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The Durability of Stabilized Flue Gas Desulfurization Sludge

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ABSTRACT

The effects of freeze-thaw cycling on the strength and durability of samples of compacted, stabilized, wet flue gas desulfurization (FGD) by-products are reported. The results of laboratory tests show a clear relationship between higher water contents and increasing vulnerability to freeze-thaw effects. In the samples tested, water contents at or above 40% were characteristic of all the freeze-thaw specimens exhibiting low strengths. Lime content and curing time were also shown to have a marked influence on the durability of the FGD material. It was shown that samples can maintain good strength under freeze-thaw conditions provided 5% lime was added before compaction and the time from compaction to first freeze was at least 60 days.

INTRODUCTION

Flue gas desulfurization processes have been implemented to remove the sulfur dioxide gas produced during the burning of coal in electric power plants. The FGD by-products are usually treated as solid waste and landfilled. However, suitable landfill sites are becoming scarce and the costs associated with landfilling are constantly rising. Therefore, identifying environmentally sound reuses for these materials is becoming an important activity. A research program is being conducted at The Ohio State University to demonstrate high volume uses of FGD by-products which may substitute for other materials now being used for land reclamation, pavement road bases, subbases, embankment fills or soil stabilization (Dick et al. 1992). An extensive laboratory test program has been set up to study the engineering properties of FGD by-products (e.g. Adams 1992, Wolfe and Wu 1992). The test results revealed that compacted FGD by-products typically have higher strengths and lower densities than those measured for natural soils commonly used in construction.

In order to evaluate the suitability of using FGD by-products in place of conventional construction engineering materials, it is important to know the durability of FGD material under various environmental conditions. Thermal stability of the material's mineral/chemical components and the overall freeze-thaw durability may be of concern when use of the proposed FGD materials includes near surface applications. In a series of laboratory experiments, the effects of alternating cycles of freeze and thaw on the engineering properties of compacted FGD sample were observed. Roy (1994) studied the effect of freeze-thaw cycling on the resilient modulus of dry-FGD. Hargraves (1995) analyzed the effect of freeze-thaw cycles on the strength of stabilized FGD sludge. Consolidation tests on stabilized FGD sludge during freeze-thaw cycling are also being conducted. In this paper, the effects of freeze-thaw cycles on the static strength of compacted FGD samples are presented.

MATERIAL DESCRIPTION

The by-product used in this investigation was provided by the Columbus and Southern Ohio Power Station in Conesville, Ohio. At the Conesville station, sulfur dioxide is removed from the flue gas by using a magnesium enhanced lime scrubbing process to produce a sulfite rich sludge. The resulting sludge is in slurry form containing only about 10% to 15% solids. The wet sludge is stabilized at the power station by mixing it with ammonia enhanced fly ash and lime, and placed on temporary sludge pads to facilitate some initial cure. After two to three days, the stabilized material is trucked to the plant landfill and disposed (Hargraves 1994).

TEST PROCEDURES

In the laboratory investigation of the influence of freeze-thaw on the strength and durability of the recompacted FGD samples, five basic steps were followed. The five steps were pre-mixing, compaction, quartering and trimming, curing and freeze-thaw cycling, and unconfined compression strength testing.

Step 1. Pre-mixing: The stabilized sludge was mixed in the lab with Conesville fly ash at a 1:1 dry weight ratio to reduce the water content before compaction. After pre-mixing, the fly ash sludge mixture was allowed to air dry, broken up mechanically, and passed through a #4 sieve. The moisture content of the sieved material was measured and the mixture sealed until needed. When samples were prepared, 5 percent by dry weight of quicklime was added to the mixture. If water was needed to bring the sample to optimum conditions, it was added prior to adding the quicklime.

Step 2. Compaction: For FGD sludge and fly ash, the moisture content is the main factor controlling compaction characteristics. The optimum moisture content at which the highest dry density is developed was determined in accordance with ASTM D698 which describes a procedure commonly known as the Standard Proctor Test. Once the optimum moisture content was obtained, several samples at that particular water content were prepared.

Step 3. Quartering and Trimming: Once a Proctor mold was formed, it was sealed in cellophane, labeled, and allowed to cure for two to five days. At the end of this period the sample had gained sufficient strength to be quartered and trimmed to a cylindrical shape (roughly 3.8mm diameter, 7.6mm height) for later compression testing. Upon completion of sample preparation, the individual cylinders were again sealed in cellophane, labeled, and allowed to cure at 23° C and 100% relative humidity.

