Coventry University and
The University of Wisconsin Milwaukee Centre for By-products Utilization,
Second International Conference on Sustainable Construction Materials and Technologies
June 28 - June 30, 2010, Università Politecnica delle Marche, Ancona, Italy.
Special Technical Proceedings ed. P Claisse, E Ganjian, F Canpolat and T Naik
ISBN 978-1-4507-1488-4 http://www.claisse.info/Proceedings.htm

Potential Applications of Dry FGD Product as Feedstock for High-Volume Construction Products.

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ABSTRACT

In order to meet the requirements of the EPA's Clean Air Interstate rule, a small power plant in Florida will install several pollution control devices, including an SO_2 scrubber. This scrubber is a circulating dry scrubber, using dry hydrated lime [calcium hydroxide, Ca(OH)2] as a flue gas desulfurization (FGD) reagent. The hydrated lime absorbs SO_2 from the gas and forms the reaction products calcium $CaSO_3$ (hannebachite, or calcium sulfite) and $CaSO_4$ (gypsum, or calcium sulfate). These reaction products, along with ash and other FGD reaction products such as $CaO/CaOH_2$ (lime) are then captured in a baghouse. This FGD material, known as Circulating Fluidized-Bed Adsorber (CFBA) material, presents an expensive disposal problem in Florida. Developing beneficial uses for this material would have profound economic and environmental implications for the utility, the community, and the environment. This paper outlines the research needed to successfully utilize this material as feedstock for commercially viable blended construction products.

INTRODUCTION

The dry FGD product from the SO_2 scrubber being installed in a coal-fired power plant in Florida exhibits physical and chemical properties different from most other Clean Coal Products (CCP), most notably elevated levels of $CaSO_3$ (hannebachite, or calcium sulfite), $CaSO_4$ (gypsum, or calcium sulfate), and $CaO/CaOH_2$ (lime). This unique high-$CaSO_3$ product presents a disposal problem due to potential groundwater contamination and landfill costs. Outside Florida, the most common applications of similar FGD materials are for geotechnical use, such as structural fill or stabilized roadbase. However, obtaining permits from the Florida Department of Environmental Protection for land application of CCP's is both time consuming and expensive.

A promising high-potential, high-value beneficial use for this dry FGD product is feedstock for construction materials, since CCP use in cement and concrete production is already accepted and supported by the Florida Department Of Transportation and the Florida engineering community [Buckley et al. 2006]. Additionally, previous research has already utilized the pozzolanic properties of blends based on high-$CaSO_3$ FGD materials for both Defined-Performance Concrete (DPC) and construction brick production.

PREVIOUS RESEARCH

Set-controlled and shrinkage-compensating cement manufacture

Calcium sulfoaluminate (CSA) cement is widely used as rapid-setting cement and shrinkage-compensating cement, with a significant and growing market demand. CSA cement presents a unique opportunity to use high-sulfite FGD material, since all sulfur compounds, regardless of form, are oxidized to the sulfate state during pyroprocessing that occurs during cement manufacturing. CSA manufacture requires less energy to produce, and generates less CO_2, than ordinary Portland cement (OPC) [Gartner 2004]. CSA cement utilizing 13% dried sulfite sludge (based upon the dry mass of the total mix design) has been made in pilot-scale production [Bhattachaja 1999]. Tests indicated concrete derived from this experimental cement had superior flow properties, as well as comparable strength and setting characteristics in comparison to typical rapid-setting cement. However, an attempt at full-scale production was unsuccessful, due to difficulties in dewatering, handling and feeding the thixotropic sludge, and the project was abandoned. Difficulty in handling FGD sludge has been well documented in literature [Berland 2003] [Tzouvalas 2004] [Whitfield 2003].

Concrete

During cement production, portland cement is always interground with gypsum as a set retardant. Previous research has shown calcium sulfite controls the setting reactions of Portland cement in the same manner as calcium sulfate [Marusin 1986]. High-sulfite FGD material may by a viable, even preferable alternative for natural gypsum for this purpose, since ultimate concrete strength has been found to increase with an increase in the percentage of calcium sulfite (relative to gypsum) in concrete mixes (Marusin 1987). Previous research performed by Wu and Naik [Wu and Naik 2002] has shown that SDA can be successfully used to control the setting and hardening of concrete when blended with Class C fly ash and sodium sulfate anhydrite. Testing showed the blended cements were generally superior to ordinary portland cement (OPC) mixes: Blended cements had equivalent or higher strength than Type I cement at the age of three days and higher, and were less vulnerable to sulfate attack, alkali-silica reaction (ASR) expansion, chloride ion penetration, and freezing and thawing resistance than OPC mixes [Wu and Naik 2003].

