Autoclaved Cellular Concrete, the Future of Fly Ash

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ABSTRACT

Autoclaved Cellular Concrete (ACC, also known as Autoclaved Aerated Concrete, or AAC) is a lightweight building product with high insulating value which can be manufactured using 60-75% fly ash by weight. Fly ash with carbon content up to 12% may be used in the mix, thereby allowing high volume use of ash from sources that do not meet ready-mix concrete specifications. For over seven years, TVA has evaluated Autoclaved Cellular Concrete as part of a strategy to locate a high volume user of coal combustion by-products on a TVA Fossil Plant site. TVA's participation in the Electric Power Research Institute (EPRI) Tailored Collaboration Project in which a portable pilot plant was used to manufacture block from various utilities and TVA's subsequent market research demonstrated that a moderately-sized production facility could be profitable if located at any one of several TVA Fossil Plants. TVA's Fuel Operations Division used the results of these studies to attract an investor to build such a plant in Clinton, Tennessee. The plant will utilize up to 100,000 dry tons of fly ash per year from TVA's Bull Run Fossil Plant. This paper will discuss the process by which TVA evaluated the potential market and awarded a contract for the first ACC plant in North America to be located at a fossil plant site and the first to use fly ash as the siliceous component.

Introduction

The Tennessee Valley Authority (TVA) is a United States Government Corporation with the mandate to strengthen the regional economy and to maintain river navigation, flood control, and a reliable supply of power at the lowest feasible price. In addition to 3 nuclear plants (5 units), 4 combustion turbine plants (48 units), 1 pumped storage plant (4 units) and 29 hydro plants (109 units), TVA operates 11 coal-fired steam electric plants (59 units) which each year produce a total of 5.8 million tons of fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) gypsum. In 1998, TVA recycled over 1.6 million tons of these materials for use in cement products, gypsum wallboard, industrial abrasives, roofing materials and highway construction. By the year 2001, TVA projects utilization at the rate of over 2.7 million tons per year. In order to achieve this utilization goal, TVA is pursuing supply arrangements with companies capable of utilizing

combustion by-products as primary raw materials in manufacturing facilities located in the immediate vicinity of TVA's coal-fired plants. One such company is Babb International, LLC (BI) which has constructed North America's first permanent Autoclaved Cellular Concrete (ACC) plant (a one-autoclave facility) using utility fly as its sole source of siliceous filler. In the spring of 2000, BI will begin operation of a full-size, multimillion dollar plant at TVA's Bull Run Fossil Plant in Clinton, Tennessee near Knoxville. As a result, TVA will be the first utility in the United States to locate an ACC manufacturing facility directly on a coal-burning utility plant reservation.

ACC is a lightweight building material which can be manufactured using water, cement, aluminum, and up to 70% fly ash by weight. Manufactured in blocks or panels, ACC provides high insulation value, is fireproof, is lightweight (some mix designs float in water) and, based on total installed cost, is less expensive to use than conventional concrete block or lumber. ACC is a widely used building product in Europe. Until recently, the abundance of inexpensive wood products in the United States has provided little incentive for the development of new building technologies; however, rapidly dwindling timber reserves and high prices for quality construction lumber make ACC an attractive substitute for lumber construction products. Two ACC plants are in operation in the US; however, these plants use mined sand as the siliceous ingredient.

The Strategy

TVA has evaluated ACC as part of a strategy to locate a high volume user of coal combustion by-products on a TVA Fossil Plant site. TVA's coal combustion by-product utilization and marketing program focuses on three strategic goals:

- Maximize the quantity of coal combustion by-products diverted from disposal into beneficial reuse.
- Minimize the cost of by-product handling and disposal at the fossil plants.
- Maximize revenue through by-product marketing.