Step 4. Curing and Freeze-Thaw cycling: The test cylinders were allowed to cure for total of 7, 28, or 60 days. At the end of the designated curing period, the freeze-thaw cycles were begun in accordance with ASTM D560. However, in the present study, two modifications to the ASTM procedure were made. First, because the minimum temperature where the test lots were located seldom goes below -18° C, the freezing temperature was -18° C rather -23° C as specified in the standard. Second, the samples were neither weighed nor brushed after each freeze-thaw cycle in order to preserve their original shape and mass for compression testing. Each temperature cycle consisted of 24 hour freeze at -18° C, followed by a 24 hour thaw in the moist cure box at 23° C. This pattern continued for 24 days, or 12 complete cycles. Throughout the curing and freeze-thaw cycling experiment, all samples remained sealed in plastic. Moisture was maintained constant because much of the material in the feed lots would be covered with either food or waste, thereby maintaining a basically constant moisture content. Furthermore, a typical element of the feedlot material would be surrounded on three sides allowing only top surface exposure, suggesting that fully exposing the laboratory samples would be farther removed from the actual conditions.

Step 5. Unconfined compression strength testing: After completion of 12 freeze-thaw cycles, the samples were tested to failure in unconfined compression according to ASTM standard D-2166.

TEST RESULTS

Figs. 1, 2, 3 show stress vs. strain curves obtained for samples cured 7, 28 and 60 days before being subjected to freeze-thaw cycling. The wide spread in stress-strain data shown in Figs.1 and 2 for the samples cured 7 and 28 days illustrates that inconsistent strength gains may occur for these cure periods. As shown in Fig.3, the peak strengths were higher and the stress-strain relationships much more consistent for the samples subjected to freeze-thaw only after 60 days of curing. Fig.4 show the effect of initial water content on the strengths of 7, 28, and 60 day freeze-thaw samples. The influence of final water content on the strength is presented in Fig.5. One can see the sharp reduction in strength as the water content for the 7 day samples surpassed 40%. The same trend can be seen in the 28 day cure samples despite the higher strengths exhibited by those samples whose water contents were below 40%. From these figures, we can see the average 7 day strength in the initial freeze - thaw group was 1.25 MPa. Overall, 28 day strength averaged 1.83MPa. For the 60 day samples, the range of water content change was much smaller which demonstrates improved resistance to water infiltration and better freeze-thaw durability than the samples allowed to cure for shorter periods of time.

SUMMARY

The results of strength tests conducted on samples subjected to cycles of freeze and thaw have been presented. From these tests, it was shown that curing time have a great influence on the strength and durability of stabilized FGD mixtures. For samples with 60 day curing time, there was more uniformity in stress strain curves and they demonstrate improved resistance to water infiltration and better freeze-thaw durability. It is recommended that 60 day curing time be needed before freeze-thaw cycling in the use of FGD by-products.

