Coal Core Composites for Low Cost, Light Weight, Fire Resistant Panels and Roofing Materials Phase IIB

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PROJECT OVERVIEW

Overview

- Funding
  - Federal = $1,149,771
- Period of Performance: 8/27/21-8/26/23
- Team Members
  - University of North Dakota Energy and Environmental Research Center (EERC)
  - Center for Applied Research and Technology (CART)

Technical Objectives Overview

- Objective 1: Complete a small pilot production facility and design a medium one
- Objective 2: Develop techniques to address recently determined market needs
- Objective 3: Determine formulations for X-MATRIX material
- Objective 4: Produce tiles for channel partners and demonstration projects
- Objective 5: Conduct certification testing of roof tiles and demonstrate full roofing system
- Objective 6: Establish Market Channel Partners

TECHNOLOGY OVERVIEW

What are X-MAT Composites?

- Ceramic core composite materials formed from raw powders mixed with our proprietary polymer derived ceramic (PDC)-forming resins
- Capable of using a variety of powdered materials in an “as-is” state
  - Coal – from Lignite to Anthracite
  - Coal Combustion Residuals (CCR) or Fly Ash
  - Coal by-products – GOB, Shale-coal
- Quick, Simple Fabrication - Particles are coated with resin then bonded together to make bulk parts
- Low-Pressure Molding at room temperature

How are X-MAT Composites unique?

- Our Polymer Derived Ceramic resins are tuned at the Atomic Level to contain varying amounts of silicon, oxygen and carbon or other elements
- Liquid resins not hazardous, cured resins UL94 V-0
- Use Raw Coal - Resin fully coats and encapsulates the filler particles
- Resin acts as binder between particles - no sintering needed
- X-MAT "Mix and Mold" Process is simple, scalable, and cost-effective - Single Batch Composite
- X-MAT ceramic composites won't burn despite having high coal content
- Low-cost inorganic resins + Coal $0.02-0.05/lb

TECHNICAL APPROACH/PROJECT SCOPE

High Level Plan

Year 1

- Build Out Prototyping Facility
- Transfer tile processing technology to WV
- Develop coloring process
- Develop texturing process
- Develop coating/sealing
- Improve toughness and impact resistance
- Determine best X-MATRIX formulations

Year 2

- Design small volume X-TILES production plan
- Build prototype lines for various tile styles
- Conduct certification testing of various tile styles
- Produce roof components for technology demonstration
- Establish market channel partners

Success Criteria

- WV facility demonstrates ability to produce both barrel and flat X-MATRIX Roof tiles in sufficient quantity for a 10’ x 12’ building
- WV facility demonstrates the ability to produce small quantities of ceramic barrel and flat tiles for Channel Partners as needed
- The properties of all tiles meet the relevant local and national code requirements

Risk and Mitigation

- Poor yield/poor strength ceramic tiles using scaled up process tiles – Fixed
- Supply chain issues – delayed equipment arrival – found substitutes

PROGRESS & ACCOMPLISHMENTS

Ceramic Roof Tile Process

- Raw powdered coal was mixed with a customized ceramic forming polymer designed to bond to the coal. The best ratio ranges from 65% to 75% coal (depending on the average particle size of the coal) to produce a “clay-like” material
- Once thoroughly mixed, the clay was pressed or rolled into the appropriate mold:
  - Barrel Tile
  - Flat Tile
- The filled mold was then placed in the curing oven to cure at 160-200°C for 2-4 hours, depending on size/thickness
- After curing the tile was demolded and placed on a ceramic plate in the pyrolysis furnace
- The plate(s) were pyrolyzed at 1000°C in inert gas for 2-4 hours to form the ceramic roof tile
- The yield percentage of crack-free tiles has been in the 80% range
- **Cracked tiles are recycled by chain-milling into “ceramic carbon ore aggregate”**

X-MATRIX Roof Tile Process

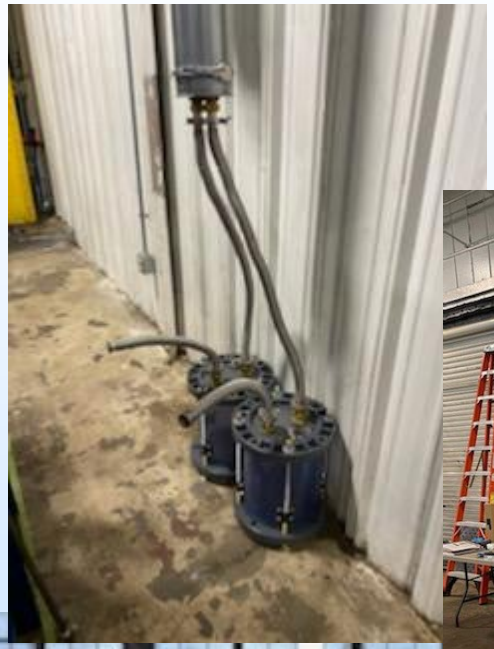
- The ceramic carbon ore aggregate was mixed with Portland Cement, water, and additives to make a coarse mortar
- The mixture was poured into either a barrel tile mold or a flat tile mold placed on a vibrating table to settle the material and remove air bubbles
- The panel was allowed to stand for 3 days in the mold and was then de-molded prior to a full cure to form the X-MATRIX roof tile.

