SUSTAINABLE BIO-COMPOSITES FOR HIGHWAY INFRASTRUCTURE: FEASIBILITY OF MATERIAL SUBSTITUTION IN EXISTING PRODUCTS

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The U.S, Forest Service regularly removes tons of dead biomass from federal forestlands to control and prevent devastating wildfires. Every year thinning young trees and brush, as well as removing dead biomass from the forest floor generates large quantities of low-grade woody material for which there is little use. Currently this biomass is either burned on-site, or at facilities to generate electricity. Finding a sustainable long-term utilization scheme for this material may generate a steady demand for this material and improve the economics of fire prevention. In this project the feasibility of substituting non-renewable materials currently used in a wide variety of highway infrastructure products, with sustainable composites utilizing low-grade woody biomass is investigated as potential alternative to burning. Devices such as traffic signs, road markers, and guardrails are installed on public roadways in high volumes. Until now, there have been no clear guidelines established for systematically assessing the viability of full or partial material substitution with more sustainable alternatives. A conceptual framework is presented, outlining necessary input information, inquiries, practical steps, and decision points necessary to determine if material substitution in a product or its individual components is viable. This procedure can assist entrepreneurs and small-scale businesses willing to enter the market, and provide opportunities in rural regions affected by the decline in the forest products industry. The application of this procedure is demonstrated on three selected highway products. Potential benefits to the environment, the economy, and local communities are discussed.

Keywords: Wood plastic composites; WPC; Highway infrastructure; Sustainable materials; Woody biomass; Forest fuel; Urban waste

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INTRODUCTION

Forest thinning and burn fuel removal from congested forestlands is a common practice used to maintain forest health and safety. In particular, the western states of the US are plagued with seasonal wildfires of high intensity. Although small-scale seasonal forest fires are considered natural events beneficial for forest health, the large amount of fuel accumulated on the forest floor due to a century of artificial fire suppression has created an environment in which any uncontrolled wildfire can rise to catastrophic proportions. Each year the US federal government spends billions of dollars to fight, mitigate, and prevent forest fires on federal lands, increase a forest's lifespan, and thus improve carbon storage benefits (Daly 2008; Barnard 2009; Hudiburg et al. 2009). These

operations create large volumes of low-grade woody biomass. An interagency memorandum of understanding between the US Department of Agriculture (USDA), Department of Energy (DOE), and the Department of the Interior (DOI) (2003), defines woody biomass as trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environments that are the by-products of forest management (USDA 2008). In healthy forests woody biomass becomes a source of needed nutrients (Eisenbies et al. 2009); however a century of artificial forest fire suppression has resulted in accumulations that the ecosystem can no longer process. Its low grade renders it nearly useless as raw material for most traditional forest products. The slash material has low bulk density, and therefore is expensive to handle and transport. As the scale and costs of forest fire prevention increase in response to this increasing threat, so does the pressure to find sustainable ways to utilize biomass that is generated in burn fuel removal operations.

In the state of Oregon alone, approximately 4.25 million acres (about 15% of state forestlands), could produce one million bone dry tons (BDT) of woody biomass from thinning of forest stands yearly, reducing the risk of catastrophic fires for over 20 years (Bowyer et al. 2006). Harvesting western juniper - considered an invasive species in Oregon's rangelands, logging slash in other timber harvests, and urban wood waste could provide an additional one million BDT of biomass (Bowyer et al. 2006). In 2005, about one million tonnes of forest residue were generated in the state (Milbrandt 2005).

Currently low-grade woody biomass from forest operations is most commonly collected in slash piles and burned onsite releasing substantial amounts of CO_2 into the atmosphere (Krankina 2010). Recently, research efforts have been focused toward efficient harvesting methods and in-situ processing for cogeneration fuel conversion (Han et al. 2010; Harrill and Han 2010). However, with the volatility of fuel economics and increasing concerns regarding CO_2 emissions, the long-term feasibility of this approach may soon be questioned. The economics of fire prevention operations might improve substantially if the patterns of utilization of the harvested material were diversified, creating consistent demand for bio-particles. Particularly, finding a steady market for products made from low-grade wood fiber might offset the costs of removal operations and provide desirable path for carbon sequestration (Mason et al. 2006; Winandy et al. 2005).

One alternate way to utilize this low-grade biomass is as filler in hybrid wood-plastic composites (Wolcott and Muszyński 2008). This path of utilization is the focus of this paper.

Fillers are often added to materials that are more expensive in order to lower the cost. In any industry using high volumes of plastic products, even moderate amounts of inexpensive fillers replacing petroleum-based polymers translate into significant savings. Filler content may also significantly alter the physical and mechanical properties of the resulting composite. Early research on waste-wood-derived fillers have shown a combination of high performance, low cost, and reduction of mold cycling times (English et al. 1996). The presence of wood particles in a plastic matrix can result not only in a less expensive material, but also improve the stiffness of the composite when compared to an unfilled plastic alone (Taylor et al. 2009). WPCs made with recycled and second generation materials have been shown to have equal or better mechanical properties,

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