Final Report · AeRock LLC. June 2001

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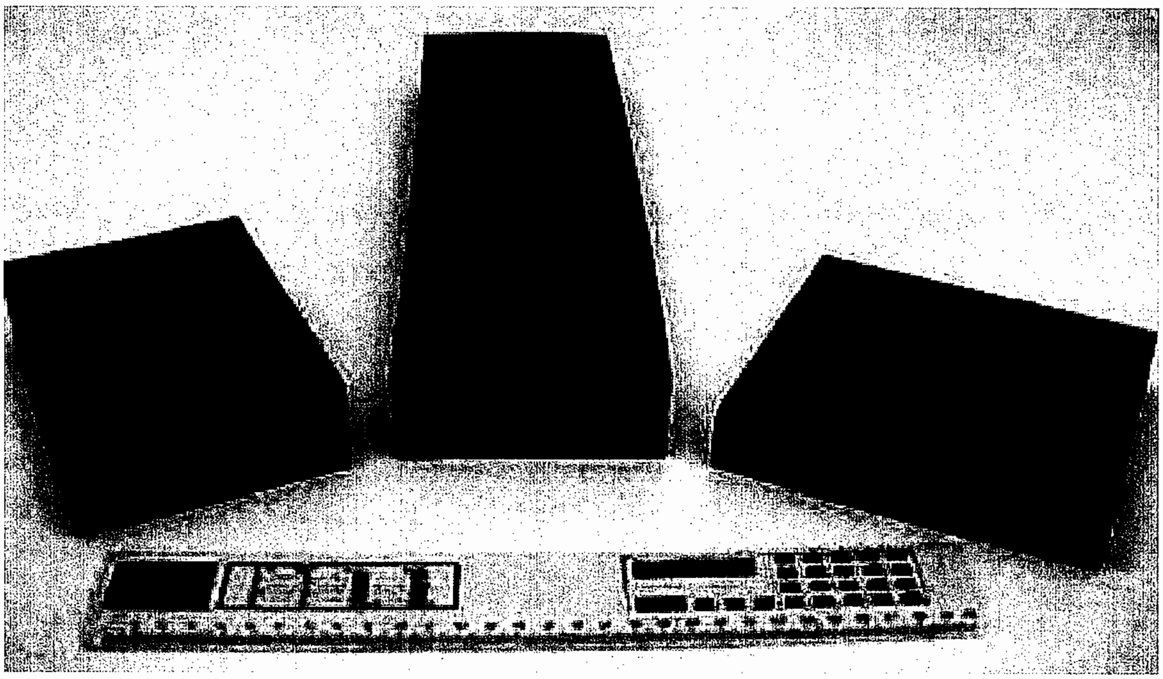

CBRC Grant

Final Report

Project start date: 4/1/00

Project end date: 12/31/00

Report for the Period: October - December 2000

Organization Name and Address:

AeRock LLC, 11021 122nd Lane, Unit Q128,
Kirkland, WA 98033

Title: Fiber-fly-ash-based wall-panel development

Project Identification No.: CBRC-0000

Project Objective and Summary of Scope:

The overall objective of the development is to bring together existing and emerging technologies, integrating them in such a way that the process:

- uses fly ash as the main component for the product's raw material input
- produces a superior siding or construction panel (hereafter the term panel will be used to describe both these products) that is about less than half the weight of conventional panels and siding. Other objectives for the panel are that it should have high strength, superior fire performance, be capable of retaining screws, have good flexural strength, be capable of use as a structural component, be water resistant, and have good thermal insulation properties.

Since the start of the work, the scope of the project has been expanded to include whole wall, floor and roof sections.

Significant Outcomes and Accomplishments:

Our research has resulted in the completion of the major objectives of the projects first phase. Several, lab-scale, full-thickness wall panels were produced using an extrusion process.