Color and Texture

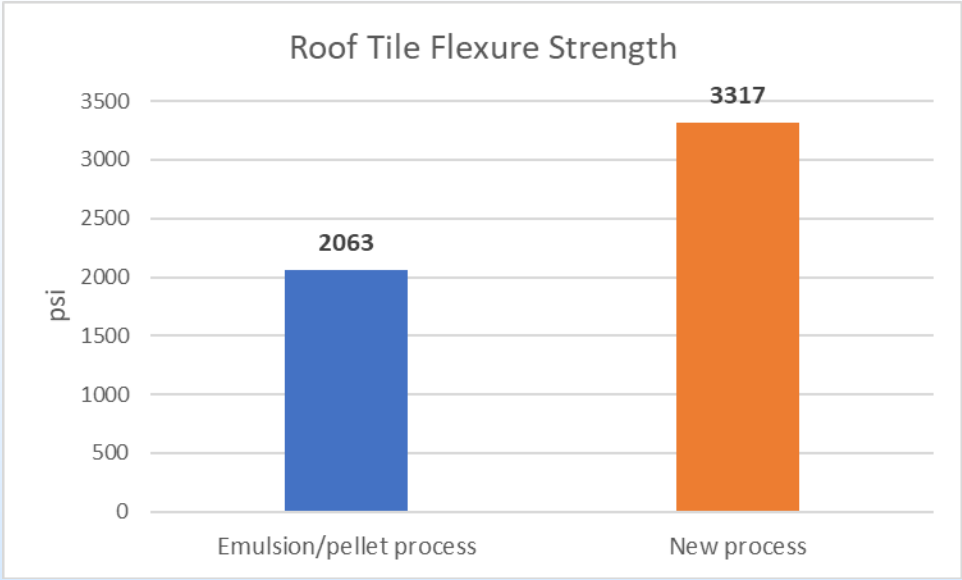
- Semplastics demonstrated that X-MATRIX roof tiles can be colored or textured using any method that works for conventional cement roof tiles
- Both Ceramic and X-MATRIX roof tiles have been colored and textured by using a room temperature curing “paint” made from various colorants including fly ash and carbon ore as pigments in a proprietary inorganic resin coating.

Pilot Line Setup

- Kiln delivered to the Bluefield, WV pilot line location and is currently working
- Installed exhaust for new large format curing oven
- Still waiting on delivery of Pugmill, and Large Clay Mixer. Delivery dates were pushed back due to supply chain delays. Current date is by end of October.
- Have run water lines and electrical in support of expected needs



Improved Tiles – Higher Resin Content



Color, Texture & Sealing

Unmodified Flat Tile

Colored and Sealed Flat Tile

Colored, Textured, & Sealed Flat Tile

Colors and textures were created using varying combinations and ratios of ceramic coal aggregate, coloring agents and a sprayable coating/sealer.

X-MATRIX Tiles

(Left) Commercially Available Concrete Tile
(Right) Cast X-MATRIX Roof Tile

(Left) Commercial Tiles (Right) X-MATRIX Tile
35% Reduction in Weight

Would result in a reduction of about 160kg per 100 sq. ft. of roofing.

Future Plans

- Seek investment and funding for production of high-end ceramic tiles
  - Scale up of facility from prototyping to being able to produce 300 tiles per day
- Seek partnership to integrate X-MATRIX technology into an existing concrete tile manufacturing line or to scale up production ourself

Key Takeaways

Coal-Derived Ceramic "Villa" Tiles Testing Results

- **PASSED** ANSI FM 4473 **Class 4** Hail Impact Resistance Standards
- **FAR EXCEEDED** Grade 1 Performance for Water Absorption and Saturation Coefficient according to ASTM C67 Standards
- **FAR EXCEEDED** Type I Wet/Dry Flexural Strength Testing according to ASTM C67/C1167 Standards

100 Square Feet of Coal-Derived Ceramic "Villa Tiles"

Side by Side with a Ludowici Clay Roof Tile

By the end of Phase IIB we will have completed certification testing on Ceramic Flat Tiles as well as the X-MATRIX variations.

These tiles will be showcased in a demonstration of a roof section that is approximately 300 sq. ft. and is installed on a structure including the ancillary components (end caps, ridge caps, etc.)

Prototype X-MATRIX Barrel Roof Tile

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- CART
  - CEO - Bruce Mutter
- EERC
  - Senior Research Engineer – Dr. Bruce Folkedahl
  - Senior Analytical Chemist – Carolyn Nyberg

APPENDIX

Organization Chart

Semplastics (Prime)

PI leading a team of Engineers & Techs

Primary Technology & Prototype Development
Project Management

CART (SubK)

Prototype Development
Product Design for Manufacturing
Pilot Line Design

EERC (SubK)

Design prototype aggregate plant, 1 ton/day
Provide ROM Quote on a 50 ton/day plant

Gantt Chart

Task	Description	Year 1				Year 2			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.1	Build out the prototype facility								
1.2	Transfer barrel tile processing technology								
1.3	Design small X-TILES production plant								
2.1	Develop process to color roof tiles								
2.2	Develop process for texturing roof tiles								
2.3	Develop seal coating process								
2.4	Improving toughness / impact resistance								
3.1	Develop X-MATRIX formulations								
3.2	Determine best formulations								
3.3	Transfer X-MATRIX technology to CART								
4.1	Build prototype lines for X-TILES								
4.2	Build prototype line for X-MATRIX tiles								
5.1	Conduct certification testing								
5.2	Produce roof components for a demo site								
6.0	Establish market channel partners								