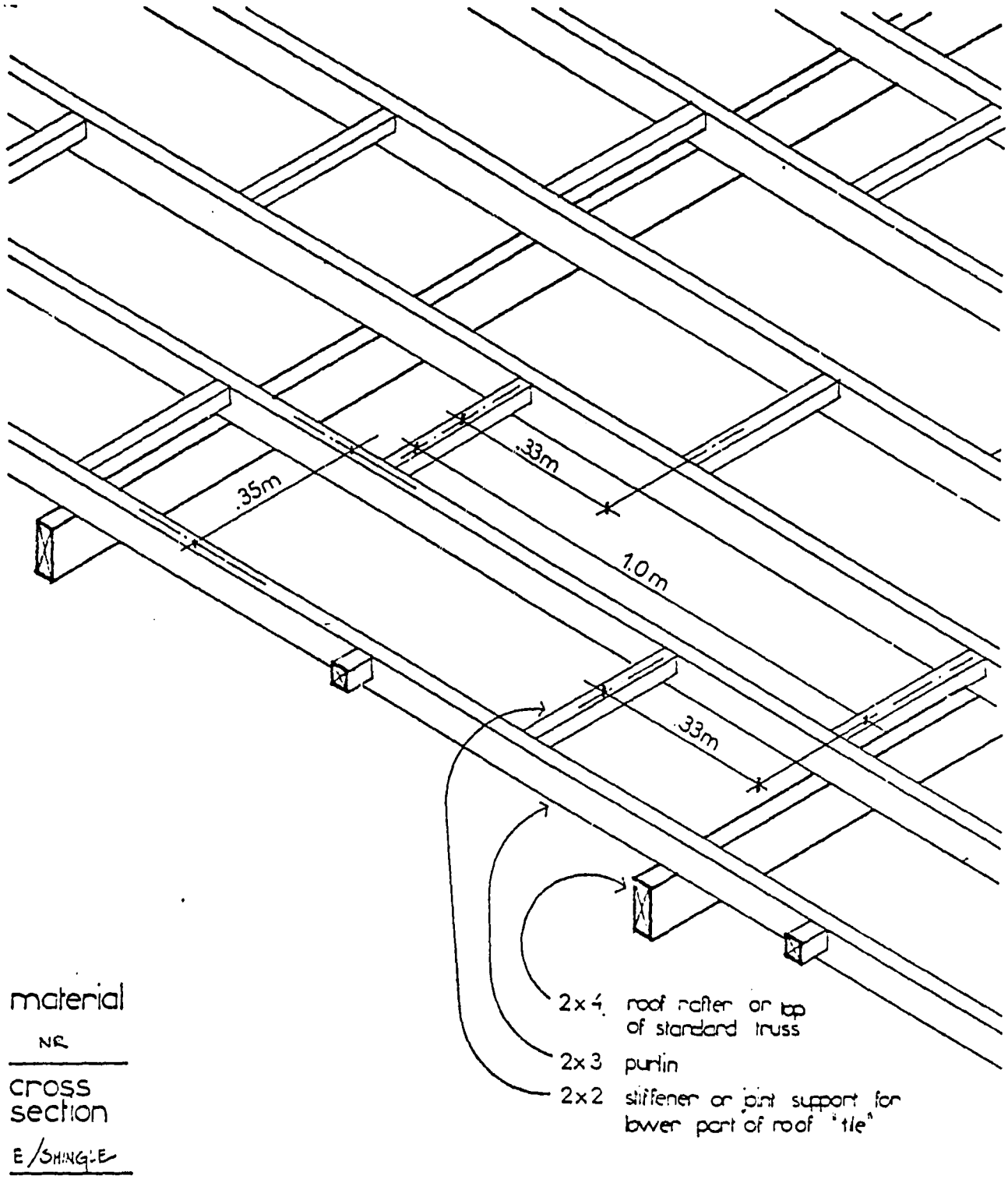
3.
JOINTS: HIP and RIDGE: covered by one of two methods; a) flexible tape and mastic; b) special cover piece of semi-rigid or rigid material.
VERTICAL JOINTS IN THE ROOF PLANE: butt joints at 1/3 points; see attached drawings.
HORIZONTAL JOINTS IN THE ROOF PLANE: 'shingles' are lapped as shown in attached drawings.

4.
FASTENING: direct nailing into substrate purlins. Nails always penetrate two layers of shingles. Nailing pattern is shown on attached drawings.

5.
SUBSTRATE: Substrate consists of standard trusses or rafters, at 1,33m on center, and with 2" x 3" purlins spaced as shown in the attached drawings. 2"x2" stiffners are required at the vertical joints of the shingles to prevent deflection at the joints. See attached drawings.

JPRF-6


35 cm
2
5
33
33
33m
10m
18 cm
5
long. section
plan
ridge cap
.76m
.35
5
5
.10
5
fascia
nail
fastening / lap
2x3 purlin
2x2 stiffner
2x4 truss member
cross section of roof structure
material
NR
cross section
E/SHINGLE
roof construction



material

NR

cross section

E/SHINGLE

substrate framing

DEVELOPMENT OF LOW-COST ROOFING FROM INDIGENOUS MATERIAL IN THE PHILIPPINES

INTERIM PROJECT REPORT

FOR

Agency for International Development

Contract No. AID/CM/Ta-C-73-12
Monsanto Research Corporation
Dayton, Ohio, U S A

National Housing Corporation
Tala Estate, Caloocan City
Philippines

Authors

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J. V. Cedro (NHC)

30th October 1976

INTERIM PROGRESS REPORT

ON

DEMONSTRATION OF LOW COST ROOFING FROM
INDIGENOUS MATERIALS FROM THE PHILIPPINES

1. INTRODUCTION

In May 1973 Monsanto Research Corporation began a program, sponsored by the U. S. Agency for International Development, to produce low-cost roofing with a wide range of applicability in the developing countries. This roofing was based on optimal use of indigenous fillers and low-cost binders. The research results were to be directed toward meeting low-cost housing needs, improving the foreign exchange position of the countries involved, and developing products that could be the basis for a local industry. The ultimate goal is to develop and demonstrate an economically and technically acceptable alternative roofing system requiring little foreign exchange in at least three countries (one each in Asia, Africa and Latin America).

Criteria for the roofing to be developed in the program were established. Any system developed must

- be competitive in cost,
- require minimum foreign currency,
- be competitive in performance,
- be durable,
- be acceptable to user,
- be competitive with respect to installation methods,
- emphasize low-capital manufacturing processes,
- use renewable or under-utilized ingredients, and
- emphasize applicability in other developing countries.

The program will cultimate in (a) the construction of at least four prototype roofs in each of the three countries, and (b) transfer of the necessary technology to qualified organization.

Four candidate composite roofing panel material system were defined that utilize from 70 to 100 per cent indigenous material. The lowest cost and most useful, indigenous filler is the sugar cane residue, bagasse. Sawdust is the second (alternative) filler of choice. The primary candidate binders include rubber, phenolic resins, and certain commercial thermoplastic resins.

