OCDO-- 96000306

INVESTIGATION OF THE USE OF FLY-ASH BASED AUTOCLAVED CELLULAR CONCRETE BLOCKS IN COAL MINES FOR AIR DUCT WORK

Final Report
D-921-02

Project Duration:
January 25, 1993 to December 31, 1994

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Submitted: June 19, 1995

This project was funded in part by the Ohio Coal Development Office, Department of Development, State of Ohio

TABLE OF CONTENTS

	Page Number
Executive Summary	ii
Full Report	
Introduction	1
A. Problem Statement	1
B. Mobile Plant Test Program	1
C. Project Objective	2
D. Project Purpose	2
E. Key Contributors	2
Technical Discussion	
A. Introduction	3
B. Mobile Demonstration Plant	3
C. Block Production	6
D. Block Laboratory Testing/Results	9
1. Fly ash block	10
2. LIMB ash block	13
3. SNRB ash block	15
E. Block Field Testing/Results	18
1. Field testing by CONSOL	18
2. Field testing by Ohio Edison	21
F. Public Exposure to the Project	22
Marketing/Commercialization Discussion	
A. Restatement of Purpose	24
B. Marketability of ACC	25
C. NACC Business Plan	26
Final Budget Summation	27
Attachments	Appendix

EXECUTIVE SUMMARY

Coal mines are required to provide ventilation to occupied portions of underground mines. Concrete block is used in this process to construct air duct walls. However, normal concrete block is heavy and not easy to work with and eventually fails dramatically after being loaded due to mine ceiling convergence and/or floor heave.

Autoclaved cellular concrete block made from (70±%) coal fly ash is lightweight and less rigid when loaded. It is lighter and easier to use than regular concrete block for underground mine applications. It has also been used in surface construction around the world for over 40 years.

Ohio Edison along with eight other electric utility companies, the Electric Power Research Institute (EPRI), and North American Cellular Concrete constructed a mobile demonstration plant to produce autoclaved cellular concrete block from utility fly ash. To apply this research in Ohio, Ohio Edison also worked with the Ohio Coal Development Office and CONSOL Inc. to produce autoclaved cellular concrete block not only from coal ash but also from LIMB ash, SNRB ash, and PFBC ash from various clean coal technology projects sponsored by the Ohio Coal Development Office.

The purpose of this project was to demonstrate the potential for beneficial use of fly ash and clean coal technology by-products in the production of lightweight block.

The mobile demonstration plant arrived at the Ohio Edison Fairlawn Service Center in Akron, Ohio on August 30, 1993 and left on November 11, 1993. In that period of time 3,150 fly ash blocks were produced of which 1,501 were useable; 405 LIMB ash blocks of which 120 were useable; 270 SNRB ash blocks of which 110 were useable; and 180 PFBC ash blocks of which none were useable. PFBC block testing was discontinued after determining the block reacted differently than others produced and fragmented and crumbled once removed from the autoclave oven.

Waste trimmings from the blocks were reused in later batches. Furthermore, condensate water analysis revealed it too can be reused during batch production. Consequently, a large scale plant production operation will have very little waste for disposal.

Blocks produced were physically, mechanically and environmentally tested at the University of Pittsburgh so that all samples/analyses of the national project were conducted at one facility. Physical and mechanical properties tested were - moisture content, shrinkage, creep, freeze/thaw resistance strength and density. Environmental properties tested were -

heavy metals in leachate, toxicity, gas chromatography, mass spectrometry, carbon content, and radon analysis.

Ohio Edison fly ash block performed well regarding shrinkage, creep, freeze/thaw recycling, and strength. This block can be used for above-ground or below-ground construction provided it is protected from excessive moisture and water infiltration. The fly ash block was 31% the weight of regular concrete block. Furthermore, leachates from fly ash autoclaved cellular concrete block have minimal affect on the environment. It may be used in a crushed form to attenuate previously polluted sites.

Ohio Edison LIMB ash block performed well regarding strength for non-load bearing construction purposes. This block can be used in below ground mine construction provided it is protected from moisture and water infiltration. The LIMB ash block was 34% the weight of regular concrete block. Leachates from LIMB ash autoclaved cellular concrete block have minimal affect on the environment. It may also be used in a crushed form to attenuate previously polluted sites.

Ohio Edison SNRB ash block performed well regarding strength for non-load bearing construction purposes, shrinkage, and freeze/thaw cycling. This block can be used in below-ground mine construction provided it is protected from excessive moisture and water infiltration. The SNRB ash block was 30% the weight of regular concrete block. Leachates from SNRB ash autoclaved cellular concrete block have minimal affect on the environment. It may also be used in a crushed form to attenuate previously polluted sites.

Field tests by CONSOL proved all three blocks can withstand flexural testing standards for underground mine use. Consequently, the Mine Safety and Health Administration has approved these materials for use in under-ground mine stopping walls.

Seven stoppings were constructed in the CONSOL Powhattan Point No. 4 Mine in southern Ohio. Miners liked the light weight and ease of working with the block. Blocks are easily damaged during transport, however. Inspections after three and seven months revealed all stoppings were still in good condition. Convergence in this mine is negligible. Consequently, this blocks should be further tested in a more geologically active mine for their comparative performance to concrete block under compression loads.

Further testing on an improved method of building stopping walls should be conducted. Blocks may be glued together rather than dry stacked and coated with mortar. Better attention to construction details in preparing a test wall may result in this method passing the prerequisite flexural strength tests.

Autoclaved cellular concrete blocks used by Ohio Edison to construct an above-ground pump house structure at our Edgewater Plant in Lorain, Ohio are performing well. After one year the walls do not appear to be weathered, cracked, chipped, or saturated.

North American Cellular Concrete prepared a business plan included herewith. They indicate the stopping wall block market to be in excessive of 30 million blocks per year which would use over 170,000 tons of LIMB ash or 150,000 tons of SNRB ash per year.

Finally, nearly 400 interested visitors have either seen the mobile demonstration plant while at Ohio Edison or requested and received information on autoclaved cellular concrete from Ohio Edison. Of the nine utilities involved in the national autoclaved cellular concrete project, Ohio Edison has been the most active in generating public and business interest in autoclaved cellular concrete. This included the first national conference on ACC held on October 28, 1933 in Fairlawn, Ohio.

FULL REPORT

Introduction

A. Problem Statement

All coal mines are required to provide ventilation to all parts of the occupied, below ground mining operation. Traditionally, this ventilation is provided by a system that pumps air through a series of air-tight shafts constructed with 8 x 8 x 16 inch concrete blocks. These blocks are carried to the construction site and installed by the miners using mortar and plaster facing to provide an air-tight finish.

Normal concrete block is heavy to work with and deforms very little before cracking under load. Consequently, mine settlement results in stress cracks in the concrete block and resulting air leakage.

Autoclaved cellular concrete block is lightweight and less rigid as it is loaded. Deformation performance is expected to exceed that of regular concrete bock. Furthermore, since the block is less dense, larger block can be used reducing the number of seams which must be plastered. Since the block is lighter, use of autoclaved cellular concrete block could reduce back injuries associated with building air duct work walls.