Brick Production

A brick consisting of high-$CaSO_4$ FGD sludge, fly ash, lime and aggregate cured with an admixture and/or steam pressure is commercially produced in several countries. This brick has higher compressive strength to typical fired-clay brick, yet are lighter and more durable. The production of this brick require very little energy to manufacture, and some power plants even offset carbon credits by producing these environmentally-friendly brick. Research conducted in the United States has also shown that dried high-$CaSO_3$ FGD sludge can be blended with fly ash and a chemical admixture then cured in an autoclave for several hours to produce a very strong block (compressive strength of ~ 7,000 psi.) [Grutzeck et al.

2006]. They surmised that the platy hannebachite crystals present in the FGD material acted as a reinforcing agent in the binder, and noted that waste heat sources and Class F fly ash generated at a power plant could be used for onsite production of the block in an adjacent facility. Also, a product utilizing the pozzolanic properties of a high-$CaSO_3$ Spray Dryer Ash and an activator has been commercialized as an OPC replacement for concrete block production in the United States [Thomes 2007].

UNIQUE PROPERTIES

To date, no specific research has been conducted examining beneficial uses of this unique dry FGD product. We propose that this dry FGD product has strong potential as a component of blended concrete and brick/block applications, as indicated by previous research and commercial applications of other high-$CaSO_3$ FGD materials. Importantly, this dry FGD product has unique physical and chemical properties that offer promising advantages over high-$CaSO_3$ FGD sludge or other CCB's for use in construction materials, as follows.

Ease of handling

Dry FGD product has a moisture content that is less than 1%, and is therefore much easier to handle than FGD sludge. Though dewatering is not specifically mentioned as a problem by Grutzeck et al [Grutzeck et al. 2006] in research describing bench-scale block production using dried hannebachite sludge, dry CFBA material would be much easier to process and manage in the full-scale production of FGD block. For this reason, dry FGD product is very promising for use as a raw material in full-scale production of blended construction materials.

Material composition

This dry FGD product does not have the large fly ash content typical of most other high-$CaSO_3$ Spray Dryer Ash materials, which allows more flexibility when used to optimize cement blends for DPC's such as sulfate-attack resistant and/or ASR-resistant concrete blends. Dry FGD product also contains lime, shown to be a necessity for pozzolanic reactions when using concrete mixes containing $CaSO_3$ and fly ash [Marusin 1987]. This strongly suggests that this dry FGD product may provide a superior formulation for making blocks than the high-$CaSO_4$ FGD/fly ash brick described earlier. Furthermore, brick produced with a high ratio of fly ash are an unattractive grey color. However, since this dry FGD product is white, the final brick product is likely to be a much more pleasant and marketable color. Pigments could easily be added to produce a color identical to fired clay brick.

Geographic Factors

In addition to material-specific advantages, several geographic factors increase the potential for effective utilization of this dry FGD material as feedstock for construction materials. All of the raw materials needed for either blended concrete or manufactured brick are within about 40 miles of this power plant. This distance is critical, since transportation costs, the leading economic factor when considering reuse options, generally limit the shipment of CCP's to within about a 50-mile radius of the powerplant [USGS 2001]. Another important market advantage available at the power plant site is a functional railhead, permitting inexpensive transport of bulk materials, by far the most economical alternative for transporting by-products from a plant site [Berland 2003].

PROPOSED WORK

The first phase of the proposed work is to prepare a formal review of literature. This literature review would provide a thorough background of the established literature related to pozzolanic CCP's. Then, with the actual dry FGD product available, Phase 2 laboratory work can begin. Importantly, the laboratory work should be focused on the practical feasibility of the required inputs, and the likely commercial value of the end product(s). Phase 2 is composed of two tasks:

1. Formulate the optimal mix proportions of dry FGD product, fly ash, activator, and OPC to produce a durable concrete blend.

2. Formulate the optimal mix proportions of dry FGD product, fly ash, and aggregate cured by admixture or autoclave to produce an attractive, high-strength, low-reactivity brick/block.

After the results of these tasks are analyzed, Phase 3 will be initiated. Phase 3 will consist of bench-scale testing of a concrete blend and/or brick production, as described above.

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