Of these four systems, the two currently showing the most promise for our roofing panel material are : (1) a meltcompounded composite of whole bagasse plus fillers and vulganization agents (80%)

bonded with natural rubber (20%); and (2) a depithed-fibrillated-oriented bagasse fiber composite (95%) bonded with phenolic resin (5%).

The roofing material from either process is compression molded to form a corrugated or flat, 2 feet x 4 feet, bagasse-fiber-filled panel having an aluminized surface coating and raw material cost between 7 and 15 ¢ (U.S.) per square foot.

An additional product of promise as a building material for exterior walls is made from a dry blend of powdered bagasse (60-70%) and phenolic resin powder (30-40%) diluted with 25-75% of wood chips.

2. SUMMARY

During the time period from September 20 to October 30,1976, a demonstration of two processes for the manufacture of low-cost roofing and building materials was carried out in the Philippines by MRC and NHC personnel. Local facilities, manpower and equipment were utilized to compound a total of 15,000 pounds of natural rubber bonded (22%) with bagasse and other fillers (78%) roofing. Compounding was accomplished in Banbury Mixers, and the material calendared into 50 inch wide sheets, at Goodyear Tire and Rubber Company.

The calendared sheets were then press cured into large 1/8 inch x 4 feet x 16 feet sheets in the large Particle Board Plant press at NHC.

The cured rubber sheets are being installed on four (4) houses located at NHC, Tala, Caloocan.

Separately there was demonstration of the preparation of a new low-cost building material (for outside walls, interior panels etc.) made from a dry blend of powdered bagasse (60-70%) and phenolic powder (40-30%). This mixture is then further diluted with wood chips at concentrations of 25-75 percent weight. The products appear to have excellent strength and water resistance, and can be made in present particle board plant process and equipment plus the use of a Banbury.

During the demonstration some problems were defined which have mainly to do with the limitations of the equipment available at NHC. (originally installed for particle board manufacture). Recommendations for equipment modifications and/or procurement were made which should make economic large scale production feasible.

The roofing and building material products made, appear to have the physical properties and low raw material cost that would enable

them to compete successfully in the market with alternative = materials including CGI sheets, Lawanit, and other hardboards.

The products also meet the original AID mission objectives of being low-cost, made from indigenous materials, low foreign exchange components, durable, and etc.

The Interim Demonstration Program will be completed by Nov.6,1976, with four (4) houses roofed with the rubber bonded, bagasse filled composite panels. Plans have been approved to construct an entirely new demonstration house, from the combination of the two materials demonstrated, to be at the International Convention Center, Roxas Blvd., Manila.

A meeting between General Gaudencio V. Tobias, Gen. Manager of the National Housing Authority and Executive Vice President of the National Housing Corporation, J. Victor S. Cedro (NHC), Col. A. R. Kabiling (NHC), Maurice Hyder (USAID) and I. O. Salyer (MRC) was held on Friday, October 29, 1976. At this meeting a decision was reached to proceed with plans for scale up and eventual commercial production. Mr. Hyder (USAID) will urge rapid consumation of the follow-on AID Washington contract to provide limited funds for laboratory size equipment, technical assistance over the next two years, and the immediate training of two Philippine engineers at MRC Dayton Laboratory in the United States.

A request is being made by the Philippine government for a quick return visit by MRC personnel, to the Philippines, to assist in following up on the recommendations.

3. CURRENT STATUS OF THE PROJECT

3.1 Compounding and Calendaring at Goodyear of Bagasse-Filled Natural Rubber Bonded, Roofing Material

Utilizing the Banbury mixing and calendaring facilities of the Goodyear Tire and Rubber Co., a total of 15,033 pounds of bagasse-filled natural rubber bonded compound was prepared. The compound contained about 22 per cent by weight and volume of natural rubber and 78 per cent of bagasse filler, vulcanizing agents, processing oil etc. The compound was divided into the following types or categories:

1.	Bagasse, no pith,	fire retardant	7175 lbs
2.	Bagasse, with pith,	fire retardant	2392 lbs
3.	Bagasse, with pith,	low cost, 50%	4783 lbs
4.	Bagasse, with pith,	low cost, 48%	683 lbs

Of the above rubber compounds, approximately 4 tons were calendered into continuous rolls or sheets, 50 inch wide x 1/8 inch thickness, and taken to NHC. There remains at Goodyear (to be picked-up by NHC) more than 6000 pounds of item No.1 in the above list.

3. 2 Pressing and Curing at NHC

A total of approximately four tons of the 50 inch wide x 1/8 inch thick rolled sheets are being pressed and cured into 4 feet x 16 feet panels on the large 5 operating automated press at NHC. The curing cycle was 30 minutes at 165 deg. C, followed by long slow cooling under pressure. The cooling cycle was necessarily long, since the press was not equipped with capability for fast cooling.

3. 3 Sawing and Installation

The large pressed sheets were cut into panel 1 ft. x 4 ft., 2 ft. x 4 ft. and 4 ft. x 4 ft. and are being installed on the four houses at NHC, Tala, Caloocan.

The schedule then calls for painting of the roofs with leafing grade off aluminized acrylic, alkyd or other outdoor paint.

3. 4 Dry Blend of Banbury Powdered Bagasse, Bonded with Phenol/Formaldehyde

"Four" 155 kilograms batches of powdered bagasse were prepared in the banbury mixer at Goodyear. Each batch contained, besides bagasse, a processing oil and red pigment (for color). Two kinds of processing oil were used. Chlorowax-40 to make a fire retardant material, and Mobilsol-30 for lowest cost product. The powdered bagasse was then dry blended with 40 per cent Monsanto P-736 phenolic molding powder using a concrete mixer. This dry blend was then molded and cured to make a bright red strong panel that is both water and fire resistant.

Importantly, NHC personnel headed by Particle Board Plant Superintendent, Joe I. Ilio, investigated the possibility of diluting the 40 per cent resin blend with various amount of fine and coarse wood chips. Compositions containing added coarse and fine chips at levels of 25 per cent, 50 per cent and 75 per cent were dry blended and cured

Some of the compositions have been tested and found to have high flexural strength and modulus, as well as good water resistance. These compositions appear to hold much promise for future development. NHC personnel are to be commended on their excellent work. Importantly, the dry blend process should be readily adaptable to the product line, and process now used for particle board.

3.5 Immediate Continuation of Development Utilizing Rented or Bought Production of Intermediate in Local Rubber Factory

Banbury mixers, mill rolls and calenders are universally used in the processing of rubber. All of these items are used in the production of the rubber bonded product. Price quotation on the compounding of the rubber bonded product at Latex City amounted to only 20 centavos/kilo, a very low production cost.