B. Mobil Plant Test Program

For this project, Ohio Edison worked with North American Cellular Concrete and used their portable autoclaved cellular block plant to produce autoclaved cellular block using a significant quantity (70%±) of fly ash from Ohio coal burning facilities. Consolidation Coal Company agreed to operationally test this block in their Powhattan Point No. 4 coal mine in southeastern Ohio. Ohio Edison also conducted testing of the block for structural and environmental assessment purposes under contract with the University of Pittsburgh.

Furthermore, Ohio Edison substituted clean coal technology wastes (LIMB waste, SNRB waste, and PFBC waste) into the design mixture in place of fly ash and conducted structural and environmental assessment tests on these blocks to compare their performance with regular concrete block and fly ash cellular concrete bock. Operational, structural, and environmental test results for all block were compiled, compared, and reported by the University of Pittsburgh and are contained herein.

C. Project Objective

The objective of this project has been to produce and lab test lightweight autoclaved cellular block that uses a significant quantity (70%±) of fly ash and clean coal technology by-products from Ohio coal-burning facilities.

D. Project Purpose

The purpose of this project has been to demonstrate the potential for beneficial use of fly ash and clean coal technology by-products in the production of lightweight block.

E. Key Contributors

The Ohio Coal Development Office of the Ohio Department of Development has been a significant co-sponsor. Along with providing support funding, the Ohio Coal Development Office participated in several open-house events including the first national conference on autoclaved cellular concrete which was held in Fairlawn, Ohio on October 28, 1993 and the planning sessions which made the demonstration project a success. The Ohio Coal Development Office also participated in the inspections of autoclaved cellular concrete blocks being tested in Powhattan Point No. 4 mine of CONSOL, Inc. in southeastern Ohio, and in meetings with the University of Pittsburgh to review their progress and results.

The significant participation and contributions of CONSOL, Inc. include the operational test and evaluation of three types of autoclaved cellular concrete used in their Powhattan Point No. 4 mine as air stopping walls. CONSOL, Inc. was indispensable in securing approval from the Mine Safety and Health Administration - Bruceton Safety Technology Center - to operationally test the three types of autoclaved cellular concrete block in underground air stopping walls. Furthermore, CONSOL, Inc. conducted horizontal load testing at their research facility in Library, Pennsylvania which led to approval by the Mine Safety and Health Administration of autoclaved cellular concrete block use in underground mines.

North American Cellular Concrete of Providence, Rhode Island operated the demonstration plant in Fairlawn, Ohio from September 13 to November 11, 1993. Plant start-up operation and daily clean-up usually took 12 hours per day.

Technical Discussion

A. Introduction

Autoclaved cellular concrete (ACC) using fly ash as a silica component has been successfully produced and utilized as a construction material in various countries of the world for over 30 years. ACC is produced by introducing ash or sand, cement and lime into a water mix. A small amount of aluminum powder is then added to the slurry and poured into a large mold. The mold can vary in size, up to 20 feet in length and five feet wide and high. The aluminum powder reacts with the ingredients to produce a hydrogen gas - the slurry in the mold rises to a large cake-like form. It is allowed to stiffen, cut to size, and then is put into a autoclave under high heat and high pressure for up to 10 hours. Fly ash is used as a total replacement for sand in large plants, especially in Great Britain. ACC production has the potential to consume large quantities of coal ash. Typically, 30 to 35 pounds of fly ash per cubic foot of finished ACC product is used. The ACC product possesses the following characteristics:

(a) Lightweight - approximately 25% the weight of concrete
(b) High insulation capability, with an R-value of 8 to 10 for a six-inch thick material
(c) A fire rating of at least two hours
(d) Impervious to termites, vermin, and rotting
(e) Easily worked with carpenter's tools, and
(f) Good sound insulation properties

B. Mobile Demonstration Plant

As part of its efforts to develop market acceptance of ACC, North American Cellular Concrete designed a mobile demonstration plant which traveled to various parts of the country beginning in 1993. Ohio Edison was one of nine participating utilities to serve as a host for the plant. The mobile demonstration plant contained all the primary elements of a full-scale stationary plant and produced ACC block using utility fly ash including material storage silos, a mixing tank, a cutting rig, an autoclave chamber, and ancillary water treatment and boiler equipment. The 1991 conceptual drawing of the mobile demonstration plant (Figure 1) looks significantly similar to the design drawings (Attachment 1) incorporated herein.

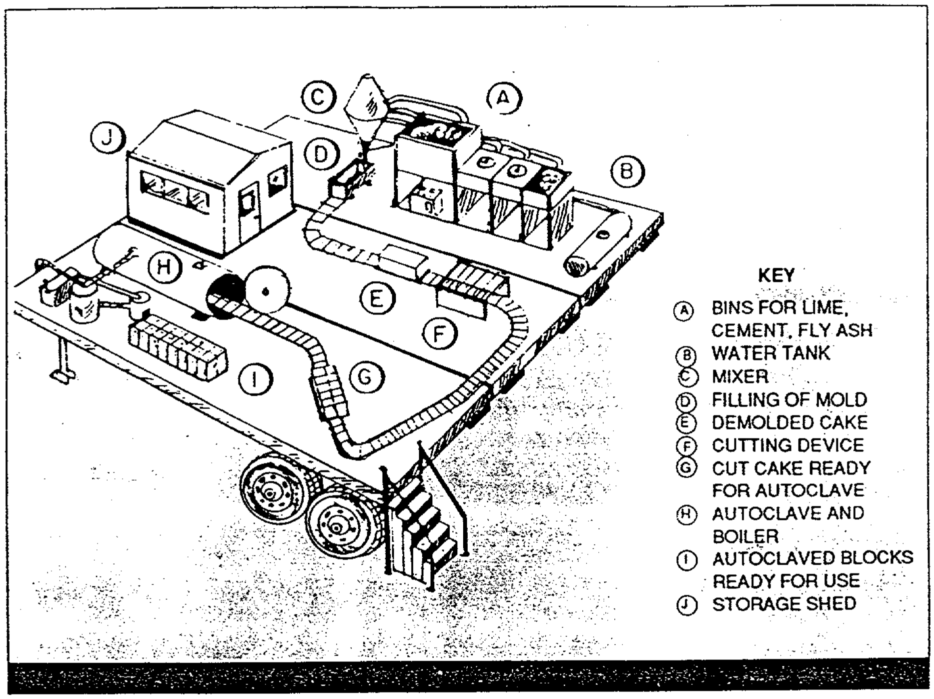

Fig. 1. Sketch of mobile demonstration plant to produce fly ash-based autoclaved cellular concrete. The sketch was conceptualized in 1991.

Figure 1

Specifically, the mobile demonstration plant consisted of the following primary equipment:

FLY ASH SILO

* approximately 140 ft^3
* complete with all necessary accessories like infeed pipe, level control, slide valve, and dust collector

ASH SCREW CONVEYOR

* capacity approximately 5 tons/h
* length approximately 11 ft
* ascending, approximately 30 degrees incl. gate valve at the outlet

ASH SLURRY TANK

* approximately 50 ft^3
* consisting of: steel tank; agitator (driven by gear motor); manually operated discharge valves; motor: approximately 1.5 KW

SLURRY PUMP

* approximately 16 gl/min
* electrically operated

LIME SILO

* capacity approximately 1,000 lb to be filled manually, complete with all necessary accessories like level control, discharge slide valve, sieve basket

LIME SCREW CONVEYOR

* capacity approximately 14.5 ft
* ascending approximately 30 degrees including pneumatically operated flap

Remark: During transport of the plant the screw conveyor will be disconnected and lowered underneath 14 ft height

CEMENT SILO

* capacity approximately 1,000 lb to be filled manually; complete with all necessary accessories like level control; discharge slide valve, sieve basket

CEMENT SCREW CONVEYOR

* capacity: approximately 5 t/h
* length: approximately 14.5 ft
* ascending slope: approximately 30 degrees including pneumatically operated flap

Remark: During transport of the plant the screw conveyor will be disconnected and lowered underneath the 14 ft height.

