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

DE-FE0031809 Project Update

Tuesday April 27, 2021
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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
• 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 kgCO₂/tonne.

Current Project Status: Flexural Properties

**Bituminous 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
Current Project Status: Flexural Properties

International Building Code (IBC) Specifications and Composite Properties

<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
Current Project Status: Oxidation Induction Time (OIT)

- Higher OIT value indicates greater oxidation resistance.
- Determined using O$_2$-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.
Current Project Status: 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 similar for CPCs and WPCs.

Tests performed according to ASTM D1299
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.
- Completed TEA studies indicate CPC manufacturing possesses attractive cost savings over WPC.
Current Project Status: ASTM D7032_Flexure Tests

- ASTM D1609 used to determine flexural properties of reinforced plastic lumber.
- Board flexure strength and modulus used to determine board load and deflection values according to IBC.
- CPC board dimensions: 5.5 in by 24 in
- Load span: 16 in

CPC Boards Exceed IBC Decking Specifications for Load and Deflection
Current Project Status: ASTM D7032_Fire Rating Tests

- CPC and WPC boards manufactured and tested at certified independent testing facility

<table>
<thead>
<tr>
<th>Class</th>
<th>Flame Spread Index</th>
<th>Smoke Developed Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-25</td>
<td>0-450</td>
</tr>
<tr>
<td>B</td>
<td>26-75</td>
<td>0-450</td>
</tr>
<tr>
<td>C</td>
<td>76-200</td>
<td>0-450</td>
</tr>
</tbody>
</table>

ASTM E84 Test Overview
- Specimen dimensions: W: 20-24 in; L: 24 ft
- Specimen mounted to tunnel ceiling
- Parameters: Heat input: 5.3 MJ/min; Duration: 10 min

ASTM E84 Steiner Tunnel and Test
Current Project Status: ASTM D7032_Fire Rating Tests

- CPC and WPC boards manufactured and tested at certified independent testing facility

### ASTM E84 Fire Ratings

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### CPC and WPC ASTM E84 Test Results

<table>
<thead>
<tr>
<th>Observation</th>
<th>CPC</th>
<th>WPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition Time</td>
<td>1:20 (Min:Sec)</td>
<td>0:46 (Min:Sec)</td>
</tr>
<tr>
<td>Max Flame Front Advance</td>
<td>10.7 ft</td>
<td>19.5 ft</td>
</tr>
<tr>
<td>Time to Max Flame Front</td>
<td>7:50 (Min:Sec)</td>
<td>6:28 (Min:Sec)</td>
</tr>
<tr>
<td>Max Temperature</td>
<td>608.8 °F</td>
<td>1105.3 °F</td>
</tr>
<tr>
<td>Time to Max Temperature</td>
<td>9:59 (Min:Sec)</td>
<td>9:05 (Min:Sec)</td>
</tr>
<tr>
<td>Falling Ash</td>
<td>No</td>
<td>9:17 (Min:Sec)</td>
</tr>
</tbody>
</table>

CPC Boards Rated Class B via Independent Testing
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

• Finish ASTM D7032 testing
• Complete deck constructability assessment.
• Manufacture railing made from CPC.
• Perform marketing study.
• Perform environmental and occupational health studies.
Concluding Remarks

• Recent CPC technology advancements:
  – Manufacturing successfully scaled using commercial WPC manufacturing line.
  – Boards exceed IBC load and deflection specifications for decking applications.
  – Boards possess ASTM E84 Class B flammability rating according to testing at independent facility.
Acknowledgements

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• OHIO: Yahya Al-Majali (PhD candidate), Sam Forshey, and Dr. Damilola Daramola.
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