Utilizing "rented" facilities of Latex City, Marvex or Manila Rubber interim production quantities of rubber compound, and calendared sheets can be produced economically. This in turn provides the necessary raw materials for molding and curing of these sheets into final product at NHC.

Two problems exist in the curing of the rubber bonded sheets in the automated hot water compression molding press at NHC.

3.5.1 The Aluminum Caul Plates

These caul plates are not sufficiently smooth and polished for use in the process. This made it necessary to use Mylar sheets to obtain good release and smooth finish of the cured panels. The caul plates need refinishing to make them sufficiently smooth that release of the finished sheets can be obtained readily using ordinary mold lubricant.

As one alternative, these smoothed caul plates could be spray coated with Teflon powder and baked on. This process however, requires a large oven which will reach the required 550-600 deg. F. fusing temperature of the Teflon. Little or no mold release is usually required with the Teflon coated molds.

A second alternative would be to apply a hard chrome plating to the present cauls; or to smooth steel plates of appropriate thickness.

3. 5. 2 Cooling of the Press Platen

The production of the rubber bonded sheets requires curing at 165 deg. C. for a minimum of 15 minutes (shown at Mabuhay) followed by cooling under pressure to a temperature below 130 deg. C.

Expediently, the NHC press could be converted to steam heating and water cooling. Cooling by only reducing steam pressure may be possible as demonstrated at Harvex. However, water cooling will be quickest, and appears to be the best solution.

Mr. Maurice Hyder of USAID has also suggested that possibly the best alternative would be to procure a new complete line designed to produce rubber bonded materials for roofing which would allow the Particle Board Plant to manufacture either urea or phenolic boards (demonstrated herein) for exterior walls.

An engineering evaluation of alternate approaches, from both the capital and operating costs standpoints need to be made to select the best method.

For interim production for the Model house etc. it is also possible to have cured sheets molded (at low cost) at a local rubber company such as Manila Rubber, Latex City, etc.

3. 6 Long Range Conversion of NHC Plant to Make both Natural Rubber Bonded and Phenol/Formaldehyde Bonded Products.

In addition to the molding press conversion already discussed, NHC needs three items of capital equipment (not now on hand) in order to economically produce the new products. These are:

3.6. 1 Banbury Mixer

A key step in both the rubber bonded and P/F bonded products is the grinding of white asbestos, plus pigments and processing oil in a Banbury mixer of appropriate size. These machines range from 3 kilogram laboratory units, thru a range of sizes up to 150 kilograms (the size No. 11 at Goodyear) and even larger. The cost of the machine is obviously related to the size of the unit and may be as much as $100,000 or more.

Best Available Document

Used units are available at lower cost and are worth considering, if bought from a reliable vendor with guarantee of condition. A requirement of the process is that the Banbury RPM should be no higher than 30 RPM, in order to avoid excessive heat build-up during processing.

The Banbury mixer will also be very useful at NHC in the manufacture of PVC floor tiles and other heavily filled compositions such as laminating films and liners which cannot now be prepared by extrusion.

3. 6. 2 Mill Rolls

The mill rolls must be sized to take the maximum capacity of the Banbury mixer. The function of the mill roll is to cool the stock from the Banbury to the point where it can be handled and calendared.

The cost of the mill roll is probably 1/2 to 2/3 that of the Banbury with which it is used. Many of the used machines are available at greatly reduced cost (compared to new) and should be considered. The mill rolls are also necessary in PVC production to take advantages of the compounding capability of the Banbury mixer.

3.6.3 Calendar Rolls

In both the rubber bonded roofing and PVC compositions the calendars are used to process the materials into continuous sheets (thick or thin). In the process, the material is densified and trimmed to the correct thickness and width. The process requires vertical feeding (with mechanical assistance) 50 inch minimum width of rolls, and at least 3 rolls. The cost of calendar, depending on size, is intermediate between range of the Banbury mixers and mill rolls.

Collectively one could spend as much as $500,000.00 or more for the Banbury, Mill rolls and Calendar

3. 7 AID Washington "Utilization" Funds for Continuation of the Program

Sometime ago it was proposed that AID would make available $50,000.00 for purchase of small scale laboratory or pilot plant equipment in each of the three countries (Philippines, Ghana, Jamaica). These funds were then to be matched by equal or larger amounts of in-country funds. These "in-country" Funds come directly from the government (in Jamaica, and Ghana).

In the Philippines the added fund might also come from the government or from PL-430 funds (if approved by NEDA and USAID)

Unfortunately these utilization funds have been delayed for a variety of reasons, including the difficulty of negotiating a mutually acceptable agreement. At the present time, we are past the pilot plant or laboratory stage, and "real money" for production equipment is needed.

However, the Utilization Funds do provide for continuing technical support by MRC personnel over the 18 month to 2 years. This latter could be more important than the $50,000.00 since it would enable MRC to assist in solving any problems that develop during the scale-up to plant production. It also provides for experience training of the Philippine personnel at MRC Dayton Laboratory; one each from NHC and NSDB.

4. CONCLUSIONS AND RECOMMENDATIONS

The National Housing Corporation already has installed at the plant in Tala, Caloocan, several items of major capital equipment which with some modifications and additions can be used to economically manufacture both the rubber bonded, and the phenol/formaldehyde bonded products. NHC also makes and markets other building materials including particle board, light weight concrete, PVC products, trusses and wooden housing components. This makes NHC a logical place for the continuing process optimization, scale up and commercial manufacture.

Specific recommendations for equipment modifications or additions in order to manufacture the building material on a large scale are as follows:

4. 1 The development of the Rubber and Phenolic bonded products should continue vigorously during the interim period, to maintain momentum and interest, and to produce material for roofing additional houses, making model houses; building materials for walls, partitions, ceiling, etc. The conversion of the five daylight particle board press to steam heating and cooling should be evaluated immediately.

4. 1 NHC to proceed to procure a complete new plant to manufacture rubber-bonded materials both for roofing and out-

door panoling.

4. 3 Expedient Alternatives Include:

- Conversion of the present NHC plant to manufacture these materials. This would necessarily still include procurement of the Banbury, Mill rolls and Calendar.

- This conversion would also require modifications to the present NHC compression molding press (for steam heating and water cooling) and smoothing and polishing (or plating) of the caul plates.

4. 4 Immediate Implementation of the AID-Washington Follow-on Utilization Program. These Funds to be Augmented by local money to provide:

- Continuing technical assistance by MRC during the two years scale up and commercialization phase.

- Training of NHC personnel at MRC Dayton, Ohio Laboratories.

- Acquisition of small scale laboratory size processing equipment (Banbury, Mill roll, Calendar,) heated and cooled compression molding press. This equipment will be used to pilot process changes, trouble shooting, etc.

4. 5 Funding for any part or all of the above from any available US-AID-NEDA PL-480 funds be considered and implemented if possible.