CEMENT AND LIME BATCHER

* capacity approximately 600 lb
* consisting of: 1 set of load cells; 2 balance containers (each approximately 250); 2 discharge flaps (pneumatically operated); air outlet filter

WATER STORAGE TANK

* insulated, approximately 400 gal with two discharge pipes and connection to the water cooler

RETURNS SLURRY SILO

* approximately 50 ft^3
* consisting of: steel tank; agitator (driven by gear motor); 2 manually operated discharged valves); motor: approximately 1.5 KW

CUTTING MACHINE

* Cuts aerated concrete cakes with oscillating wires. During cutting process simultaneously the cake is deshuttered. The cutting speed is adjustable. The horizontal top cutting is done manually. The machine consists of: a welded steel frame; cutting advance via 2 synchronized spindles; gear motor with mechanical speed control; guides for the top cut, top cut device (manually operated).

AUTOCLAVE

* working pressure: 250 psi
* internal diameter: 4'9"
* cylindrical length: approximately 15 ft
* complete with: all required connection; condensate outlet; rail track and rail traverse; autoclave support - one fixed, others movable; accessories such as gauges, chart recorder, steam safety valves, and valves for infeed and outlet; insulation. Autoclave provided for vacuum. All valves for steam infeed and outlet as well as the drainage valve for condensate, executed according to U.S. standards and safety regulations.

STEAM BOILER

* capacity 500 kg/h, 175 ft^3/hr, 250 psi
* heating system: electric
* Boiler with large water and steam chamber, automatic operation; electric control; automatic water control; insulation; including water treatment plant and all other accessories like steam piping, pressure recorder, etc.

COMPRESSOR

* maximum 120 psi . . . 1/min, including tank, safety valves, electric control, piping within the mobile plant

DOME TENT

* Used to protect the plant from the weather, this tent covered a surface area of 60 ft x 30 ft and had attachable side panels to retain heat.

A full list of equipment is included in the attached Operations Manual for the Autoclaved Cellular Concrete mobile demonstration plant (Attachment 2). The operations manual also details the specifics for start-up, a typical week of operation, and take down of the mobile plant.

The mobile demonstration plant was designed to be assembled and operating within five working days. At Ohio Edison the mobile demonstration plant arrived on August 30, 1993, the boiler was inspected and approved on August 31, and the equipment and tent structures were completely erected by September 10, 1993.

C. Block Production

The mobile demonstration plant was designed to produce 90 blocks per day (3 batches of 30 blocks) which were cured overnight in the autoclave oven. Production of 90 blocks per day was a critical element in meeting the production goals set by Ohio Edison for this project. Our expectation was to produce 400 usable standard size (8" x 8" x 16") block per week from the following types of ash and their expected total yields.

Ash Type	Expected Yield
1. Standard fly ash from Ohio Edison R. E. Burger Plant	2,000 blocks
2. Limestone Injection Multistage Burner (LIMB) ash from Ohio Edison Edgewater Plant	200 blocks
3. SO_x NO_x RO_x BO_x (SNRB) ash from Ohio Edison R. E. Burger Plant	200 blocks
4. Pressurized Fluidized Bed Combustion (PFBC) ash from American Electric Power Tidd Plant	200 blocks

Furthermore, the 2,000 blocks from standard fly ash would consist of two strengths and two sizes:

1200 standard size (8" x 8" x 16") block of high strength (435 psi)

400 standard size (8" x 8" x 16") block of low strength (240 psi)

200 optimum size (8" x 16" x 16") block of high strength (435 psi)

200 optimum size (8" x 16" x 16") block of low strength (240 psi)

Sources of materials chosen for the project were secured and samples were sent to the North American Cellular Concrete batch design lab in Chantilly, Virginia in July 1993 for mix designing.

Block production was below expectations. Of 3,150 R.E. Burger Plant ash blocks molded, 1,501 were useable. Of 450 LIMB ash blocks molded, 120 were useable. Of 270 SNRB ash blocks molded, 110 were useable. And of 180 PFBC ash blocks molded, none were useable.

Block production was below expectations for several reasons. First, production did not start until September 13 due to delays in receiving and constructing the plant. Second, design mixes made in Chantilly, Virginia under laboratory conditions did not react the same under field conditions. Consequently, this led to mix design adjustments for field conditions and an inability to make high strength and low strength block. Third, cool weather adversely affected early morning production. Even when the tent side flaps were down, overnight chilling of the tanks and molds impacted cake rise in the first batch. Often the first batch had to be discarded because it did not reach 16 inches in height. (2)

PFBC block testing was eliminated after two days of batches revealed that during autoclaving, the block reacted differently than all other materials tested. Rather than creating a cementitious bond, the block fragmented, cracked, and crumbled. It is apparent that the make up of this ash is sufficiently different from all other ashes tested that autoclaving is inappropriate. It is theorized that a higher percentage of magnesium oxide in the PFBC ash causes the material to expand slightly which counteracts autoclave curing. Also, the lower percentage of silica oxide in PFBC ash reduces the pozzolanic strength of the block. Chemical compositions of the various ashes are included. See Attachments 3, 4, 5, and 6.

Block production under mobile plant conditions revealed the following considerations for permanent plant design and operation.

First any permanent plant should maintain an on-site lab for periodic raw material analysis (particularly fly ash) and batch design modification. A quality assurance/quality control procedure should be established to assure design strengths can be attained and maintained as fluctuations in raw material characteristics occur. Such a lab should include compression testing equipment to assess batch design samples and compare those results with actual batch production blocks to assure batch designs accurately characterize production block characteristics and to periodically sample and verify production block consistency to maintain quality. (3)

Second, a permanent plant should maintain a constant building temperature during production hours to minimize impacts due to the weather. Stated in a slightly different manner, raw material storage, mixing equipment and curing molds should all be maintained at fixed temperatures. After cutting, "green" blocks should be protected from varying weather conditions until they are placed in the autoclave for curing.

Third, based on observations of block which failed to rise sufficiently, it may be possible in a larger scale production facility to produce block with different characteristics on one face of the block verses the other five surfaces. When the mold was cold due to ambient weather conditions, blocks in contact with the cold surface appeared to have fewer and smaller bubbles than blocks not in contact with the mold. This is a fruitful area for further research. It may be that by controlling the surface temperature of a mold, and by engineering a variety of sizes and shapes of molds that a variety of autoclaved cellular concrete products can be produced. A block with a less permeable, stronger, load bearing surface and an internal less dense insulation area may be possible.

Fourth, since autoclaved cellular concrete block is lighter and not as strong as concrete block, block produced for market should be carefully palletized and corners should be protected during transport.