AeRock has successfully created several full-thickness prototype panels. These panels mark the beginning of our complete building system. The panels will have a high R-value, be resistant to fire, rot and pests and be highly durable yet lighter in weight than concrete. The panels are designed as a structural insulated panel (SIP). The SIP system allows for improved thermal performance, reduced infiltration and greater moisture control over conventional methods.

With the completion of this initial mix design R&D and lab-scale panels, we are now moving forward with a full independent laboratory by September 2001 and following that in early 2002, a full-sized prototyping facility to develop full-size *AeRock* panel.

AeRock has received encouraging expressions of interest from potential licencees (the business model is to license the technology).

Subsequent work has enabled us to produce panels that are extremely tough as well as having high strength (15,000 psi). We are able to vary properties of panels for different applications through control of the materials preparation and process parameters. The process is very economic and ready for commercial deployment.

Funding Status:

Requested: $22,052.00

Received: $20,000.00

6 Jun 2001

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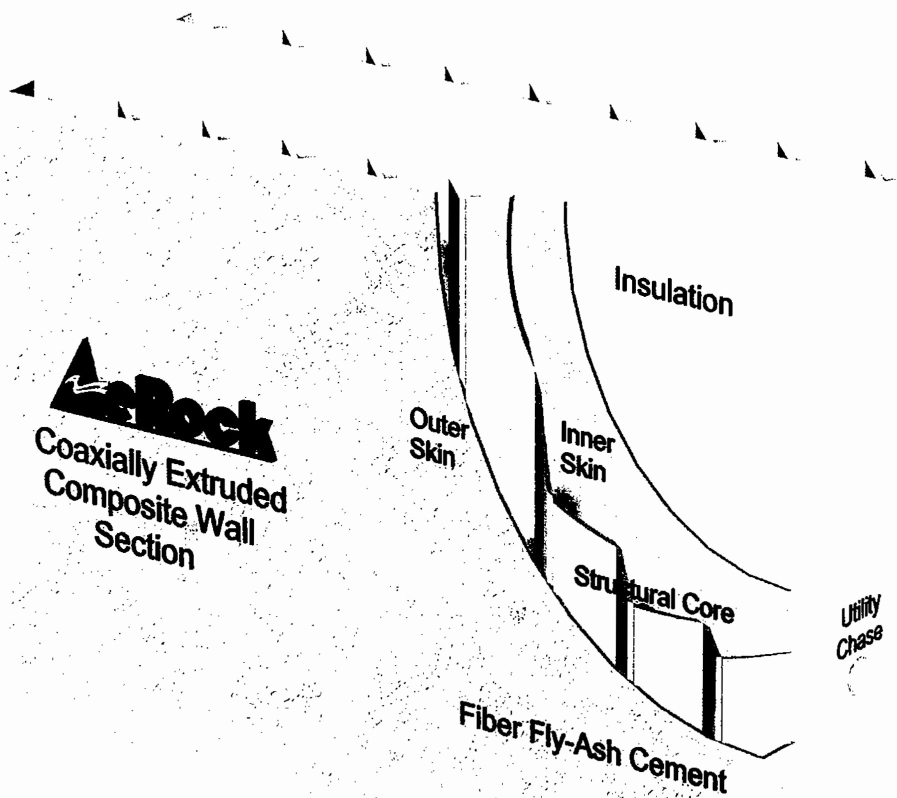

CBRC Final Report

Title Page

Fiber Fly Ash Based Wall Panel Development
Final Report
Reporting Period Start Date: April 1, 2000
Reporting Period End Date: December 31, 2001

Prime Contract No. 98-166-UND

Submitted by:
AeRock LLC
11021 122nd Lane, Unit Q128
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Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202

Disclaimer

Abstract

Bringing together existing and emerging technologies to produce a superior siding or construction panel that uses fly ash as a primary raw material was the objective of this study. The scope of the project was later expanded to include whole wall, floor, and roof sections.

