Direct Utilization of U.S. Coal as Feedstock for the Manufacture of High-Value Coal Plastic Composites

DE-FE0031809 Project Update

Monday October 19th, 2020
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Purpose and Alignment

Purpose

- Develop coal-based composite materials for high volume construction applications
- Utilize pulverized coal or waste material from prep plant or settling ponds
- Initial Applications: Decking, railing, and framing

Composite Decking Market

- U.S. composite market currently valued at over $1 billion annually
- 12.5% AGR (2015-2020)

+1% Market Share Increase = $50M in Annual Composite Sales

Trex Investor Presentation, August 2020
Project Team and Specifics

Project Specifics

• DOE Project Manager: Anthony Zinn
• Principal Investigator: Jason Trembly
• Lead Institution: Ohio University (OHIO)
• Industry Partners: CONSOL Energy and Engineered Profiles
• Consultant: Clear Skies Consulting
• National Laboratory: Pacific Northwest National Laboratory

Period of Performance

• October 1, 2019 to September 30, 2021

Project Budget

• Total: $2,006,578
• DOE Share: $1,500,000
• Cost Share: $506,678
**Project Objectives**

- **Overall:** Develop a coal plastic composite (CPC) formulation which is cost competitive and meets or exceeds ASTM and IBC specifications
- **Phase 1**
  - Demonstrate continuously manufactured CPC boards meet or exceed ASTM and IBC specifications for decking applications
  - Identify additional promising decking applications for CPC materials (Railings, posts, etc.)
- **Phase 2**
  - Demonstrate CPC board performance in the field
  - Identify CPC material installation methodologies
  - Identify additional non-decking applications for CPC formulations
  - Develop CPC marketing plan
Initial Technology Status: TRL-4

**CPC and WPC Flexure Properties**

CPC materials require 62% less energy to manufacture and generate 44% less emissions than WPCs. Including HDPE adds 4800 MJ/tonne and 280 kgCO$_2$/tonne.

### Current Project Status: Flexural Properties

#### Bituminous Formulations

<table>
<thead>
<tr>
<th>Category</th>
<th>IBC Spec</th>
<th>P8/CPC</th>
<th>PRB/CPC</th>
<th>WPCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;W (lbs/ft²)</td>
<td>100</td>
<td>4047-4677</td>
<td>3481-4275</td>
<td>2034-3992</td>
</tr>
<tr>
<td>&lt;Floor Deflection (in)</td>
<td>0.040</td>
<td>0.025-0.038</td>
<td>0.021-0.033</td>
<td>0.015-0.025</td>
</tr>
<tr>
<td>&lt;Stair Deflection (in)</td>
<td>0.125</td>
<td>0.054-0.084</td>
<td>0.047-0.073</td>
<td>0.034-0.054</td>
</tr>
</tbody>
</table>

- Test performed per ASTM D790
- Bituminous formulations possess greater strength.
- All CPC formulations meet IBC specifications for decking applications.
- CPC Safety Factors: 34-46

#### PRB Formulations

- Test performed per ASTM D790
- Bituminous formulations possess greater strength.
- All CPC formulations meet IBC specifications for decking applications.
- CPC Safety Factors: 34-46

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**International Building Code (IBC) Specifications and Composite Properties**

- **CPC/Bituminous:**
  - Flexural Strength: 33.0
  - Flexural Modulus: 39.7
  - Formulation 1:
    - Flexural Strength: 39.0
    - Flexural Modulus: 37.0
  - Formulation 2:
    - Flexural Strength: 36.7
    - Flexural Modulus: 30.4
  - Formulation 3:
    - Flexural Strength: 18.7
    - Flexural Modulus: 21.4
  - Formulation 4:
    - Flexural Strength: 0.9
    - Flexural Modulus: 1.5

- **PRB Formulations:**
  - Flexural Strength: 33.0
  - Flexural Modulus: 39.7
  - Formulation 1:
    - Flexural Strength: 38.9
    - Flexural Modulus: 37.0
  - Formulation 2:
    - Flexural Strength: 36.7
    - Flexural Modulus: 30.4
  - Formulation 3:
    - Flexural Strength: 18.7
    - Flexural Modulus: 21.4
  - Formulation 4:
    - Flexural Strength: 0.9
    - Flexural Modulus: 1.5
Current Project Status: Oxidation Induction Time (OIT)

- Higher OIT value indicates greater oxidation resistance.
- Determined using O\textsubscript{2}-based isothermal DSC method.
- Bituminous formulations possess higher OIT values in comparison to PRB formulations.
- Bituminous OIT values greater than most commercial WPCs.