Fifth, some waste material was reused as a raw material. Further testing should be done to determine if a batch of block produced solely from block trimmings and waste material has the same, similar, or dissimilar properties of block produced from raw materials. Such tests would determine plant solid waste disposal costs and could lead to production of block with yet undetermined characteristics.

Sixth, results of autoclave condensate water analysis were very good. A copy of the results are attached. (Attachment 7) Based on this analysis, the City of Akron authorized disposal of plant condensate water to the sanitary sewer system. It may be possible to use condensate water as part of the batch water supply and, thereby, eliminate a source of waste.

Finally, it was observed that of the variety of sources of aluminum used at the mobile demonstration plant, pulverized aluminum supplied by The Reynolds Company was the most reliable and provided the most stable results.

D. Block Laboratory Testing/Results

For the variety of block produced by Ohio Edison in the autoclave cellular concrete mobil plant, the University of Pittsburgh conducted a wide variety of physical, mechanical, and environmental tests of the block.

The University of Pittsburgh was chosen to conduct these tests not only for their capability to conduct such work but also because they were under contract with the Electric Power Research Institute (EPRI) to conduct these same tests on all samples from the national tour of the autoclaved cellular concrete mobile plant. Consequently, results from Ohio Edison fly ash, LIMB ash, and SNRB ash block can be compared to national results when that information becomes available in early 1996.

Physical and mechanical properties testing included:

* moisture content/absorption
* dry shrinkage
* creep
* freeze/thaw durability
* compressive strength
* tensile strength
* flexural strength
* block density

Environmental properties evaluated included:

* heavy metals analysis of leachate
* toxicity testing
* gas chromatography/mass spectrometry
* total organic carbon
* radon testing

Attachment 8 is the final report by the University of Pittsburgh which presents the above specified data.

Results of all tests conducted will be summarized for each of the three block types tested by the University of Pittsburgh. For a complete and thorough summary of these results, please refer to Attachment 8 from the University of Pittsburgh.

1. Ohio Edison R. E. Burger Plant Fly Ash Block:

   Moisture Content

   The block displayed an extremely rapid moisture accumulation tendency due to its porous nature. Furthermore, 90% of the moisture accumulation during block immersion in water occurs within the first hour. Furthermore, as moisture is absorbed into the block, it adversely affects the structural strength of that block. Consequently, for structural uses in contact with groundwater, it will be important to incorporate an impermeable barrier to protect the block from degradation of strength.

   Shrinkage of block from conventional fly ash did not exceed 0.07%.

   Creep

   The total creep was calculated as the difference between final deformation under pressure and the dry shrinkage. Residual deformation was less than 0.06%. Consequently, block shrinkage and creep should have negligible impact on block structural performance.

   - Freeze-Thaw Cycling

   After 15 freezing and thawing cycles, blocks from conventional fly ash had lost less than 5% of their mass. Consequently, these blocks are considered satisfactory for frost resistance.

   Compressive Strength

   Conventional fly ash block had an average compressive strength of 295 psi. For autoclave cellular concrete purposes, this is considered on the low end of a range of strengths from 250 to 800 psi. Comparatively, concrete has a compressive strength in the range of 2,000 to 5,000 psi and masonary block has strengths that range from 1,200 to 1,600 psi.

   Ohio Edison conventional fly ash block pore sizes were significantly wider than autoclave cellular concrete optimum pore size diameters. This likely contributed to the lower strengths. This can be corrected in the batch design.

Of concern, however, is the impact which moisture content has on the compressive strength of the block. For tests on Ohio Edison conventional fly ash block, compressive strength decreased by over 37% as the moisture content reached 60%. Uses of block where they come in contact with water or groundwater should be avoided unless proper steps are taken to prevent water infiltration.

<u>Tensile Strength</u>

The average tensile strength of conventional fly ash block was 36 psi or about one-eighth the compressive strength. This is considered normal. Consequently, blocks in tension should be evaluated to determine if reinforcing is needed.

<u>Flexural Strength</u>

The average flexural strength for conventional fly ash block was 92 psi. The ratio of the average flexural strength to the average compressive strength was acceptable.

<u>Block Density</u>

The block density averaged 33 pounds per cubic foot. Thus, an 8" x 8" x 16" block weighed approximately 20 pounds compared to 64 pounds for a solid concrete masonary block. The low density and related high void diameters suggest that higher strength block can be designed.

<u>Heavy Metals Analysis of Leachate</u>

For five different particle sizes of material, the following results occurred using the EPA-TCLP test method for leachate compared to the drinking water standard (DWS):

* Arsenic	Did not exceed 5 x DWS
* Barium	Met DWS
* Cadmium	Met DWS
* Chromium	Met DWS
* Lead	Met DWS
* Mercury	Met DWS
* Selenium	One sample reached 20 x DWS. The remaining four samples did not exceed 12 x DWS.
* Silver	Did not exceed 2 x DWS

Consequently, leachate from building materials made of conventional fly ash autoclave cellular concrete block have a minimal effect on the environment.

Waste autoclave cellular concrete block building products should be handled and disposed as any other cementitious building product.

It was further found that autoclaved cellular concrete demonstrated a capacity to significantly lower the concentrations of certain heavy metals. This suggests that crushed ACC may be used to attenuate previously polluted waste sites.

Toxicity Testing

Tests indicate the conventional fly ash autoclaved cellular concrete block stimulate microbial growth.

GC/MS Testing for Organics

There was no significant presence of organic constituents in the conventional fly ash autoclaved cellular concrete block.

Total Organic Carbon

The total organic carbon averaged 2 parts per million (ppm) for the ASTM leachates. This is considered insignificant.

Radon Testing

Closed container radon flux testing on conventional fly ash autoclaved cellular concrete block found radiation results well below the 4 pCi/L action level established by EPA. Results were comparable to hollow core concrete blocks.

2. Ohio Edison LIMB Ash Block:

Moisture Content

The block displayed an extremely rapid moisture accumulation tendency due to its porous nature. Furthermore, 90% of the moisture accumulation during block immersion in water occurs within the first hour. Furthermore, as moisture is absorbed into the block, it adversely affects the structural strength of that block. Consequently, for structural uses in contact with groundwater, it will be important to incorporate an impermeable barrier to protect the block from degradation of strength.

Shrinkage of block from LIMB ash exceeded the 0.07% upper limit. LIMB ash block exhibited an average drying shrinkage of 0.087% which is outside recognized acceptable limits.

Creep

The total creep was calculated as the difference between final deformation under pressure and the dry shrinkage. Residual deformation was approximately 0.27%. Consequently, block shrinkage and creep could have a detrimental impact on block structural performance.

Freeze-Thaw Cycling

After 15 freezing and thawing cycles, blocks from LIMB ash had lost over 50% of their mass. Consequently, these blocks are not satisfactory for frost resistance.

Compressive Strength

LIMB ash block had an average compressive strength of 168 psi. For autoclave cellular concrete purposes this is considered extremely low.

LIMB ash block pore sizes were in line with autoclaves cellular concrete optimum pore size diameters, yet the material did not exhibit favorable mechanical properties or good durability. It is not likely that this flaw in compressive strength can be corrected by alternate batch design.

Of additional concern is the impact which moisture content has on the compressive strength of the block. For tests on LIMB ash block, compressive strength decreased by over 32% as the moisture content reached 60%. Uses of block where they come in contact with water or groundwater, or where the block can be subject to freezing must be avoided.