The project achieved both product and process objectives. The product objective of the project was to engineer lightweight cementitious wall panels and building siding using fly ash as a primary raw material. The resulting panel is about half the weight of conventional panels and siding, and exhibits high strength, water resistance, superior fire performance, and good thermal insulation properties. It is also capable of being used as a structural component and can retain screws. The process objective was to use as high of ash content as possible, while still achieving a quick-setting mix.

Three different technologies were examined to determine which was most effective in the production of ash-containing panels. The first technology examined was a 3-D structural design with square or hexagonal ribs. Filling the space between the ribs with aerated fly ash (or other insulation) was the goal of the second technology. The third technology produced a fast setting, high-strength, fiber-fly-ash cement for the cellular structure.

Executive Summary

The overall objective of the development is to bring together existing and emerging technologies, integrating them in such a way that the process:

- Uses fly ash as the main component for the product's raw material input.
- Produces a superior siding or construction panel (hereafter the term panel will be used to describe both these products) that is about less than half the weight of conventional panels and siding. Other objectives for the panel are that it should have high strength, superior fire performance, be capable of retaining screws, have good flexural strength, be capable of use as a structural component, be water resistant, and have good thermal insulation properties.

Since the start of the work, the scope of the project has been expanded to include whole wall, floor and roof sections.

Research has resulted in the completion of the major objectives of the projects first phase. Several, lab-scale, full-thickness wall panels were produced using an extrusion process.

AeRock has successfully created several full-thickness prototype panels. These panels mark the beginning of our complete building system. The panels will have a high R-value, be resistant to fire, rot and pests and be highly durable yet lighter in weight than concrete. The panels are designed as a structural insulated panel (SIP). The SIP system allows for improved thermal performance, reduced infiltration and greater moisture control over conventional methods.

With the completion of this initial mix design R&D and lab-scale panels, we are now moving forward with a full independent laboratory by September 2001 and following that in early 2002, a full-sized prototyping facility to develop full-size *AeRock* panel.

AeRock has received encouraging expressions of interest from potential licensees (the business model is to license the technology).

Subsequent work has enabled us to produce panels that are extremely tough as well as having high strength (15,000 psi). We are able to vary properties of panels for different applications through control of the materials preparation and process parameters. The process is very economic and ready for commercial deployment.

Experimental

During the first phase of the project, research focused on combining fly-ash cement with a variety of recycled natural and polymer fibers. The cement used is alkali activated and derived from Class C Powder River Basin (PRB) coal ash. Fiber types utilized range from old newsprint to recycled polypropylene.

To make initial strength determinations of the mixes, compressive strength tests were performed on 2" square cubes. Fiber contents ranged from 0.6 wt% - 6 wt% for cellulosic and from 0.2 wt% - 2.0 wt% for polymer.

Seven different cellulosic fibers were evaluated during this phase. These fibers are old newsprint, office waster paper, old corrugated containers, cleaned old corrugated containers, kenaf, eucalyptus and a Douglas fir/hemlock blend. Additionally two fiber treatment methods were evaluated; calcium carbonate loading and acetylation.

The cellulosic fibers appeared to retard the reaction of the fly-ash cement. Both initial and final set times have shown a linear increase with increases in fiber content. Fibers with greater refinement (office waste paper) do not retard the mix to the extent of lesser-refined fibers (old corrugated containers). A new fly-ash cement formulation is underdevelopment that should offset the effect of the cellulosic fibers.

Both calcium carbonate loading and acetylation produced measured gains in compressive strengths over non-treated fibers. Both of these processes are energy intensive and will add processing costs to the final product. A cost-benefit analysis would need to be undertaken to determine the appropriateness of fiber treatment with these methods.

Two different polymer fibers have been evaluated at this point; recycled polypropylene and high-density polyethylene. Both have yielded compressive strengths similar to that of cement and sand (ASTM C-109).

The next stage of this research focused on flexural strength testing of various mixes and reformulating the cement to perform better with cellulosic fibers.