EVALUATION OF BAGASSE FILLED/PHENOLIC
RESIN BONDED PROCESS FOR FABRICATING
LOW COST BUILDING PANELS

at

NATIONAL HOUSING CORPORATION

During Time Period

June 20 - July 9, 1977

IVAL O. SALYER Program Manager AID	
JOSE V. CEDRO Coordinator	NHC-PVC
JOSE I. ILIO PBP Superintendent	NHC-PBP
JULIAN P. CAUSING PBP Supervisor	NHC-PBP
CLARITA DE GUZMAN PBP Quality Control Supervisor	NHC-PBP
MARCELO P. AYAG PBP Production Foreman	NHC-PBP
SALVADOR SENADOR PBP Production Foreman	NHC-PBP
SANTIAGO PAJARILLO PBP Production Foreman	NHC-PBP

1. INTRODUCTION

In May 1973, Monsanto Research Corporation (MRC) began a research program for the United States Department of State, Agency for International Development, to develop a low cost roofing in three tropical developing nations (Philippines, Ghana and Jamaica). The New Roofing Material was to make optimal use of local labor and resources, along with high percentages of indigeneous fillers and minimum quantities of resin binders. The goal was to demonstrate an economically, technically and environmentally acceptable roofing material requiring little foreign exchange and which could be used for other portions of the house as well. The research results were to be directed toward meeting needs for low cost housing, improving the foreign exchange position of the countries involved, and developing products that could be the basis for a local industry.

In fulfillment of these objectives, four candidate roofing panel composites were defined that utilize 70-95% of a preferred indigeneous filler (bagasse), along with 30-5% of binder resin (natural rubber, phenolics, and ABS thermoplastic). Sawdust or "wood chips" is the second, alternative, filler of choice.

Several visits have been made to the Philippines during the 4-year time period of the contract. During the last two years,

three of the four roofing systems developed have been investigated, to varying degrees, in collaboration with the National Housing Corporation (NHC), at Tala, Caloocan City. In work completed in Sept.-Oct. 1976 a sufficient quantity of the rubber bonded roofing panel were fabricated using a combination of Goodyear/NHC equipment, to roof four (4) employee houses located at the NHC site. Although attractive from the standpoint of utilizing a 100% indigeneous binder resin (natural rubber) this product required high temperature steam heating and water cooling for consistent curing on a practical molding cycle. The chipboard hydraulic pressing equipment at NHC is not, at present suitable for this process (pressurized hot water heating, no cooling).

Accordingly, at the request of NHC, and US-AID, another visit by MRC personnel to the Philippines was scheduled to demonstrate one of the alternate systems based on "dry blends" of bagasse filler and phenol/formaldehyde resin binder. It was expected that this process could more readily be adapted to existing NHC particle board plant manufacturing equipment and that the product could probably be used for all portions of the house, including roofs, exterior walls, ceilings etc. The materials and process developed during the demonstration are to be used in the manufacture of one or more complete model houses, at some to-be-selected site.

This report summarizes the results botained in collaborative work between NHC and MRC contract personnel, during the time period June 20 to July 9, in developing the bagasse filled (70-95%), phenolic resin bonded (30-5%) process in fabrication of 4 ft x 16 ft composite panels, of the general types required for house construction.

2. SUMMARY

During the relatively short time period of the current visit (June 20-July 12) the bagasse filled (70-95%), phenolic bonded (30-5%) dry blend process for fabricating 4 ft x 16 ft panels was intensively studied by NHC personnel. Five tons of bagasse in various forms (whole, cut, wet depithed, coarse, fine) were processed ("powdered") in the large Banbury mixer at Goodyear Rubber Co. These materials (5 types) were transported to NHC, and dry blended with powdered and liquid phenolic resins (30-5%) and molded on the large particle board press to form composite panels (4 ft x 16 ft).

Simultaneously, a comparable quantity of whole bagasse was cut and screened in standard NHC particle board plant processing equipment to determine whether this material could be used as well, thereby eliminating the need for any equipment not available at NHC.

Although most of the work was done with imported Monsanto resin (Resinox 736) locally manufactured (Borden MC 282) phenolic powder was also evaluated. Some work was completed to determine whether a plywood liquid glue (Borden HL-4645) could be used as a binder resin for the bagasse filled composite. This liquid phenolic resin investigation was especially important since this

would permit existing chipboard plant equipment to be used with minimum modification.

The practical and economically feasible range of powdered phenolic resin binder was established to be 5-30% wet, with higher resin levels required for the most demanding applications (eg. roofing) and progressively less for exterior wall panels, interior ceiling and etc. The possibility exists to develop still lower density materials, with very low resin content, which could be used for acoustical and thermal insulation. The inherently good fire retardance qualities of the phenolic bonded bagasse makes it attractive for these insulation applications.

The optimum ratio of bagasse to wood chips in the composite panel has been investigated and a level of 50% fine wood chips/ 50% bagasse tentatively established - although this point is still being investigated.

Pressing time and temperature cycles were also investigated. Good cures were obtained in cycles of 6-10 minutes at 135°C, and 3 minutes at 150°C (in small scale tests).

The physical properties of the products, including density, modulus of rupture, water absorption and swelling of the products were determined on all products, and found to be excellent for the intended applications. Density is greater than 1.0 gm/cc over the entire range of resin concentrations from 7.5% to 30%.

Modulus of rupture (MOR) values are also high at all resin levels. For example, at 10% resin concentration MOR values of up to 460 kg/cm^2 (6,545 psi) were obtained. Moisture content and % swell values were also low for all samples averaging about 5% in each case.

One problem which requires some further effort is the difficult release of the molded boards from the aluminum caul plates. In a few instances sticking was severe. While this problem can be minimized by generous application of mold release lubricant, a better solution would be to refinish (smooth and polish) the aluminum caul plates to reduce or eliminate the problem entirely. That this solution is possible has already been demonstrated in molding of similar panels in Jamaica.

From the physical properties, and the anticipated material and manufacturing cost, it appears that an economically viable plant process for manufacturing building panels, based on bagasse filled/phenolic bonded composites has been demonstrated. With further work, and only minor revisions in NHC-Particle Board Plant equipment, these materials can be manufactured on a continuous production basis If successfully followed up, the products developed can create new large markets for NHC products and make efficient use of this large PBP plant again possible.

It also seems likely that materials for an entire house, not just roofs, can be developed around the bagasse filled/phenolic resin bonded systems demonstrated in this program. Fabrication of one or more model houses from these materials is planned.

3. CONCLUSIONS

1. The most useful form or type of bagasse appears to be whole bagasse which is dried and cut (without separating fines and coarse) in the NHC particle board plant. With this type of bagasse it does not appear that it will be necessary to powder the material in a banbury at Goodyear (as heretofore).

2. Mixtures of bagasse and wood chip fillers have been investigated and optimum ranges of composition are being established.

3. Minimum and useful range of resin binder content has been established for several anticipated applications.

4. Production of the bagasse filled/phenolic resin bonded composite roofing (building) material has been successfully demonstrated on a plant scale at NHC.