Tensile Strength

The average tensile strength of LIMB ash block was 18 psi, or about one-ninth the compressive strength. This is considered normal. Blocks in tension should be evaluated to determine if reinforcing is needed.

Flexural Strength

The average flexural strength for LIMB ash block was 39 psi. The ratio for the average flexural strength to the average compressive strength was acceptable.

Block Density

The block density averaged 38 pounds per cubic foot. Thus, an 8" x 8" x 16" block weighed approximately 22 pounds. The higher density (when compared to conventional fly ash block) and the smaller void diameters suggest that higher strength block may not be possible.

Heavy Metals Analysis of Leachate

For two different particle sizes of material, the following results occurred using the EPA-TCLP test method for leachate compared to the drinking water standard (DWS):

• Arsenic	Did not exceed 3 x DWS
• Barium	Met DWS
• Cadmium	Met DWS
• Chromium	Did not exceed 2 x DWS
• Lead	Met DWS
• Mercury	Met DWS
• Selenium	Did not exceed 20 x DWS
• Silver	Met DWS

Consequently, leachate from LIMB ash autoclaved cellular concrete block has a minimum effect on the environment.

Waste autoclave cellular concrete block should be handled and disposed as any cementitious building product.

It was further found that autoclaved cellular concrete from LIMB ash demonstrated a capacity to significantly lower the concentrations of certain heavy metals. This suggests that crushed ACC may be used to attenuate previously polluted waste sites.

Toxicity Testing

Tests indicate that LIMB ash autoclaved cellular concrete block produced a toxic effect on bioluminescent bacterial organisms that became more pronounced as the dilution of the leachates increased. Similar behavior of the leaching blank demonstrated that the leaching fluid may have been the reason for this result.

GC/MS Testing for Organics

There was no significant presence of organic constituents in the LIMB ash autoclaved cellular concrete block.

Total Organic Carbon

The total organic carbon averaged 1 ppm for the ASTM leachates. This is considered insignificant.

Radon Testing

Closed container radon flux testing on LIMB ash autoclaved cellular concrete block found radiation results well below the 4 pCi/L action level established by EPA. Results were comparable to hollow core concrete blocks.

3. Ohio Edison SNRB Ash Block:

Moisture Content

The block displayed an extremely rapid moisture accumulation tendency due to its porous nature. Furthermore, 90% of the moisture accumulation during block immersion in water occurs within the first hour. Furthermore, as moisture is absorbed into the block, it adversely affects the structural strength of that block. Consequently, for structural uses in contact with groundwater, it will be important to incorporate an impermeable barrier to protect the block from degradation of strength.

Shrinkage of block from SNRB ash exceeded the 0.07% upper limit. SNRB ash block exhibited an average drying shrinkage of 0.09% which is outside recognized acceptable limits.

Creep

Creep data for SNRB ash block is not yet available from the University of Pittsburgh. It will be provided as a report modification at a later date.

Freeze-Thaw Cycling

After 15 freezing and thawing cycles, blocks from SNRB ash had lost over 6% of their mass. The recognized acceptable limit is 5%. Consequently, these blocks are not satisfactory for frost resistance. A positive result was that the block lost only 10% of its strength due to freeze thaw cycling. It may be possible to increase the cement content of this mix and produce an acceptable product which is higher in strength, lower in shrinkage, and better withstands freeze-thaw cycling.

Compressive Strength

SNRB ash block had an average compressive strength of 168 psi. For autoclave cellular concrete purposes this is considered extremely low.

SNRB ash block pore sizes were in line with autoclaved cellular concrete optimum pore size diameters, yet the compressive strength is low. While alternate batch design may improve freeze-thaw and shrinkage characteristics, the compressive strength may not increase significantly.

Of additional concern is the impact which moisture content has on the compressive strength of the block. For tests on SNRB ash block, compressive strength decreased by 37% as the moisture content reached 60%. Uses of block where they come in contact with water or groundwater must be avoided.

Tensile Strength

The average tensile strength of SNRB ash block was 13 psi or about one-thirteenth the compressive strength. This is considered acceptable. Blocks in tension should be evaluated to determine if reinforcing is needed.

Flexural Strength

The average flexural strength for SNRB ash block was 39 psi. The ratio for the average flexural strength to the average compressive strength was acceptable.

Block Density

The block density averaged 32 pounds per cubic foot. Thus, an 8" x 8" x 16" block weighed approximately 19 pounds. The lower density (when compared to conventional fly ash block) and the smaller void diameters suggest that a somewhat higher strength block may be possible.

Heavy Metals Analysis of Leachate

For two different particle sizes of material, the following results occurred using the EPA-TCLP test method for leachate compared to the drinking water standard (DWS):

- Arsenic — Did not exceed 3 x DWS
- Barium — Met DWS
- Cadmium — Met DWS
- Chromium — Met DWS
- Lead — Met DWS
- Mercury — Met DWS
- Selenium — Did not exceed 20 x DWS
- Silver — Met DWS

Consequently, leachate from SNRB ash autoclaved cellular concrete block has a minimum effect on the environment.

Waste autoclave cellular concrete block should be handled and disposed as any cementitious building product.

It was further found that autoclaved cellular concrete from SNRB ash demonstrated a capacity to significantly lower the concentrations of certain heavy metals. This suggests that crushed ACC may be used to attenuate previously polluted waste sites.

Toxicity Testing

Tests indicate that SNRB ash autoclaved cellular concrete block produced a toxic effect on bioluminescent bacterial organisms that became more pronounced as the dilution of the leachates increased. Similar behavior of the leaching blank demonstrated that the leaching fluid may have been the reason for this result.

GC/MS Testing for Organics

There was no significant presence of traceable organic constituents in the SNRB ash autoclaved cellular concrete block.

Total Organic Carbon

The total organic carbon averaged 2 ppm for the ASTM leachates. This is considered insignificant.

Radon Testing

Closed container radon flux testing on SNRB ash autoclaved cellular concrete block found radiation results well below the 4 pCi/L action level established by EPA. Results were comparable to hollow core concrete blocks.

E. Block Field Testing/Results

For this project, autoclaved cellular concrete block was field tested by Consolidation Coal Company (CONSOL) in their Powhattan Point mine in southeastern Ohio. Also, remaining conventional fly ash autoclaved cellular concrete block was used by Ohio Edison in constructing a pump house building at the Edgewater Plant of Ohio Edison in Lorain, Ohio.

1. Field Testing by CONSOL

In a letter dated May 4, 1992, CONSOL agreed to test autoclaved cellular concrete as air stoppings in their underground mine. In compliance with the Ohio Coal Development Office request that an Ohio mine be used in the test, CONSOL agreed to use its Powhattan Point No. 4 mine in Clarington, Ohio. See Attachment 9.

In a meeting with CONSOL representatives on February 21, 1994 it was decided that eight stoppings would be built, six using conventional fly ash blocks, and two made up of 50% SNRB blocks with 50% fly ash blocks, and 50% LIMB ash blocks with 50% fly ash blocks. The 50/50 splits were required because there were insufficient numbers of SNRB and LIMB ash blocks produced to complete entire stoppings.

Prior to using autoclaved cellular concrete blocks in their underground mine, the blocks were required to undergo flexural testing to meet U.S. Department of Labor, Mine Safety and Health Administrations standards for stopping wall material; ASTM E 72-80 standard. This test is described in detail in Attachment 10.