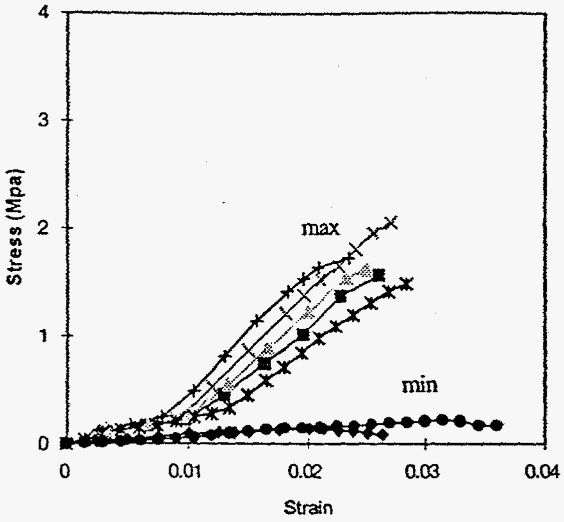

Fig.1 Stress vs. Strain curves for 7 day cure samples

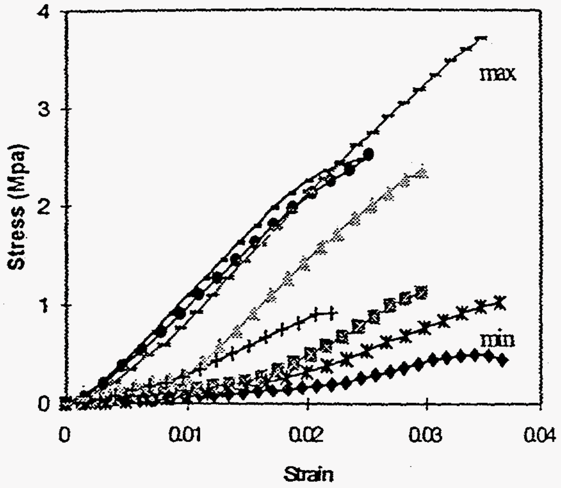

Fig.2 Stress vs. Strain curves for 28 day cure samples

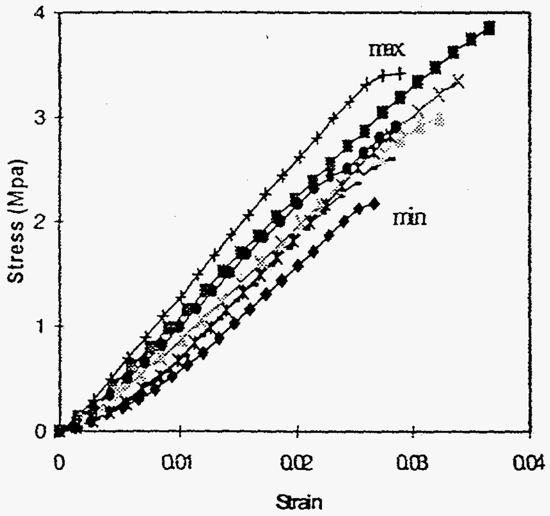

Fig.3 Stress vs. Strain curves for 60 day samples

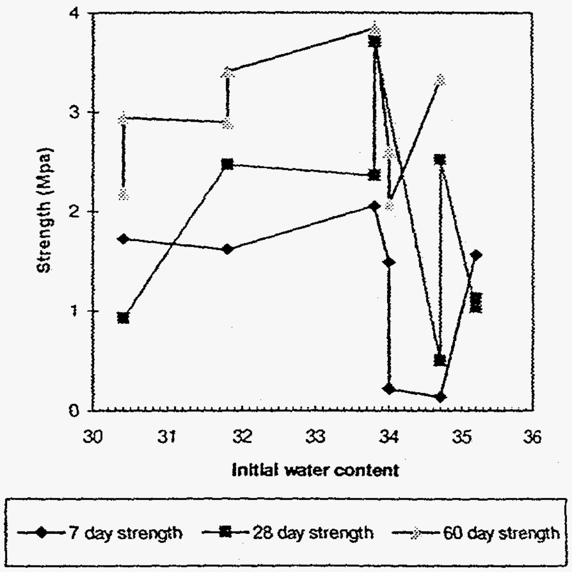

Fig.4 Effect of initial water content on the strength of 7, 28, 60 days cure freeze-thaw samples

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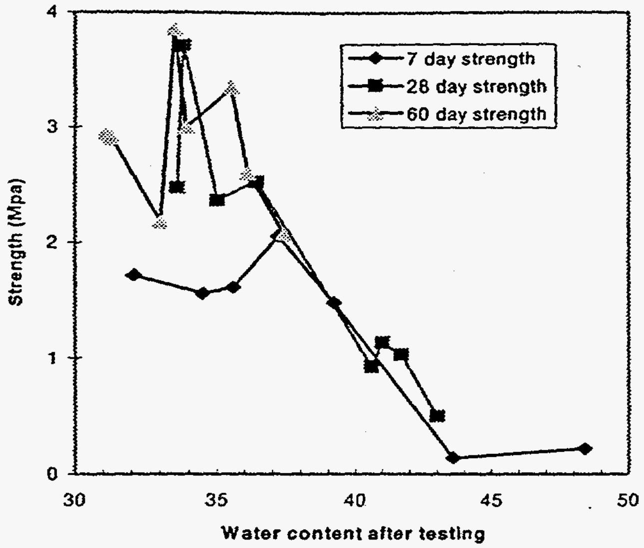

Fig.5 Effect of after testing water content on the strength of 7, 28, 60 days cure samples

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