Toward Manufacturing Green Materials for Sustainable Housing

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Abstract

- Researchers have been using different approaches to address challenges related to the fabrication of sustainable building materials such as reproducibility, reliability, and using renewable materials while preserving properties.
- Recent studies have applied wood-based insulating material, in combination with ceramic binding agents, to create novel green samples of varied dimensions. This new material can lead to fully-capable load-bearing house components (e.g., wall systems) with high-insulation high-strength properties, where burning is not required in the molding process.
- In this study, we have investigated mechanical properties and ecological traits of the new material by calculating composition-dependent properties and life-cycle assessment (LCA) via modeling. Using eco-audit data and materials modeling software, we have conducted systematic analyses of several housing siding samples and evaluated different traits including mechanical properties, price, energy, and CO_2 footprint.
- Overall results from this study were found to be in good agreement with recent experiments reported elsewhere independently, and mechanical properties together with LCA data of the new material are significant in determining sustainable alternatives compared to other counterparts.

Introduction

Building materials are highly valuable in today's society due to increasing population growth and environmental issues [1]. In particular, green building materials are important as they are non-toxic, are reusable, renewable and often recyclable at a modest cost. There is a great interest to create environmentally friendly house components (e.g., house sidings, etc.) which maintain or improve their mechanical and eco-friendly properties. Literature reviews and recent experimental studies show several types of green materials that are available to date. Investigators [2] have reviewed the development of sustainable construction material using industrial and agricultural solid waste. Other researchers have reported creating bricks using alternative binders and biomass to produce light-weight and low cost [3-5].

In this study, a new green material for creating house sidings is investigated. The mechanical properties and eco-factors (energy and carbon dioxide footprint) is evaluated systematically. This project is significant as we attempt to replace traditional cedar or fiber cement sidings with alternative (eco-friendly and affordable) sidings. The latter will have low carbon footprint as its manufacturing does not involve firing samples. This would offer an effective and economical way to utilize industrial wastes to produce green house components for sustainable building materials.

Figure 1. Photos of representative waste materials (left, middle) and new alternative wood-base material (right).

Procedure

Below are the main steps used in analyzing properties and environmental impact of several house siding materials, using material design software [19]:

1. Identify materials: Upon literature review of current green materials for house sidings, select specific materials and structures (i.e., composition, sizes, shapes).

2. Perform predictive modeling: Results will facilitate selection of desired mechanical properties, eco-factors (energy, CO_2 footprints), and price of new composite candidates.

3. Analyze role of material composition and binder: Systematically, we evaluate how these parameters affect properties and performance of potential house sidings.

4. Generate LCA and evaluate results: Establish "bill of materials" by entering data on all parts, manufacturing, transportation and use options needed to create house siding. Generate eco-audit reports and evaluate environmental impact. Review modeling and LCA data, identify least environmentally impactful and most advantageous materials.

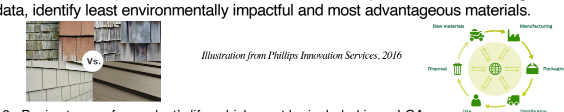

Figure 2. Basic stages of a product's life, which must be included in an LCA.

Results

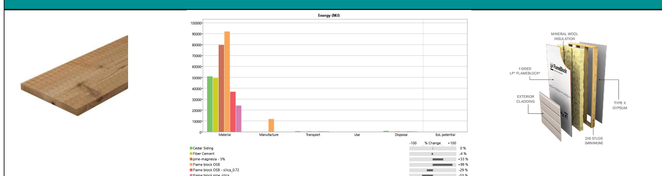

Figure 3. Environmental impact of each phase of a potential siding material, in terms of energy (MJ). The number of siding planks analyzed is the average amount needed for a single-family home.

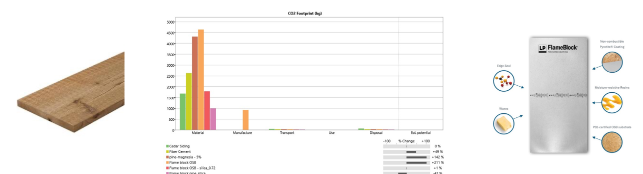

Figure 4. Environmental impact of each phase of same siding material, in terms of CO_2 emission (Kg). The number of siding planks analyzed is the average amount needed for a single-family home.

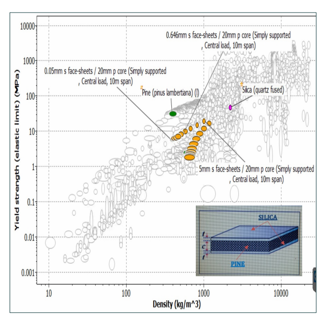

Figure 5. Yield strength-density plot displaying results for sandwich panels (insert, pine core, silica face sheet) of varying thicknesses.

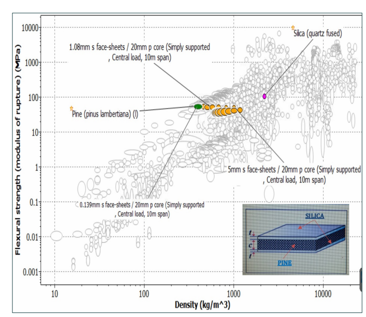

Figure 6. Flexural strength-density predictive results for sandwich panels (insert, pine core, silica face sheet) of varying thicknesses.

Discussion / Conclusions

Previous experimental and modeling studies on select green samples made of similar wood-base material (Fig. 1) revealed that the mechanical properties display high variability depending on composition, size and quality of components.

Results indicate the most impactful material for house sidings is Flame block OSB (Fig. 3 and 4). The hypothesis is that by modifying the siding's composition and binder type, the impact to the environment could be decreased. The effect of resins (painting, enamel baked coating, polymer powder coating) was also evaluated and LCA results show that OSB with polymer powder coating is the least eco-friendly in the manufacture stage.

To our knowledge, this is the first investigation to assess the effect of material and binder on the mechanical properties and eco-factors of the new green material. The combination of design, predictive modeling, and LCA evaluation allows researchers to determine the technical and commercial feasibility of the new house sidings.

Additional studies are needed to test whether the novel material is capable to sustain loadings predicted by modeling. Once satisfactory compositions are determined, future efforts will need to include other mechanical tests and economic analysis for feasibility of large-scale sustained manufacturing.

Future research on which sustainable materials are best suited based on geographic location (i.e., possibly by ArcGis mapping software) for practical manufacturing processes.

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