Tests performed according to ASTM D3895
Current Project Status: Oxidation Activation Energy

- Activation energy determined via isoconversional analyses in air at multiple ramp rates.
- Higher activation energy indicates more stable material.
- Results indicate bituminous CPC formulations should have longer product life than WPCs.
- PRB CPC formulations more susceptible to oxidation.
The current project status is focused on Flash/Self Ignition Temperatures (FIT/SIT).

- **FIT**: Temperature at which volatiles ignite with external flame.
- **SIT**: Temperature at which material ignites in absence of flame.
- CPC formulations possess higher FIT values than WPCs.
- SIT values are similar for CPCs and WPCs.

Tests performed according to ASTM D1299.
## Current Project Status: Rate of Burning (RoB)

Tests performed according to ASTM D635

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Burning Rate (mm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% coal</td>
<td>24.79</td>
</tr>
<tr>
<td>Formulation 1</td>
<td>22.1</td>
</tr>
<tr>
<td>Formulation 2</td>
<td>20.1</td>
</tr>
<tr>
<td>Formulation 3</td>
<td>17.7</td>
</tr>
<tr>
<td>Formulation 1</td>
<td>25.7</td>
</tr>
<tr>
<td>Formulation 2</td>
<td>23.8</td>
</tr>
<tr>
<td>Formulation 3</td>
<td>18.6</td>
</tr>
<tr>
<td>Trex</td>
<td>32.8</td>
</tr>
<tr>
<td>Choicedek</td>
<td>35.0</td>
</tr>
<tr>
<td>Timbertech</td>
<td>35.0</td>
</tr>
<tr>
<td>Veranda</td>
<td>40.9</td>
</tr>
<tr>
<td>Fiberon</td>
<td>30.1</td>
</tr>
</tbody>
</table>

- Comparable to ASTM E84 for composite boards.
- Lower RoB value indicates less flammable material.
- CPC formulations possess significantly lower RoBs than WPC.
- Bituminous formulation RoBs slightly lower than PRB formulations.

Tests performed according to ASTM D635
Current Project Status: TEA/LCA

- Process simulations developed to accurately assess material/energy balances for a commercial manufacturing facility.
- Sensitivity analyses underway:
  - Capacity, feedstock pricing, formulation, operating costs, etc.
- Analyses to date indicate 25-40% reduction in operating costs in comparison to WPC manufacturing.
- Projected manufacturing energy and GHG emissions reductions.
Current Project Status: Continuous CPC Manufacturing

• Continuous manufacturing underway at Engineered Profiles (Columbus, OH).
• Materials mixing system procured and installed.
• Extrusion tooling developed and installed on commercial extrusion line.
• Formulation development initiated in January with board manufacturing trials beginning in July.
Current Project Status: Board Development Timeline

Market Benefits & Path Forward

Market Benefits

• Lower or equivalent priced product with better properties.
• Utilizes pulverized coal or mining waste materials.
• Easily translatable manufacturing methodologies.

Technology-to-Market Path

• Results from project will provide blueprint to design, build, and operate a commercial CPC manufacturing facility.
• Additional market applications and new research areas have been identified.
Next Steps

- Complete ASTM D7032 testing with CPC boards.
  - If necessary, refine CPC formulations.
- Continuously manufacture CPC boards for use in full-size decks.
- Perform marketing study.
- Perform environmental and occupational health studies.
- Develop and execute scale-up and commercialization plan.
Concluding Remarks

• Analyses indicate CPC formulations have equivalent or superior properties in comparison to WPCs for decking applications.
• TEA and LCA studies indicate attractive manufacturing cost savings and energy/emissions reductions compared to WPCs.
• CPC manufacturing has been successfully scaled to a commercial WPC manufacturing line.
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