5. Physical properties of the products including density, modulus of rupture, moisture uptake, and swelling in water have been shown to be very good (compared to urea/formaldehyde bonded wood chips).

6. The anticipated raw material and manufacturing costs, and product properties makes the bagasse filled phenol/formaldehyde bonded composite material suitable for a wide range of applications.

7. The use of phenol/formaldehyde resins has been successfully introduced to NHC personnel, and technology transfer in the processing and curing of these resins effected.

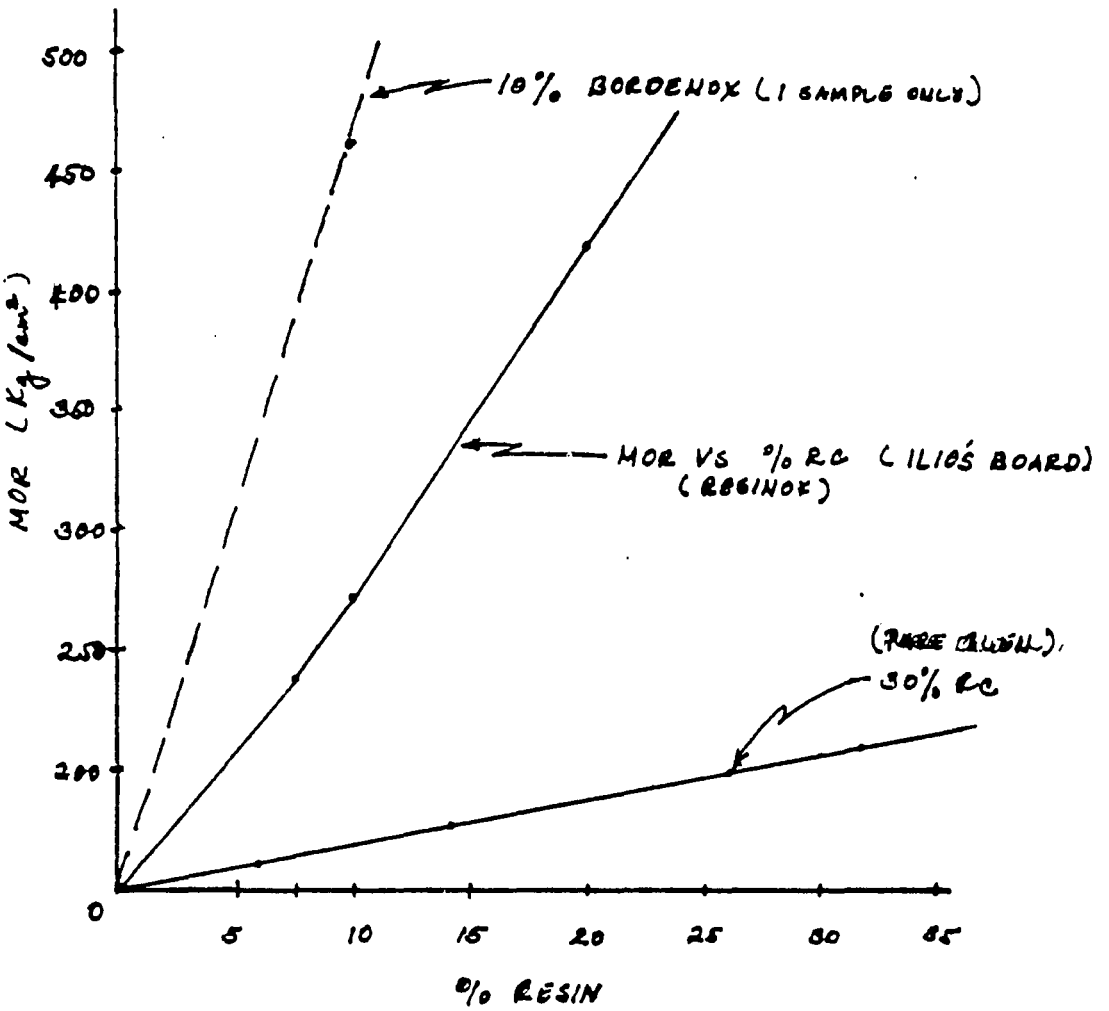
8. The operating base provided by the bagasse filled/phenolic dry blend process can be expanded in the future via purchase of new plant equipment to enable additional types of low cost building materials (developed in the AID sponsored research) to be manufactured.

4. RECOGNITION

The NHC-PBP personnel listed on the cover page have extended themselves "beyond the call of duty" to accomplish a great deal over a very short time period. This included working over the entire weekend of July 2, 3, 4 as well extra hours on many other days. As General Tobias expressed it, "How better could we express the true meaning of Philippine-American friendship day, (July 4) than by working together to develop low cost building materials which can be used to mitigate the acute housing shortage."