On March 8, 1994 Ohio Edison conventional fly ash autoclaved cellular concrete block was tested for flexural load resistance by Professional Service Industries Incorporated of Pittsburgh, Pennsylvania. The ASTM E72-80 standard is 30 pounds per square foot. The average flexural strength achieved was 61.8 pounds per square foot.

These results were presented to the Chief of the Industrial Safety Division of the Mine Safety and Health Administration of the Department of Labor on March 18, 1994.

The test results of March 8 and the meeting of March 18 led to approval on March 31 to use the autoclaved cellular concrete block in CONSOL's underground mine. See Attachments 10, 11, and 12.

Ohio Edison autoclaved cellular concrete block was shipped to CONSOL Powhattan Point No. 4 mine immediately after we received this approval.

During May, 1994 seven stoppings were built in their mine. All stoppings were constructed by dry stacking the blocks and plastering all or portions of each block on both sides of the stopping.

Of the seven stoppings constructed, six used conventional fly ash autoclaved cellular concrete block and one stopping consisted of 1/2 SNRB ash block and 1/2 LIMB ash block due to the shortage of that block.

We observed construction of stopping No. 1 on May 19, 1994. Representatives from Ohio Edison, Ohio Coal Development Office, and North American Cellular Concrete accompanied CONSOL personnel underground to observe the initial stopping wall installation.

Blocks delivered to the work area appeared to be badly damaged due to careless handling and unloading. Bundling of palletized blocks using protective cardboard corners would solve this problem. Special bundling/palletization standards should be requested of each mine using the block so that underground transport of the block can be accomplished with minimal damage to the block. Although CONSOL personnel requested the 8" x 16" x 16" block be cut prior to shipment, during installation they agreed the larger block could have been used "as is" since miners tended to carry two 8" x 8" x 16" of these light-weight blocks at one time anyway. Using larger block will decrease the time necessary to construct a stopping wall. CONSOL personnel constructing this initial stopping liked the ability to cut and shape the block to fit the ribbing of the sidewalls and ceiling. A simple hand saw was used to cut the block.

Once the block was cut and placed, it was coated with B-bond plaster. Block on the left side of the stopping were coated dry while block on the right side of the stopping were wetted just prior to applying plaster. We observed that dry ACC block absorbed moisture from the plaster. Also, plaster application on the dry ACC block was more difficult. During the three-month inspection in August, 1994 and the seven-month inspection in December, 1994, both the left side and right side of this stopping appeared to be functioning well with no noticeable difference in performance.

North American Cellular Concrete personnel and Ohio Edison personnel, after watching the stoppings constructed in the CONSOL mine, believe that an easier method of building stoppings could be devised. They suggested that rather than dry stack ACC block and mortar both sides to develop the necessary lateral strength, that the blocks could be glued together with latex mortar, achieve the necessary lateral strength and eliminate the need for mortar. CONSOL agreed that if Ohio Edison and North American Cellular Concrete could provide additional block and mortar to their test facility in Library, Pennsylvania that the ASTM E72-80 flexural strength test could be duplicated.

From May through July the following stoppings were constructed by CONSOL:

* Stopping No. 1 of conventional fly ash ACC block

  One-half the stopping wall was wetted prior to plastering.

* Stopping No. 2 of conventional fly ash ACC block

  All blocks were wetted prior to plastering.

* Stopping No. 3 of conventional fly ash ACC block

  All blocks were dry prior to applying plaster only over block joints. This appears to save time and material during stopping wall construction.

* Stopping No. 4 the left side of which is made of SNRB ash ACC block and the right side of which is made of LIMB ash block

  All blocks were wetted prior to plastering.

* Stopping No. 5 of conventional fly ash ACC block

  All blocks were dry prior to applying plaster. This stopping had a man door installed initially and protrusion holes cut into it at a later date to pass electrical wiring through the stopping wall.

* Stopping No. 6 was reserved to later test higher strength ACC block to be supplied by North American Cellular Concrete

* Stopping No. 7 of conventional fly ash ACC block combined with regular masonary block. The bottom four feet of this topping were of regular masonary block. However, laborers located and retrieved the remaining ACC block to build the upper six feet of

this unusually high stopping wall because it was easier to use.

All blocks were wetted prior to plastering.

Use of autoclaved cellular concrete block for constructing underground mine stopping walls appeared to be successful. Laborers who installed the stoppings commented very favorably on the weight of the block as well as the ease of cutting and shaping the block.

The light weight of the block may help reduce back inquiries in situations where stopping construction is above chest height but for general block handling, laborers were observed carrying two or three of these light weight block as compared to one 64-pound masonary concrete block.

Furthermore, cutting the block to fit the stopping sidewall ribbing is easier than chipping masonary concrete block and may reduce eye injuries although no data is available to substantiate this observation.

A final observation is that later wall penetrations such as those observed at test Stopping No. 5 should be easier to create with the softer ACC block which can be easily cut or drilled.

Attachment 13 is the CONSOL summary of ACC block performance in this test. The three-month and seven-month inspections of all stoppings found them to be performing satisfactorily. CONSOL has suggested this block be further tested in a mine where convergence (roof sag or bottom hoofing) is more significant and places the block in early compression.

2. Field Testing by Ohio Edison

In April, 1994, 400 remaining conventional fly ash autoclaved cellular concrete block from the mobile demonstration plant were taken to the Ohio Edison Edgewater Plant and used to construct an above-ground pump house structure. See Attachment 14.

Three sides of the pump house were made of autoclaved cellular concrete. The remaining side was made of conventional hollow core concrete block. The autoclaved cellular concrete block and concrete block were integrated by varying the thickness of mortar used between rows of block.

The purpose of this test is to observe autoclaved cellular concrete block along with concrete block under harsh damp weather conditions. The pump house is located on the north side of the Edgewater Plant near Lake Erie.

Furthermore, the walls of autoclaved cellular concrete block have three different surface treatments. One wall is completely unprotected, the second wall is coated with only a waterproofing agent, and the third wall is coated with B-Bond plaster similar to that used in the underground mine test.

The pump house was inspected in April, 1995. There were no observable differences among the four walls. The blocks did not appear to be weathered, cracked, shipped or saturated. The wall coated with B-Bond plaster showed no signs of cracking or spalling. We will continue to observe the performance of this building which is exposed to severe weather conditions.

An additional 50 conventional fly ash autoclaved cellular concrete block were delivered to CONSOL's test facility in Library, Pennsylvania in early September, 1994. CONSOL constructed an ACC test panel using these block bonded together with thin set mortar as was suggested by North American Cellular Concrete and Ohio Edison personnel. After 28 days of required curing, on October 7, 1994, the test panel was horizontally loaded in accordance with ASTM E72-80 until it failed. The test panel failed after an incremental horizontal load of 14.5 pounds per square foot (PSF) was applied. The test standard is 39 psf. After the test was conducted, the test panel was disassembled and inspected. It appears the thin-set mortar holding the blocks together may have been improperly applied. Further testing using proper mortaring tools, dampening the contact surface of the blocks prior to mortaring and tapping the block into place is warranted.