Between 1985 and 1997, TVA laid the foundation for its core marketing program based on the sale of high quality boiler slag, fly ash, and gypsum into the building materials industry. By the year 2001 this core market will utilize 2.5 million tons of by-products per year, or roughly 43% of TVA's production. Long-term agreements for slag and gypsum utilization have resulted in the construction of processing facilities adjacent to three TVA plants with constant rates of utilization and revenue year-round. Fly ash marketing provides high utilization rates and high revenue during the building season, but, due to the lack of dry storage capacity, TVA plants must dispose of significant quantities of fly ash during the winter or during other lulls in construction throughout the year. The unsold 57% of TVA's production consists of off-season disposal and by-products of variable or marginal quality such as fly ash with high or variable carbon content, ponded fly ash, gypsum with high fly ash content, slag from western coals, and pyrite-containing bottom ash.

Long-term planning for ash disposal resources requires utilities to know three to ten years in advance what impact by-product utilization will have on manpower, equipment, maintenance, and the development of future disposal capacity. Expanding TVA's core by-product marketing business by locating multiple year-round, high-volume users of non-specification by-products within sight of coal-burning power plants addresses each of the three goals of increasing utilization, reducing cost, and generating revenue.

EPRI Study

In 1993 TVA participated in the Electric Power Research Institute (EPRI) Tailored Collaboration project to demonstrate the ACC process for manufacturing lightweight concrete building materials using recycled utility fly ash. A total of ten utilities participated in the project: Public Service of Indiana, New England Power, United Illuminating, Ohio Edison, Alabama Power, Georgia Power, Niagara Mohawk, Union Electric Power, Sierra Pacific Power, and TVA. A small pilot plant facility was constructed and moved to each utility in turn, and ACC block were produced with utility fly ash from each site. TVA hosted the pilot plant at the Shawnee Fossil Plant near Paducah, Kentucky in the spring of 1994. This project demonstrated the feasibility of producing ACC with fly ash as the primary raw material from a number of different plants and coal types across the U.S.

Market Study

As a follow-up to the pilot plant demonstration, TVA conducted a market study which assessed various investment scenarios for construction of ACC manufacturing facilities in the Tennessee Valley. Under contract to TVA, LAW Engineering prepared a Feasibility Study and Market Survey for Autoclaved Cellular Concrete to evaluate regional demographics and construction activities, major markets for the TVA plants, and the potential Autoclaved Cellular Concrete (ACC) market share for manufacturers in the vicinity of TVA plants. The final report also presented financial analyses for startup of a small ACC plant and additional cases for a larger plant. The key assumption for the analyses is: "ACC materials are not intended to be used as direct replacement materials in the present construction methods. ACC is a specialty alternative construction method and must be evaluated using total installed cost not on material cost alone."[1]

LAW surveyed key contacts in the manufacturing and construction industries in order to gauge the receptivity of the US market to ACC. Interviews were conducted with:

- Two European ACC manufacturers
- A regional vice president of construction for a major US home builder
- A major, quality masonry contractor
- A small, custom, high end home builder
- Several individuals who are building or considering building with ACC block.

Barriers

Based on these interviews, the study identifies several barriers to residential and commercial markets for ACC:[1]

- Reluctance toward change and little interest in new products by architects and developers.
- No interest in new products by buyers, homeowners, residential developers, commercial developers.
- Homebuyers' perception of ACC may not be favorable in the short term; ACC may not be viewed as a "quality material."
- Resistance to change by trades involved in residential and commercial construction.
- Costs of the "learning curve" while working with a new product.
- Investors may not be able to lose money in short run as ACC becomes accepted by industry.
- Start up costs associated with promoting and teaching industry to build with ACC.
- Lower R-value per inch of ACC compared to wood frame with insulation.
- Possible building code barriers: manufacturers may need to "sell" product to public agencies.
- ACC is designed to replace wood, fiberglass insulation, concrete block and precast concrete tilt-ups: materials that industry is generally satisfied with now.