PHENOLIC BOARD
EXPERIMENTAL RUN

MOR VS % RESIN

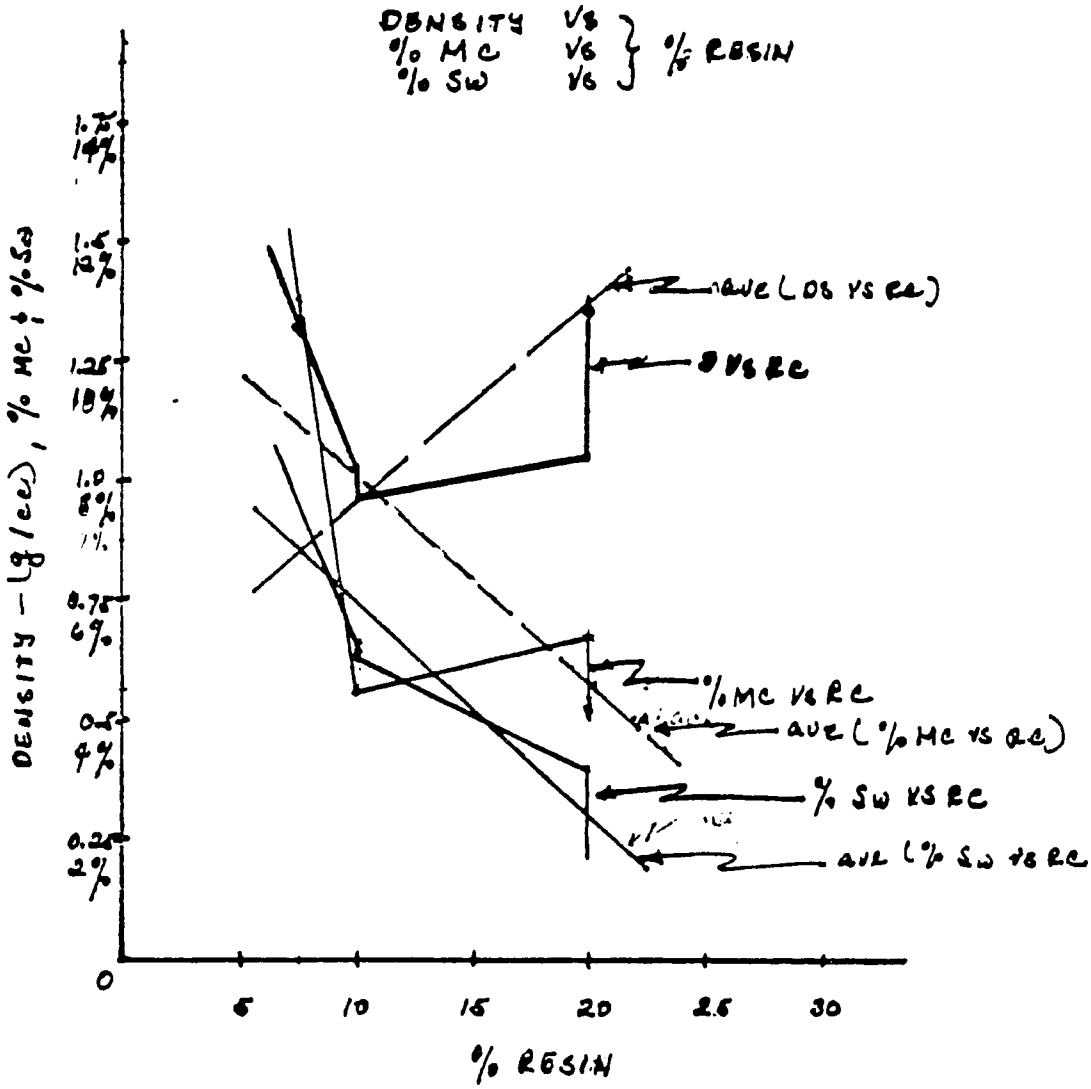


A. BAGASSE - WOOD CHIPS BAGASSE TYPE	MOR (AVE.)	% RESIN
#1 (W-B) CUT w/o PIGMENT	237.57 Kg/cm²	7.5 % RESINOX
#5 (W-B) CUT w/ PIGMENT	221.35 Kg/cm²	10% RESINOX
#5	460.92 Kg/cm²	10% BORDENOX
#1	423.11 Kg/cm²	20% RESINOX

B. PURE BLEND - 30% RESIN - ROOFING MATERIALS

#1	206.64 Kg/cm²	#4	206.16 Kg/cm²
#2	184.5 Kg/cm²	#5	206.5 Kg/cm²
#3	184.5 Kg/cm²	AVE:	206.69 Kg/cm²

PHENOLICS BOARD
EXPERIMENTAL RUN



DATA & RESULTS:

TYPE	% RESIN	DENSITY	% MC	% SW
#1	7.5% (RESINOX)	1.249 g/cc	11.2%	7.6%
#5	10% (RESINOX)	0.9747 g/cc	4.475%	5.2%
#6	10% (BORDEMOX)	1.058 g/cc	9.3%	4.90%
#5	20% (RESINOX)	1.0817 g/cc	4.1%	3.21%
#1	20% (RESINOX)	1.1065 g/cc	5.2%	2.30%

APPENDIX J

SELECTION, FABRICATION, AND USE OF TEMPORARY MOLDS FOR PROTOTYPING

APPENDIX J

SELECTION, FABRICATION, AND USE OF TEMPORARY MOLDS FOR PROTOTYPING

An important aspect of any plastic or rubber process is the availability of appropriate molds which are compatible with the materials being molded, will provide the desired surface finish, and from which the rubber or plastic can be separated. This last factor is highly critical, since most plastics and rubbers are excellent adhesives. Lessening of mold problems can be achieved both through tailoring of the formulations, and modifications to the mold.

Various minor additives contained in the developed formulations all assisted in providing release at mold surfaces. In the case of the phenolic, however, internal release could not be provided and thus had to be introduced at the mold surface. Two techniques are available for enhancing release at a mold surface, first providing a very high polish so that mechanical adhesion is minimized and/or secondly, covering with a release agent which provides an interface between the material and the mold preventing any chemical bonding.

In the experimental work it was shown that molds consisting of aluminum caul plates were preferred for the BRP, BRR, and BOB materials with standard silicone or stearate release agents being used with the BRR and BOB materials. The BRP material was a real problem. One, and only one, release agent was shown to resolve a tough mold release problem inherent in the excellent adhesion of the phenolic resin. The BRT material could be molded on aluminum surfaces, but steel surfaces were just as adequate.

Throughout the program, in the laboratory and in pilot runs in various plants, molds in the form of aluminum caul plates were used almost exclusively (In Ghana, steel plates were used in the BRR process). Implied in the use of the caul plates is that confinement around the periphery of a mold is not required. This was true and was due to the very poor flow of the unmolded roofing materials even when heated. The very high filler loading of a fibrous nature caused this poor flow which was very advantageous from the standpoint of simplicity of molds. Typically, however, a molder would prefer to have a little more flow available to provide a greater versatility in making various sizes and shapes of parts.

In the program there was a need for corrugated molds to (a) make available corrugated lab samples for structural analysis, (b) make available small samples to illustrate and sell the various materials in the participating countries, (c) work out process steps for practical roof size corrugated panels, and (d) make available reasonable sized corrugated panels for roofing demonstrations in the participating countries. Production type corrugated molds range in cost from $5000 for a sq ft lab mold, up to $30,000 for one to make a part 2 1/2 ft x 7 ft in size and require long delivery times. Once made, also change in the size or shape of the corrugation could be achieved only by making another mold at an equal cost.

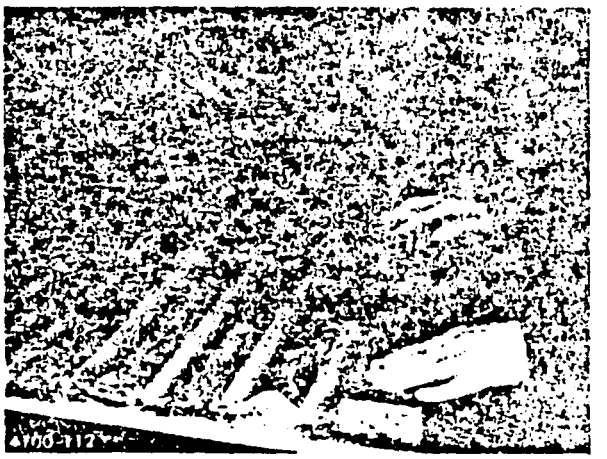
Since actual corrugation and panel sizes and shapes could not be determined until the materials were fully developed, corrugated panels were needed as early as the second year of the program, and budgeted funds and times (spread over three participating countries) were strained, a process for making temporary molds that resulted in costs one tenth of that for permanent molds was considered. The process incorporated casting with a low melting alloy, Kirksite, where casting provided the economic benefit.

