

# Defining a research program for cement, brick and block production from a novel FGD product

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## INTRODUCTION

The DFGD material that will be produced by the SO<sub>2</sub> scrubber being installed at Gainesville Regional Utilities (GRU) Deerhaven 2 power plant is a dry byproduct also known as Circulating Fluidized-Bed Adsorber (CFBA). This byproduct exhibits physical and chemical properties different from most other FGD material, most notably elevated levels of CaSO<sub>3</sub> (hannebachite, or calcium sulfite), CaSO<sub>4</sub> (gypsum, or calcium sulfate), and CaO/CaOH<sub>2</sub> (lime). This unique high-CaSO<sub>3</sub> FGD material presents a disposal problem for GRU due to potential groundwater contamination and landfill costs. The most common applications of similar FGD materials are for geotechnical use, such as structural fill or stabilized roadbase. However, obtaining permits from FDEP for land application of Clean Coal Products (CCP) would be unlikely in the current political climate. Use as feedstock for construction materials offers a promising high-potential, high-value beneficial use for GRU's high-CaSO<sub>3</sub> CFBA, since CCP use in cement and concrete production is already accepted and supported by the FDOT and the Florida engineering community<sup>1</sup>. Previous studies have successfully blended high-CaSO<sub>3</sub> FGD materials as a cementitious component of Defined-Performance Concrete (DPC) and brick materials. A brief summary of the research regarding these uses follows.

A research program of the potential applications of GRU's Dry Flue Gas Desulfurization (DFGD) material for cement, brick, or block production is detailed in this paper. A background of the material as it relates to the main proposed applications, Portland cement and brick/concrete paver production, is first introduced. Then, the proposed research, scope of work, and laboratory testing plan are discussed.

## PORTLAND CEMENT

During ordinary portland cement (OPC) production, CaSO<sub>4</sub> is always interground with clinker as a set retardant. Previous research has shown CaSO<sub>3</sub> controls the setting reactions of Portland cement in the same manner as CaSO<sub>4</sub><sup>2</sup>. High-CaSO<sub>3</sub> FGD material may be a viable, even preferable alternative for CaSO<sub>4</sub> for this purpose, since ultimate concrete strength has been found to increase with an increase in the percentage of CaSO<sub>3</sub> (relative to CaSO<sub>4</sub>) in concrete mixes<sup>3</sup>. Previous research by Wu and Naik<sup>4</sup> has shown that Spray Dryer Ash, another high-CaSO<sub>3</sub> FGD material, can be

used to control the setting and hardening of concrete when blended with class c fly ash and sodium sulfate anhydrite. Testing showed that these blended cements were generally superior to OPC mixes, with higher compressive strengths, less vulnerable to sulfate attack, alkali-silica reaction (ASR) expansion, chloride ion penetration, and freezing and thawing resistance than OPC mixes<sup>5</sup>.

## CONCRETE BRICK/BLOCK PAVER PRODUCTION

A brick consisting of high-CaSO<sub>4</sub> FGD sludge, fly ash, lime and sand cured with an admixture and/or steam pressure is commercially produced in several countries. ASTM C73, Standard Specification for Calcium Silicate Face Brick includes grading standards identical to those for clay face brick for severe weathering, and moderate weathering<sup>6</sup>. These brick have higher compressive strength to typical fired-clay brick, yet are lighter and more durable. The production of these 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<sub>3</sub> 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.)<sup>7</sup>. Also, a product utilizing the cementitious properties of a high-CaSO<sub>3</sub> Spray Dryer Ash and an activator has also been commercialized as an OPC replacement for concrete block production in the United States<sup>8</sup>.

## PROPOSED RESEARCH

To date, no published research has been conducted examining beneficial uses of the unique DFGD material produced by GRU. We propose that this DFGD material has strong potential as a component of Portland concrete and brick/block applications, as indicated by previous research on other high-CaSO<sub>3</sub> FGD materials. Importantly, DFGD material has unique physical and chemical properties that offer promising advantages over high-CaSO<sub>3</sub> FGD sludge or other CCB for use in construction materials, as follows.

The material handling characteristics of this DFGD are superior to handle than FGD sludge, due to a moisture content that is less than 1%. For this reason, DFGD is very promising for use as a raw material in full-scale production of blended construction materials.

Also, the composition of the DFGD material produced by GRU does not have the large fly ash content typical of most other high-CaSO<sub>3</sub> Spray Dryer Ash materials, which allows more flexibility when used to optimize cement blends for DPC's such as sulfate-attack resistant or ASR concrete blends. DFGD material also contains lime, shown to be a necessity for pozzolanic reactions when using concrete mixes containing CaSO<sub>3</sub> and fly ash<sup>3</sup>. This strongly suggests that DFGD material may provide a superior formulation for making pavers than the high-CaSO<sub>4</sub> FGD/fly ash brick described earlier. Furthermore, brick/pavers currently produced with fly ash blends tend to have an unattractive grey color, due to the high ratio of fly ash used in the blend. Since DFGD

material is almost white in color, the final product is likely to be a much more pleasant and marketable color. Pigments could also easily be added to produce a specific desired color.

In addition to material-specific advantages, several geographic factors increase the potential for effective utilization of the DFGD material produced by GRU in construction materials. All of the raw materials needed for either blended concrete or manufactured brick are within about 40 miles to Deerhaven. 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<sup>9</sup>. Another important market advantage available to GRU is the railhead at Deerhaven, permitting inexpensive transport of bulk materials, by far the most economical alternative for transporting by-products from a plant site<sup>10</sup>.

## PROPOSED SCOPE OF WORK

This proposed study will focus on the mechanical feasibility of introducing GRU's by-product, in the dry, unprocessed state, into existing bulk construction materials. An assessment of the relative economy of such bulk replacement will also be quantified. The specific bulk replacement applications to be investigated include:

1. Portland Cement.
2. Concrete Block/Pavers.

Bench-scale testing of such production will be conducted and the mechanical properties of the resulting properties will be evaluated in accordance with ASTM/AASTO standard test methods, described on the following page.

## PROPOSED LABORATORY TESTING PLAN

To test the viability of the GRU by-product for portland cement replacement, it is proposed that a standard Portland cement concrete mix be prepared in the laboratory with varying amounts (three different levels) of the GRU by-product added as a replacement for the Portland cement and/or other cementitious material content in the mix design. With all other variable being constant, the properties of the hardened concrete will be measured and recorded. Testing of the concrete will be performed in accordance ASTM/AASHTO standards, and will include:

1. Plastic properties (temperature, slump, unit weight, air content);
2. Compressive Strength at 7, 14, and 28 days;
3. Flexural Strength at 28 days; and
4. Surface Resistivity (Indirect Measure of Durability).

To test the viability of the GRU by-product for concrete block/pavers, it is also proposed that a standard Concrete Masonry Unit (CMU) mix be replicated in the laboratory with varying amounts (three different levels) of the GRU by-product added as a replacement

for the Portland cement and/or other cementitious material content in the mix design. With all other variable being constant, the properties of the Block/Paver will be measured and recorded. Testing of the Block/Paver will be performed in accordance ASTM/AASHTO standards, and will include:

1. Mortar Cube Compressive Strength;
2. Block/Paver Unit Compressive Strength;
3. Water Absorption; and
4. 5-Hour Boiling Test (Indirect measure of Durability).

Based on the results of the proposed testing, recommendations will be provided regarding the practical feasibility of employing the GRU by-product as a bulk replacement for Portland cement and/or other cementitious materials in these common construction products. Again, an economic assessment of such bulk replacement will also be provided.

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