Methods for evaluating flexural strength of the fiber fly-ash mixes were evaluated. The specimen dimensions and apparatus from ASTM C-348, *Standard Test Method for Flexural Strength of Hydraulic Cement Mortars* were adopted for use in the flexural testing of this project. The method was augmented through the use of a linear variable displacement transducer, which was used to directly collect strain data of the specimen being tested. Additionally stress data was also collected with a pressure transducer. All data was recorded at a rate of 10 Hz on a digital computer.

Due to some unique material property requirements dictated by project goals, a custom specimen forming apparatus was used. The apparatus allowed the specimens to be cast in a 3-gang mold, consolidated through vibratory action and cured under compression. This method resulted in a marked reduction of variations within sample strengths.

In addition to collecting stress and strain data, dimensional and weight measurements were taken for each specimen. All data was collected and recorded digitally. These additional measurements allowed for the calculation of moment of inertia. This value combined with the stress vs. strain curves permitted for the calculation of modulus of elasticity and modulus of rupture for each individual specimen.

A non-destructive testing regime was also started in this phase of research. Sonic modulus, or time-of-flight, was measured on every sample. A piezo-electric film was used to measure the frequency of a compression wave passing through the long-axis of the sample. The compression wave was generated by tapping on the sample end with a brass hammer. All data was reduced in real-time via digital computer. This sonic modulus data will be evaluated and correlated with the static modulus of elasticity data.

Several, lab-scale, full-thickness wall panels were produced using an extrusion process. Additional research was focused on the use of FGD fly ashes in the mix.

Initial problems with low strengths of the cellulose fiber and fly-ash cement mixes were resolved. The low strengths were attributed to lignins in the cellulose adversely affecting the cement reaction. The cement was reformulated to account for this and has yielded high strengths. Additionally, work with hybrid blends of fibers has resulted in significant gains in flexural strengths and toughness.

Results and Discussion

AeRock has successfully created several full-thickness prototype panels. These panels mark the beginning of a complete building system. The panels will have a high R-value, be resistant to fire, rot and pests and be highly durable yet lighter in weight than concrete. The panels are designed as a structural insulated panel (SIP). The SIP system allows for improved thermal performance, reduced infiltration and greater moisture control over conventional methods.

The overall objective for this project is to complete the four phases of research and development: I) panel R&D at FPL in Madison, WI; II) building system design; III) cutting system/CAD R&D; and IV) pilot plant and manufacturing process. With the completion of this initial mix design R&D and lab-scale panels, moving forward with research requires that the pilot manufacturing system be implemented in order to fully develop the AeRock panel. The research and development of the optimal panel configuration and building system will be led by experimentation with full-size extruded panels.

AeRock has also successfully completed preliminary work on combining flue gas desulfurization (FGD) ash (both Class C and Class F) with cement. FGD's have been used to replace cement in amounts up to 50%. Results show that high volumes of FGD ash can be incorporated into the AeRock panel while still maintaining structural design goals. This beneficial use of an increasing available, recycled resource falls directly inline with AeRock's core goals.

Subsequent work has enabled AeRock to produce panels that are extremely tough as well as having high strength (15,000 psi). AeRock is able to vary properties of panels for different applications through control of the materials preparation and process parameters.

Conclusion

Several full-thickness prototype panels have been successfully created using high CCBs as the primary starting material. Since these panels are the basis of AeRock's complete building system, it can be concluded that high volumes of CCBs may be used in a new building system. Acceptance of this new building system will take time, as has been the case for other non-traditional building systems such as autoclaved aerated concrete. It is anticipated that the advantages of the AeRock system will facilitate the acceptance of this type of building system.

With the completion of this initial mix design R&D and lab-scale panels, AeRock is moving forward with a full independent laboratory by September 2001 and following that in early 2002, a full-sized prototyping facility to develop full-size AeRock panel.

AeRock has received encouraging expressions of interest from potential licensees (the business model is to license the technology). The process is very economic and ready for commercial deployment.