Kirksite metal molds are cast molds designed for limited or pilot production. Casting minimizes costs for two major reasons. First, shapes of various types which require extensive metal machining in a permanent type steel mold can be replicated through a much lower cost wood pattern-making technique. Secondly, copper heating and cooling lines and/or electric heaters can be incorporated during casting of a mold which otherwise requires a multitude of machine operations.

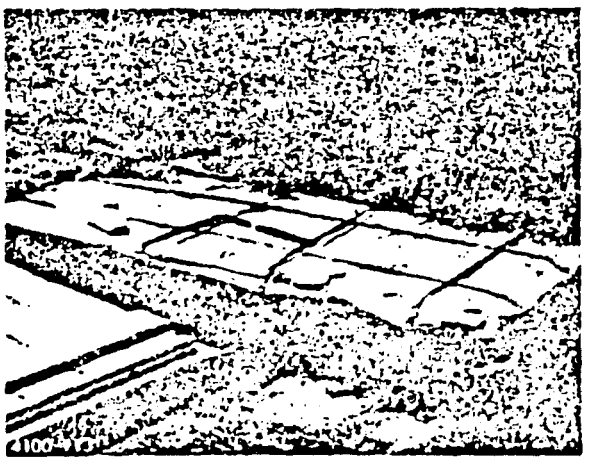
The disadvantages of the cast type molds are their higher weight, non-uniform shrinkage on casting causing distortion of the desired shape, melting at 650°F, and the lack of highly polished mold surfaces which determine the appearance of the molded part. These disadvantages, for the most part, compromise little compared to the cost and time savings inherent in the cast molds. Unfortunately, as will be discussed, the problem of non-uniform shrinkage, especially of a larger mold, was more severe than anticipated.

The procedure for making a cast Kirksite mold is essentially that of making cast iron parts. First patterns are made from wood, plaster negatives are cast around these patterns, a negative of the plaster casting is made in wet sand, and finally hot metal is cast into the sand impression. The mold making as accomplished first included making a bottom wood pattern of the size and shape of the bottom of the intended part, as illustrated in Figure J1 for the 2.5 ft x 7 ft corrugated mold that was made. Woodworking techniques were used which are state of the art to the pattern making industry. After initial sculpturing, the pattern was adjusted with plaster to achieve effects such as rounded corners, etc.

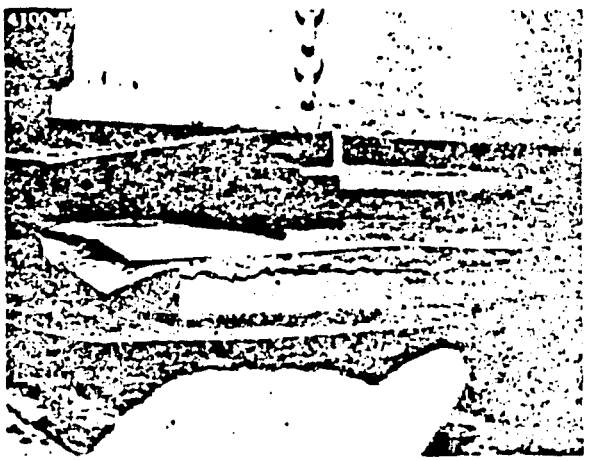
(a) A wood pattern was first made that would determine the profile for the bottom of the part eventually to be made.



(b) The wood pattern had corrugations with amplitudes of one inch and periods of three inches.



(c) One of the corrugated molds was shipped to Standard Building Products in Jamaica and remains there.



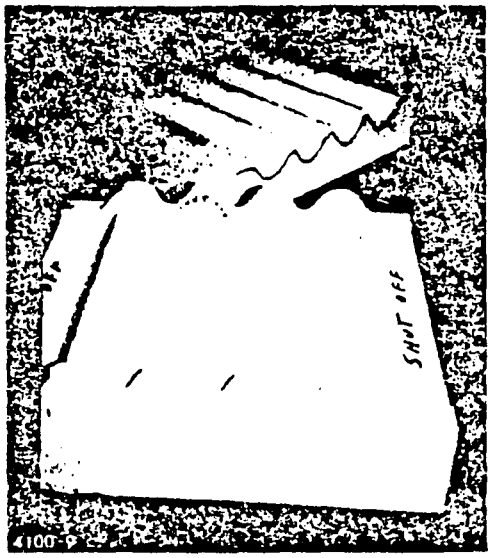
(d) The other mold was installed temporarily at the American Plywood Association where process development was conducted.

Figure J-1. Two temporary molds for preparing 2.5 ft x 7 ft. corrugated panels were fabricated using a casting process in conjunction with a wood pattern.

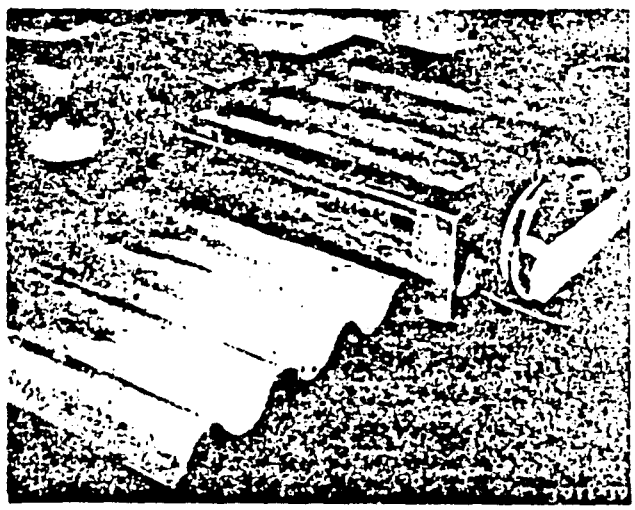
The pattern size and contours must be adjusted (enlarged) to account for both expected and non-uniform shrinkage of the Kirksite during the cooling stage of the casting process, and to account for the shrinkage of plastics inherent in their being molded hot and then cooled. This is probably the toughest part of the mold making, especially when trying to match some other given shape, requiring skill, engineering capability and, most of all, experience.

After the bottom pattern was made, wax sheets the thickness of the part eventually to be molded were laid on the pattern. This wax surface developed the contour for the bottom surface of the top part of the mold. Plaster impressions of both this top wood/wax pattern and the bottom wood pattern were then made by casting. During this casting, the outside contours of the mold were incorporated to provide the overall dimensions, attachment points, etc. In this way, a plaster replica of the final mold was made as shown in Figure J2.

