1-1-2015

"This RCEU Project Aims at Studying the Feasibility of using Bamboo Fiber as an Alternative to Synthetic Fibers to Reinforce Composite Materials for Civil Structure Applications"

Hongyu Zhou
University of Alabama in Huntsville

2015 Research and Creative for Undergraduate Students (RCEU) Proposal

Mentoring Faculty Information

Hongyu Zhou, Ph.D.
Assistant Professor
Department of Civil and Environmental Engineering
The University of Alabama in Huntsville
5000 Technology Drive, Rm S244, Huntsville, AL35899
Email: Hongyu.Zhou@uah.edu
Phone: (256)824-5029 (Office) Fax: (256)824-6724

Project Summary

This RCEU project aims at studying the feasibility of using bamboo fiber, as an alternative to synthetic fibers, to reinforce composite materials for civil structural applications. This research investigates properties of the new materials that are uniquely critical for infrastructural applications, such as constructability and durability under long-term weather exposure. The approach for bamboo selection, fiber extraction, and chemical treatment will optimized to raise the bar in the composite fabrication, which would produce materials that achieve high mechanical performances, comparable to those of synthetic materials. The environmental durability of the material will be studied using accelerated aging tests, where the performance metrics will be evaluated using both mechanical testing and scanning electron microscopy.

As one of the fastest growing plants on earth, some species of bamboo grow at a rate of 20 cm/day. The composition of bamboo culms consists of cellulose, hemi-cellulose, and lignin, see Fig. 1. Owing to its weak biological constituents, lignin has low mechanical strength on its own, but the strong cellulous fibers (vascular bundles) render bamboo timber superior strength and ductility than most ligneous natural materials. The specific tensile strength of bamboo has been found to rival that of steel[1]. Natural bamboo timber has long been used as building materials. However, only recently have researchers begun extracting fibers of various plants, including bamboo, to study their potential in composite applications[2].

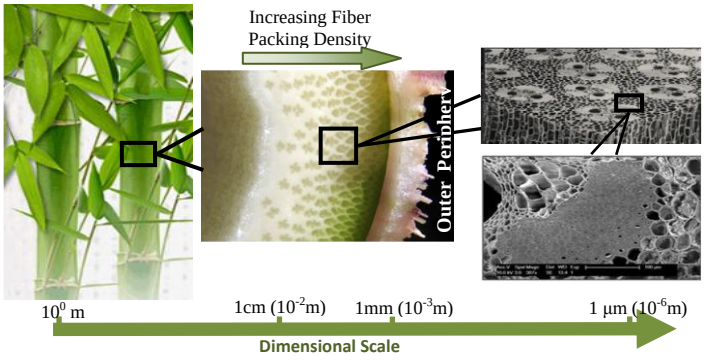

Fig. 1. Bamboo as a functionally graded natural composite

Despite the many advantages (e.g., specific strength/stiffness, low self-weight etc.) fibrous composites offer over conventional construction materials such as steel, the drawbacks of synthetic fibrous composites are also well documented[3]. Moisture take-up and creep of E-glass fiber under sustained load have limited the use of GFRP to non-primary structural components; carbon fiber, on the other hand, has shown brittle failure and modulus mismatch with the substrate materials. The increasing utilization of fibrous composite materials in infrastructural applications is urging a revolution in fiber manufacturing technologies, where the economic and

[1] Tan T et al. Acta Biomate,7:3796-803, 2011.
[2] Ray AK et al. J Mater Sci, 40(19):5249-53, 2005.
[3] Bakis CE et al. Comp Sci Tech, 61(815):823, 2001.

environmental concerns have prompted increasing interests in natural materials and plant-based composites, in harmony with the green building movement and the push for sustainability. To date, synthetic fiber production is still an energy consuming. The production of glass fibers, for example, consumes approximately 48 MJ/kg energy and results in 2.04 kg/kg CO_2 emissions[4]. Bamboo, on the other hand, is of abundant availability. Maturing in 3 to 4 years, the production of bamboo can offset carbon emissions by sequestering approximately 60 tons of CO_2 per hectare per year, showing enormous potential as a more sustainable alternative to its synthetic counterparts.

The ***objective*** of this research is to investigate bamboo fiber as a sustainable source of reinforcement for infrastructural materials to fully or partially replace synthetic fibers, such as glass and carbon. In particular, a durable and weather-resistant bamboo fiber reinforced polymer material will be developed, and it will be used for fabricating building envelope components such as wall panels or as retrofitting material for structural members such as concrete girders. The development of plant-based materials that are durable enough to withstand long-last exterior weather exposure is a challenge which requires both *material processing and engineering* and *structural-level studies*. To address the technical challenges involved in this research, a research plan is proposed to 1) develop reliable fiber extraction and treatment technique to minimizes the strength loss and increase the environmental durability, 2) to roll fibers into flexible sheets that can be easily handled by construction workers, and 3) to verify the compatibility of the bamboo-fiber composite with its potential substrates such as concrete.

Student Duty

The undergraduate research assistants will work under the faculty advisor's supervision to:

- Study the chemical treatment process for natural fiber materials. Experiments will be performed to investigate the effects of various chemical processing techniques (e.g., alkaline treatment, acetylation) on fiber strength and durability.
- Design and perform mechanical testing to study the strength, ductility, and failure mechanism of bamboo fiber composites. The mechanical tests will be performed at the new SHM&IM laboratory. Students will have access to a number of state-of-art testing equipment including MTS servo-hydraulic test machine, vacuum infusion set etc.
- Evaluate the compatibility of bamboo fiber composites to concrete substrate. Small scale reinforced concrete beam specimens will be made and retrofitted using the bamboo fiber composites. The specimens will be tested to evaluate the strength and ductility.

It is expected that the students will work full-time (32-40 hrs/week) for 12 weeks during summer 2015. Office space located in Tech Hall and computers will be made available to the enrolled students. The students will have access to the newly established structural hazard mitigation and intelligent materials laboratory located in the high-bay area of Tech Hall.

Mentor Supervision and Interaction

The faculty mentor will oversee the project throughout the performance period, including supervising the student and design the testing protocols associated with this project to ensure all project objectives are achieved. The mentor will examine all student's work and provide the assistance and resources needed. The student will report (in written or oral format) to the mentor periodically on a weekly base, and the mentor will ensure the student is progressing as planned. It is expected that a brief research report will be generated towards the end of the project.

[4] Joshi SV et al. Comp Part A,35:371-6, 2004.