Additional factors which were considered in the analysis were:

- Labor costs: Tennessee is a right-to-work state, and labor availability was rated either high or medium in the vicinity of all TVA Fossil Plants; hourly wages varied by $3.00 across the Valley.
- Ash disposal costs: Each plant was rated according to fly ash disposal costs.
- Local desire to have a new plant: For each Fossil Plant, the study presented a summary of incentive programs available from states, local governments, and industrial development boards as well as local recruitment efforts and results. The study also identified specific high-interest regions.
- Access to low cost transportation: The economics and logistics of truck, rail and barge were examined, and shipping routes to major outlet cities were identified.
- The volume of residential and commercial construction within a defined market region: Clarksville, Chattanooga, Knoxville, Memphis, and Nashville account for 70% of residential permits and for over 80% of commercial contracts which include office buildings, strip malls, and industrial buildings
- Population levels and population size versus population growth rates: With the exception of the Atlanta metropolitan area, very large cities tend to grow slowly, due to diseconomies of scale (crime, smog, land prices, taxes, congestion). The projected growth rate of the cities in the TVA region ranges from 0.5% to 2.5%.
- Total market potential

To determine the locations at which an ACC plant would most benefit TVA, the Fossil Plants were ranked by Market Potential versus Ash Disposal. The remaining factors were used in the financial analysis portion of the study.

Results

The results of the financial analyses, using a capital investment of $25 million for a plant producing 5.3 million cubic feet annually and with a 50%/50% block/panel product mix, indicated a Return on Investment (ROI) in the range of 11 to 24%. These results are consistent with returns projected by European ACC companies for a plant in the US (20 to 35%).[1]

Based on the siting and financial analyses, the following recommendations were made:[1]

- Locate an ACC plant within the largest potential market area based on minimizing transportation costs to major market locations.
- Locate an ACC plant at a dry fly ash handling facility to avoid potential costs and problems associated with wet handling facilities.
- Because the project return on investment will probably be low to nonexistent for the first several years, potential investors should be willing to look longer term for return on investment.
- A significant barrier to ACC's use is the price driven approach of American construction.
- A significant barrier to ACC's use is the lack of American design codes. Since this study was conducted, TVA has obtained rights to use the ACC codes developed by EPRI for EPRI Blocks.
- Because the majority of building permits (70%-80%) are granted in the five major metropolitan areas of Tennessee, the focus for ACC should be on achieving acceptance in one or two large cities first, then spreading out to other smaller city permitting agencies.

Why did TVA initiate this study? TVA's business is power production, and, in the era of deregulation, investment of the millions of capital dollars required for construction of a manufacturing facility is best spent on preserving or increasing generation assets. It was TVA's intention to prepare the study to be shared with likely investors. The study has been referenced by the contractor for business planning purposes and has been reviewed by banks, industrial development boards, and other potential sources of capital in the early stages of developing a financing package. TVA's Fuel By-Products Department used the study as a tool to develop an agreement with BI to build an ACC manufacturing facility on a TVA fossil plant reservation. With annual fly ash production of about 160,000 tons per year, Bull Run will be able to supply its existing cement replacement market while supplying up to 100,000 tons of fly ash per year to ACC. Annual plant production will be 6-10 million blocks initially, with future expansion planned for panel construction. Construction of the ACC plant will extend the life of on-site disposal capacity to 20-35 years, thereby deferring development of new disposal capacity. Sale of

fly ash for ACC will also generate revenue for TVA. Operation of the ACC facility will create at least 75 direct jobs and provide opportunities for other service-related jobs, satisfying TVA's mandate for regional economic development.

The Future

The Bull Run Fossil Plant will be capable of producing up to 10 million blocks per year and supplying the Knoxville, Oak Ridge, and Chattanooga markets. Once accepted in these markets, the potential exists for 2-3 additional plants to be located at TVA plants within the Valley. These additional plants will serve markets reaching to St. Louis to the northwest, Memphis in the west and Birmingham and Atlanta to the south. Ultimately, ACC block plants could utilize up to 400,000 tons per year of off-specification ash that otherwise would be landfilled.

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REFERENCES

[1]LAW Engineering, Feasibility Study and Market Survey for Autoclaved Cellular Concrete, 1995.