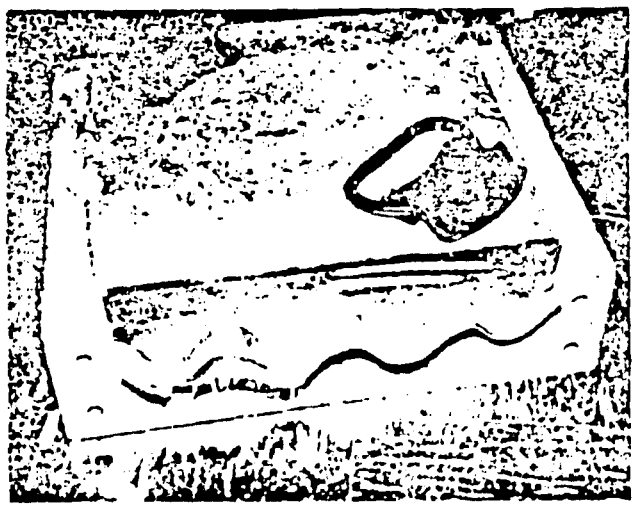
The plaster replica of the mold was first used to evaluate the mold design with respect to size, shape, ability to be filled, ability to get a part out, ability to fit into a press, etc. At this stage, the plaster mold could have been scrapped at little cost, if some problem was observed. Modifications could then be made to the original patterns to remedy any shortcomings. As the plaster replica checked out, it was used as a form around which wet sand was packed to form negatives of the top and bottom halves of the mold. The plaster models were then removed from the sand and Kirksite cast into the cavity, left to cool, and removed. Only minor polishing, alignment and finishing were then required.



(a) Plaster replica of mold used as a form to make a sand impression for casting into with Kirksite metal.



(b) View showing top insert and bottom of mold separated.



(c) Side view showing BRR rubber sheet in place for molding. Electric heaters inserted permanently on rear side.

Figure J-2. A one foot by one foot temporary corrugated mold was cast for laboratory preparation of specimens using a relatively low cost process.

In the program, an approximately one square foot laboratory mold, shown in Figure J2, was made. This mold was used both to make samples and to evaluate the Kirksite technique, since experience with such type molds was limited at MRC. The results were excellent, providing the mold from which a number of small corrugated parts were made of the BRR material. Such molded corrugated samples were highly beneficial to the technology transfer aspects of the program, in getting across the point that the materials being made were for roofing. Even the small corrugated panels had a satisfactory "feel" when handled by interested individuals. The corrugation turned materials with an unobvious application into what appeared to everyone as roofing. It was also found from this experimental mold that the non-polished mold surfaces introduced no problems in molding or any undesirable appearance, that the BRR material did not need to be confined by the mold at the sides and that cast in electric heaters was practical.

Based on the good experience with the one sq ft Kirksite mold, and after a corrugation profile of interest was determined, a large mold for making 2.5 x 7 ft corrugated parts was made. The shape selected came from that of a corrugated aluminum panel used extensively in low cost housing in Jamaica. This shape was different from that of any corrugated iron or aluminum in the United States, having a depth of about 1 inch and a period of about 3 inches. The corrugation pattern was accepted because it was satisfactory structurally for all the alternative materials being considered, was optimum with respect to economics dictated by the amount of material required (which increases as the amplitude of the corrugation increases), and because any panels would be compatible with existing corrugated aluminum and its various accessory pieces, such as ridge caps, flashing, ridge cap seals, etc. Thus, panels made from any of the alternative roofing materials could be installed without the necessity for

making accessory pieces, which was out of the question with the budget constraints of the program. Compatibility with other roofing was also of interest and would thus be demonstrated. The width and length of the panels were selected based on compatibility with usual purlin spacing and the practical aspect that the mold had to fit into an available press. Presses with dimensions greater than 4 ft x 8 were not readily available in the U.S. or any of the participating countries.

The mold was designed having in mind that it would be used in conjunction with the BOB material and be used first for process development at the University of Washington pilot plant. It was hoped that the mold could then be shipped to one of the participating organizations, along with the developed process details and parts made therefrom.

One mold was made at Alger Pattern and Tool, Indianapolis, Indiana, and shipped to the University of Washington for process development. Included in the mold was copper tubing for heating and cooling. No electric heaters were included because of the significant additional cost, and lack of their necessity in this particular mold. The mold was installed in a single daylight, side loading press at the American Plywood Association, Tacoma, Washington (at no cost to the program). It was heated by contact with the steam-heated platens of the press (The internal piping was not used). The bottom of the mold was just laid into place in the press and the top chained up in a temporary fashion after bolting on angle irons to the ends of the mold to extend outside of the press, as shown in Figure J1.

A BOB panel was molded with the Kirksite mold. It performed very well with respect to overall function, and the various process details for the BOB material system were worked out.

However, a lack of uniformity of thickness throughout the molded panels was a major problem caused by the particular mold. The molded parts were to have a thickness of 0.125 inches, but in fact had an average thickness of 0.173 inches. This was not good but could have been remedied somehow. The real problem was a variation in thickness over the panels from as low as 0.065 up to 0.265 in. Because preweighed mats are used in the manufacture of the BOB, this variation in thickness manifested itself in an acceptable density variation over the panels anywhere from double to half that desired. A profile of the part thickness was established from a few molded panels. A pattern to this non-uniformity and thickness could not be found such as all being on one side, or one end, edges being different from the middle, etc. which complicated the situation and any immediate ultimate solution.

However, having in hand this profile, attempts were made to reduce the thickness variation in parts by laying thin lead sheets onto the surfaces of the mold where the greatest thicknesses existed. In this way, better parts could be made. Considerable time and skill was required to keep the lead sheets in their proper place and much material was sacrified in cutting up of parts to determine original and modified thickness profiles. At least 30 usable panels were manufactured at the University of Washington/ American Plywood Association pilot plant facilities using the lead modified mold.

Knowing the non-uniformity and thickness problem, and having quantified it with the existing mold, the mold maker (Alger Tool) was instructed to fabricate a second mold (intended to be used at Standard Building Products, Jamaica) taking into account the shortcomings of the first mold. The mold maker accepted this, and after numerous trials at making a better mold, delivered one that had improved, but still a marginal thickness variation

for the BOB material system. This mold, shown in Figure J1, was shipped to, and remains at, Standard Building Products, Spanish Town, Jamaica. (Photos taken of the inside of the mold when at Alger Tool, where it could be opened, were severely underexposed and thus the mold cannot be shown).

The corrugated mold sent to Standard Building Products was intended for use with the BOB process. The BOB process was, at that time, under prime consideration for the demonstration in Jamaica. The mold was not used, however, because the BOB process was dropped from consideration in the demonstration, and getting the mold into the press at Standard Building Products would have severely hampered their routine manufacturing schedule into which the demonstration manufacturing had to be fitted.

In conclusion, two large and one lab size temporary molds exist for making corrugated parts that can be used for further process development. However, they are not adequate for any pilot production. They could be melted down to recover the Kirksite and make a new mold, but whether or not a cast mold would be suitable for large parts is yet to be determined. At this point, any planning would require anticipating the use of smaller cast molds for some development stages, and to get practice at making parts in the participating countries, but any production would have to include the use of machined molds at their known high costs.