

Chapter 1

Introduction

The available timber supply of the world is shrinking. The trend is toward lower quality and more expensive timber for the manufacture of wood products. In Southeast Asia, tropical timber logs, and most of the tropical wood-based products, have been either banned or discouraged from many European markets, as well as other parts of the world. End-users of wood-based products have realized the serious danger to the environment if certain natural forest stands are depleted. In the Northwestern U.S. timber harvests are less than half of their levels of just ten years ago. Increasing public pressure to reduce harvesting on private lands in the Southeast has raised legal issues over landowner rights. Since the demand for these products will continue, an alternative or substitute for timber is desirable. A suitable substitute for timber should possess comparable properties and be compatible with existing processing technology. A fast growing and abundant species is preferable. Bamboo is such a material.

Bamboo has phenomenal growth rate potential, with some species growing at a rate of 15 to 18 cm daily, with maximum height in just four to six months [8]. Some bamboo species can grow to over 30 meters high and have a diameter of 40 to 60 cm. There are about 1,200 species of bamboo in the world. Historically, bamboo has been used in its natural form for light frame construction and furniture, and as a fiber feedstock for pulp and paper. Several researchers had studied bamboo as a raw material for particleboard [9, 15], strandboard [13] and composite beams [12]. None of these studies have addressed the bamboo-adhesive interaction.

All of the potential composite applications require adhesive to bond together the bamboo elements. Adhesive is a significant cost of production, and is typically not in abundant supply in the regions of the world where bamboo is currently available. In a building material such as oriented strandboard (OSB) the adhesive represents about 25% of the cost of production, which amounts to about \$5 million in annual adhesive cost for a single OSB mill. Future development of bamboo composites will require a thorough analysis of bamboo and the interaction between bamboo and adhesive. The analysis of bamboo for use in structural composite products includes the physical and mechanical testing of the substrate, adhesive penetration analysis of the substrate, acidity and wettability of the substrate. Physical and mechanical analysis of prototype bamboo composites is also necessary. Such information forms the basis of a technical feasibility study for new product development.

The successful completion of this study will impact timberland harvests, new product development, and rural economic development. While this project will not directly lead to these economic and social benefits, it will serve as a starting point for a new family of products and a new approach to agricultural and forest land use. With respect to the abundance and multiple species of bamboo in the world, it would be beneficial to have a database of fundamental adhesive bonding characteristics, which could be adapted to other bamboo species and other composite products.

The agriculture industry could adopt bamboo for cultivation in plantations, thus promoting bamboo as an environmentally friendly and renewable building material of the future. Malaysia has the basic resources to support a bamboo industry. Nearly all of the bamboo harvested is consumed domestically. Bamboo offers a multitude of different end-

products and has a high potential for development. There is a need for higher valued products from bamboo. Rather than exporting increasing quantities of tropical timber (which may not be feasible due to worldwide efforts to preserve tropical rainforests), the manufacture of structural products from bamboo would convert a relatively low value raw material into a higher value export product. This would have obvious economic benefit to rural agriculture in Malaysia. Structural products could be exported to the Pacific Rim market, including Japan and the U.S., who could adopt these products as direct replacements for existing building materials.

Bamboo has already been cultivated successfully in the Southeastern States of the U.S [14], and can thrive in temperate climates. Underutilized agricultural lands in rural America could be placed into production of bamboo. Existing manufacturing facilities for the production of wood-based composites might be adaptable to the use of bamboo, or new facilities could be introduced near potential bamboo growing areas. A typical OSB mill consumes approximately 20,000 tons of wood annually, with a cost of roughly \$12 million. The wood supply is usually within a 50 to 70 mile radius of the mill. Within the last 5 years 13 new OSB mills have been constructed in the U.S., with a combined annual capacity of more than 2 million tons of product [65]. The use of bamboo in this manner would not be a dramatic departure from current practices, as wheat stalks have recently been adopted as a raw material for non-structural particleboard production in North Dakota and Manitoba.

The U.S. is highly dependent on wood as a raw material for building construction, printed media, furniture, chemicals, and countless other products. More wood is used in the U.S. building construction market than all other materials combined. As the demand

for wood products has grown, the available timber supply has declined. One alternative is to harvest timber overseas to supply the U.S. market. This approach merely transfers the land use and environmental problems to another country, which often has a strong economic incentive to ignore the potential environmental impacts.

This dissertation is written in manuscript format. Chapter 2 is the review of the literature. Chapter 3 evaluates the physical properties of Calcutta bamboo. The properties investigated in Chapter 3 are the relative density, dimensional stability and the equilibrium moisture content. Chapter 4 evaluates the mechanical properties of Calcutta bamboo, namely the bending strength and stiffness, and the tension strength. Chapter 5 measures the pH and the wettability of Calcutta bamboo. Chapter 6 evaluates the adhesive penetration of Calcutta bamboo. Chapter 7 presents analysis of the suitability of Calcutta bamboo and the prototype bamboo parallel strip lumber (BPSL), which were evaluated for its physical and mechanical properties. Finally, Chapter 8 concludes the analysis of Calcutta bamboo as a raw material for structural composite products.

1.2 Objectives

The main objective of this study is to analyze the suitability of Calcutta bamboo (*Dendrocalamus strictus*) for structural composite materials. The physical properties, mechanical properties, surface properties, wettability and adhesive penetration of Calcutta bamboo, as well as the properties of a prototype bamboo composite product are investigated. It is hoped and anticipated that this dissertation will be the guideline and standard procedure in analyzing other bamboo species, as well as other new materials for the manufacturing of structural composite materials.