F. Public Exposure to the Autoclaved Cellular Concrete Mobil Plant Project at Ohio Edison

On January 25, 1993 when Ohio Edison assembled a team to receive the autoclaved cellular concrete mobile plant, we discussed our goals to generate interest in the process and product. We established a goal to demonstrate the mobile plant to 400 interested visitors. As of the end of January, 1994, 384 people interested in autoclaved cellular concrete and the demonstration project had seen or received materials on the project from Ohio Edison.

The following significant events and presentations have increased the state and national interest in autoclaved cellular concrete as a result of this project sponsored in part by the Ohio Coal Development Office:

1. A plant kick-off meeting was conducted for project participants, dignitaries, and media on September 16, 1993.

2. Ohio Edison established a visitation schedule for interested businesses and university personnel from within our service territory. Presentations and tours of the mobile demonstration plant were given twice per day each Tuesday and Thursday from September 21 through October 28, 1993.

3. On October 28, 1993, the first national conference on ACC was held in Fairlawn, Ohio. Busses were rented to transport conference attendees to and from the demonstration site. The conference was sponsored by Ohio Edison Company and the Ohio Coal Development Office. See Attachments 15, 16, 17, 18, and 19.

4. Kornylak Incorporated, an equipment builder from Hamilton, Ohio showed interest in being considered an equipment supplier for this and other ash-to-product applications.

5. North American Cellular Concrete notified Ohio Edison of their intent to work with Ryan Homes to build model homes of autoclaved cellular concrete in Pittsburgh and Florida.

6. In March, 1994, autoclaved cellular concrete block was introduced to the Mine Safety and Health Administration of the U.S. Department of Labor. Samples and test results presented led to the eventual approval of autoclaved cellular concrete block in underground mine stoppings.

7. The Electric Power Research Institute (EPRI) of Palo Alto, California working in concert with the nine participating electric utilities participating in the autoclaved cellular concrete demonstration plant national project has begun to pursue national building code approval of autoclaved cellular concrete.

8. EPRI participated in Earth Day activities on April 19-20, 1994 in Washington, D.C. by handing out ACC block samples and literature on converting ash to beneficial products. Materials they handed out are in Attachment 20.

9. Ohio Edison made two presentations on autoclaved cellular concrete to students of the Kent State University-Energy and Power Class.

10. Ohio Edison presented information on autoclaved cellular concrete and the demonstration plant to the Lorain County Consumers Panel in Lorain, Ohio on May 5, 1995. The presentation was enthusiastically received.

11. Ohio Edison accompanied 28 local contractors to visit and inspect the autoclaved cellular concrete home constructed by Ryan Homes and Duquesne Light in Coraopolis, Pennsylvania. While the Duquesne Light aspect of the national project is not part of this research effort with the Ohio Coal Development Office, it did create opportunities for more Ohio businesses to observe autoclaved cellular concrete in use. Attachment 21 is a series of photographs of that house during construction.

12. Ohio Edison made a presentation to Ohio EPA personnel from their Southeast Office on autoclaved cellular concrete and the mobile demonstration plant in November, 1994.

Of the nine utilities involved in the national autoclaved cellular concrete project, Ohio Edison has been the most active in generating public and business interest in autoclaved cellular concrete. Such efforts would not have been possible without the support of the Ohio Coal Development Office and the efforts of North American Cellular Concrete.

Marketing/Commercialization Discussion

A. Restatement of Purpose

The purpose of this project has been to demonstrate the potential for beneficial use of fly ash and clean coal technology by-products in the production of lightweight block. While market analysis was not outlined by Ohio Edison as part of this program, some marketing opportunities can be discussed generally. Also, North American Cellular Concrete prepared a business plan in 1994. See Attachment 22. It should be noted that the Diversified Services Department of Ohio Edison Company has reviewed these available materials and has undertaken a more comprehensive assessment of the marketability of autoclaved cellular concrete and is evaluating commercialization costs. Their work and work products are beyond the scope of this project and are considered confidential.

B. Ohio Edison Comments Regarding Marketability of Autoclaved Cellular Concrete

As the technical reports by the University have shown, autoclaved cellular concrete has properties which make it an advantageous building material.

1. Fly ash autoclaved cellular concrete block has sufficient strength, durability, freeze thaw resistance, insulation value, and fire resistance to make it a valuable commercial, industrial, and residential building material. See Attachment 8. Ohio Edison autoclaved cellular concrete fly ash blocks have successfully been used in constructing underground stopping walls in CONSOL's Powhattan Point mine. For this purpose autoclaved cellular concrete block has already been approved by the Mine Safety and Health Administration for use in underground mines. The product is popular with miners, because of its light weight and ease of shaping to fit existing openings. This appears to be a market ready to be pursued.

   Ohio Edison autoclaved cellular concrete fly ash blocks have also successfully been used in constructing a pump house building at the Ohio Edison Edgewater Plant in Lorain, Ohio. The pump house will be evaluated for resistance to periodic harsh weather. So far, the block has performed admirably.

   Finally, it should be noted that the nine participating utilities are working here with the Electric Power Research Institute (EPRI) to secure building code approval for the use of autoclaved cellular concrete block. Attachment 23 is the RILEM recommended practices for construction using ACC. This can be converted to U.S. standards and become the basis for construction code modifications.

2. LIMB ash autoclaved cellular concrete block has sufficient strength, durability and fire resistance to make it a valuable mining industry stopping wall building material. Autoclaved cellular concrete block has already been approved for use in underground mines. The underground mine situation eliminates freeze-thaw concerns. Furthermore, block shrinkage is less of a factor in short wall situations as is the case with mine stoppings. At 38 pounds per cubic foot, the block is about one-third the weight of concrete block presently being used. This would reduce the frequency of back injuries associated with building stopping walls and lifting/carrying/placing block. Also, the ease of shaping the block to fit irregular openings could reduce

eye injuries which result as concrete block are chipped to fit into place. Furthermore, wall penetrations are much easier to make in this softer block than in concrete masonary block. Care should be taken, in using this block in underground stoppings where water can build up on one side of the stopping wall as increasing moisture into the block substantially reduces it strength.

3. <u>SNRB ash autoclaved cellular concrete block</u> is very similar to LIMB ash block and should make an excellent stopping wall building material. Furthermore, SNRB ash autoclaved cellular concrete block is 15% lighter than LIMB ash block yet has the same compressive strength of 168 psi.

C. North American Cellular Concrete Business Plan

North American Cellular Concrete points out that the construction industry in the United States represents approximately 8% of the Gross National Product and that wall products account for $50 billion of the U.S. Construction Industry. NACC expects to capture at least 1/2% (or $250 million) of this market during its first 10 to 20 years of producing autoclaved cellular concrete.

North American Cellular Concrete also points out that the market for stopping wall block may be in excess of 30,000,000 blocks per year east of the Mississippi River. A 30 million block market (6" x 8" x 16" block) would use over 170,000 tons of LIMB ash or 150,000 tons of SNRB ash per year.

The North American Cellular Concrete Business Plan is Attachment 22.

While it appears that the higher strength fly ash autoclaved cellular concrete block may be destined for the commercial industrial and residential building market, LIMB ash and SNRB ash autoclaved cellular concrete block could be used to fill the stopping block wall market using the exact same technology.

It is possible for one plant to periodically vary raw material sources to produce a variety of products/materials for a variety of markets.

Final Budget Summation

Table 1 represents the estimated project costs from the original Statement of Work for OCDO Proposal D-921-02.

The expected costs of the primary participants in the study were as follows:

Participant	Total Cost of Participation
Ohio Edison	$146,000
Ohio Coal Development Office	75,000
CONSOL, Inc.	58,000
North American Cellular Concrete	16,000

The combined Ohio Edison/Ohio Coal Development Office expected cost was $211,000.

The final costs of the primary participants in the study are:

Participant	Total Cost of Participation
Ohio Edison	$133,000
Ohio Coal Development Office	75,000
CONSOL, Inc.	58,000
North American Cellular Concrete	20,000

Table 2 shows the total project expenses by major category and contributions of all cosponsors, including the Ohio Coal Development Office.

Finally, Table 3 itemizes the expenditures by Ohio Edison which the Ohio Coal Development Office funds will be used to cover. Elements for Table 3 have been chosen from Ohio Edison accounting records to assure that all Ohio Coal Development Office funds are spent within the State of Ohio. Attachment 24 itemizes the accounts payable and materials/supplies charged to the autoclaved cellular concrete project identified by Ohio Edison accounting as Job No. Z3901.

Table 3 identifies the items for which the Ohio Coal Development Office funding will be used to reimburse Ohio Edison. The last, and largest two items on this table are reimbursements to Ohio Edison for Autoclaved Cellular Concrete Team member salaries for the 1719 hours of team effort on this project and the 758 hours of non-team labor on this project.

TABLE 1

AUTOCLAVE BLOCK PROJECT CONTRIBUTIONS (EXPECTED COSTS)

PARTICIPANT	CASH	PERSONNEL	MISCELLANEOUS EXPENSES	TESTING	TRAVEL	LINE TOTALS
Ohio Edison Company	$70,000	$57,000	$15,000		$4,000	$146,000
Ohio Coal Development Office	75,000					75,000
CONSOL Inc.		48,000		$10,000		58,000
North American Cellular Concrete		16,000				16,000
TOTAL PROJECT CONTRIBUTIONS						$295,000

TABLE 2

AUTOCLAVE BLOCK PROJECT CONTRIBUTIONS (FINAL COSTS)

PARTICIPANT	CASH	PERSONNEL	MISCELLANEOUS EXPENSES	TESTING	TRAVEL	LINE TOTALS
Ohio Edison Company	$125,000	$ 6,000	$ 1,000		$1,000	$133,000
Ohio Coal Development Office	75,000*					75,000
CONSOL Inc.		48,000		$10,000		58,000
North American Cellular Concrete		20,000				20,000
TOTAL PROJECT CONTRIBUTIONS						$286,000

* OCDO contributions will be used to repay an additional $50,000 of Ohio Edison personnel salaries associated with the Autoclave Cellular Concrete Project and an additional $25,000 of Ohio Edison project costs associated with the ACC Project. Ohio Edison total personnel costs were $56,000, and Ohio Edison total miscellaneous expenses were $26,000.

TABLE 3

ITEMIZED CONTRIBUTIONS OF THE OHIO COAL DEVELOPMENT OFFICE FOR PROPOSAL D-921-02

ACCOUNTS PAYABLE

Supplier/Item (Outside Vendors)	Cost	OCDO Contribution
Wolff Bros. Supply In - Pamphlets	$ 108.19	$ 108.19
Wolff Bros. Supply In - Pamphlets Tax	6.90 St.	6.90 St.
Wolff Bros. Supply In - Pamphlets	602.55	602.55
Putnam Transfer & Sto - Dumpster	220.75	220.75
Summit Paint & Decora - Signs & Posters Tax	7.02 St.	7.02 St.
Summit Paint & Decora - Signs & Posters	112.32	112.32
United Parcel Service - Material Delivery	169.68	169.68
Frontier Tank Center - Misc. Equipment	187.36	187.36
Corporate Caterers - Buffet for Open House	442.25	442.25
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Tank Center - Misc. Equipment Tax	11.71 St.	11.71 St.
Discount Drainage Sup. - Misc. Equipment Tax	8.28 St.	8.28 St.
Discount Drainage Sup. - Misc. Equipment	132.45	132.45
Frontier Tank Center - Misc. Equipment	50.65	50.65
Gregory S. Edwards - Local Help	370.70	370.70
Frontier Trailer Sale - Water Tank Rental	700.00	700.00
American Printing, Inc. - Handouts	898.00	898.00
The Crawford Company - Pamphlets	3,280.35	3,280.35
B & B Advertising Ser - Handouts	975.00	975.00
Postmaster - Postage	2,520.81	2,520.81
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Vance Charters, Inc. - Bus Rental for Tour of ACC Plant	100.00	100.00
The Crawford Company - Pamphlets Tax	205.02 St.	205.02 St.
B & B Advertising Ser - Handouts Tax	60.94 St.	60.94 St.
American Printing Inc. - Handouts Tax	56.13 St.	56.13 St.
Frontier Trailer Sale - Water Tank Rental	700.00	700.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Gregory S. Edwards - Local Help	370.70	370.70
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Consolidated Plastics - Misc. Equipment	76.62	76.62
Treasurer of State - Permit for Boiler	33.25	33.25
Smith Sign Company - Signs for Site	45.00	45.00
Roadway Express, Inc. - Miscellaneous	101.82	101.82
Consolidated Plastics - Misc. Equipment Tax	4.24 St.	4.24 St.
Smith Sign Company - Signs for Site Tax	2.81 St.	2.81 St.
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Frontier Trailer Sale - Water Tank Rental	350.00	350.00
Roadway Express, Inc. - Miscellaneous	170.95	170.95
Laidlaw Waste Systems - Dumpster	30.66	30.66
Frontier Trailer Sale - Water Tank Rental	325.00	325.00
Artists Inc. - Logos for Posters Tax	197.57 St.	197.57 St.
Artists Inc. - Logos for Posters	3,161.18	3,161.18
Gregory S. Edwards - Local Help	696.08	696.08
Frontier Trailer Sale - Water Tank Rental	700.00	700.00
Frontier Trailer Sale - Water Tank Rental (Part Week)	70.00	70.00
Frontier Trailer Sale - Water Tank Rental Refund	-349.95	-349.95
Overnite Transport - Courier	240.56	240.56
D & J Masonry, Inc. - Block Handling/Hauling	400.00	400.00
Messmore/Timmerman SE - Misc.	349.50	349.50
Centra, Inc. - Misc.	945.00	945.00

TABEL 3 (Continued)

MATERIALS & SUPPLIES

Supplier/Item (Ohio Edison Storeroom)	Cost	OCDO Contribution
Cable CU 600 3-1/C	$1,360.83	$1,360.83
Conduit Rigid PVC	41.11	41.11
Coupling Conduit Str	2.87	2.87
Bend, Conduit PVC	29.17	29.17
Drum (Used) 55 Gal	22.31	22.31
Rope Polyester	98.60	98.60
Coveralls Disposable	14.03	14.03
Coveralls Disposable	14.03	14.03
Coveralls Disposable	15.39	15.39
Liner F/RBR Gloves	10.90	10.90

OHIO EDISON PAYROLL

Item Hours	Cost	OCDO Contribution
758.25 Hours - Ohio Edison Labor	$12,630.63	$10,000.00
1,719 Hours - Ohio Edison ACC Team Effort	42,975.00	40,000.00

Totals	$80,562.92	$74,957.29