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# The Behavior of Coal Combustion Products in Structural Fills - A Case History

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## ABSTRACT

Construction of a building pad to support any structure requires proper preparation of the site and a complete geotechnical evaluation of the behavior of the on-site materials. Equally important is a thorough characterization of the engineering properties of the material to be used for the fill. When Coal Combustion Products (CCPs) are used in the fill, this characterization should include the identification of strength, compressibility, and potential for swell. In 1997, a CCP was supplied to the site of a shopping center in suburban Richmond, Virginia where a number of commercial buildings, roadways and parking lots were to be constructed.

Stabilized spray dryer ash was placed in lifts to depths ranging from two to six feet. Several of the buildings began to exhibit signs of distress during construction or shortly after completion. One structure was closed within a few months of opening. It was then removed and rebuilt on the same site. Construction of other buildings was halted until ground modifications were made. The causes of the observed structural distress and the role played by the coal combustion products are the subject of this paper.

## INTRODUCTION

Traditionally, the majority of coal combustion products generated by the nation's utilities have been disposed in landfills or stored in surface impoundments. The identification of cost effective, technically sound, and environmentally responsible programs for the beneficial use, rather than disposal, of these materials has been goal of many research and demonstration projects over the past several years. Collins et al.[1] investigated the use of residues from FBC boilers as replacements for aggregate. Nodjomian[2] and Payette et al.[3] described the successful use of CCPs as structural fills in highway embankment reconstruction. Dick et al.[4,5] and Wolfe and Cline[6] have documented several field applications of compacted CCPs. Based on laboratory tests, Masashi and Katsumi[7] proposed using CCPs in roadway and embankment construction, as well as as an amendment in soil improvement and/or stabilization applications. Solem-Tishmack et al.[8] examined the suitability of FBC ash in waste solidification/ stabilization.

Deschamps[9] conducted a detailed evaluation of using FBC and stoker ash materials in a highway structural fill.

The data collected from the above field investigations and laboratory studies show that structural fills can be satisfactorily constructed from CCPs provided the material to be used is adequately characterized and placed using accepted engineering methods and practices. The ASTM Standard Guide for Use of Coal Combustion By-Products in Structural Fills (E1861-97) describes a set of procedures that should satisfactorily characterize the geotechnical characteristics of FGD materials. This standard also emphasizes the need for proper design and construction of CCP fills, including adequate site preparation, provision for internal drainage, sufficient compaction, and corrosion protection for embedded materials. In many but not all respects, CCP fills share proper design and construction criteria with fills constructed from soil.

## SITE OBSERVATIONS

Coal combustion products were used as structural fill in the construction of a shopping center consisting of twelve major retail buildings and a number of smaller structures as well as roadways and parking facilities in suburban Richmond, Virginia. From a review of publicly available historical materials, it is apparent that the previously undeveloped site was characterized by poorly drained Roanoke loam soil that experienced perched water conditions much of the year. Records reflect several development plans for this property over the preceding decades, none of which came to fruition. Historical geotechnical surveys of the site all reflect that the land was too wet to be successfully developed without significant additional expense.

In Virginia, CCPs are “exempt from regulation as a solid waste if beneficially reused as a base, subbase or fill material under a paved road, the footprint of a structure, a paved parking lot, sidewalk, walkway or similar structure or when processed with a cementitious binder to produce a stabilized structural fill product which is spread and compacted with proper equipment for the construction of a project with a specified end use” (9 VAC 20-80-160)[10]. CCPs managed under this regulation are not subject to solid waste facility permitting, however CCPs may not be placed in areas where the vertical separation between the CCP and the maximum seasonable water table or bedrock is less than two feet (9 VAC 20-84) [10].

## LABORATORY TEST PROGRAM

Following the procedure described by Adams[11], one-dimensional swell tests were conducted on compacted samples of the CCP being used as fill. Three different bulk samples were collected for testing. In the first sample, specimens were collected from an area that had been previously stabilized with 3% Lime Kiln Dust (LKD) and compacted (Rich1 & 2). The second bulk sample was collected from a stockpile of FGD to which the LKD had been added but the CCP had not yet been compacted (Rich 3). The third sample consisted of FGD without the LKD. An amount of LKD equal to 3% of the dry weight of the FGD was added in the laboratory immediately prior to testing (Rich 4 & 6). Test specimens from each sample group were compacted in the laboratory to 100% of Standard Proctor density (ASTM D-698) at optimum water content and at water contents above and below optimum. Swell against a nominal seating load of 2.2 kPa (45 psf) applied to insure measurement system integrity has been monitored for nearly three years. Each specimen has had free access to water throughout the entire test period. As shown in the swell test results presented as Figure 1, the maximum swell recorded varied from less than 0.2% for a specimen compacted at optimum moisture content (Rich 1) to slightly less than 2% for a sample compacted at more than 10% below the optimum water content (Rich 6). Samples compacted at high water contents (Rich 2 & 3) have undergone volume changes of less than 0.2% to approximately 1.5% over the nearly three year monitoring period. One sample (Rich 4), which had been compacted at the optimum water content, has recorded a maximum volume change of 1%. However, as can be seen in the data presented in Figure 2, an increase in the nominal seating load from 2.2 kPa to 8.7 kPa (45 psf to 181 psf) decreased the amount of swell measured in this sample (Rich 5) to less than 0.2%.

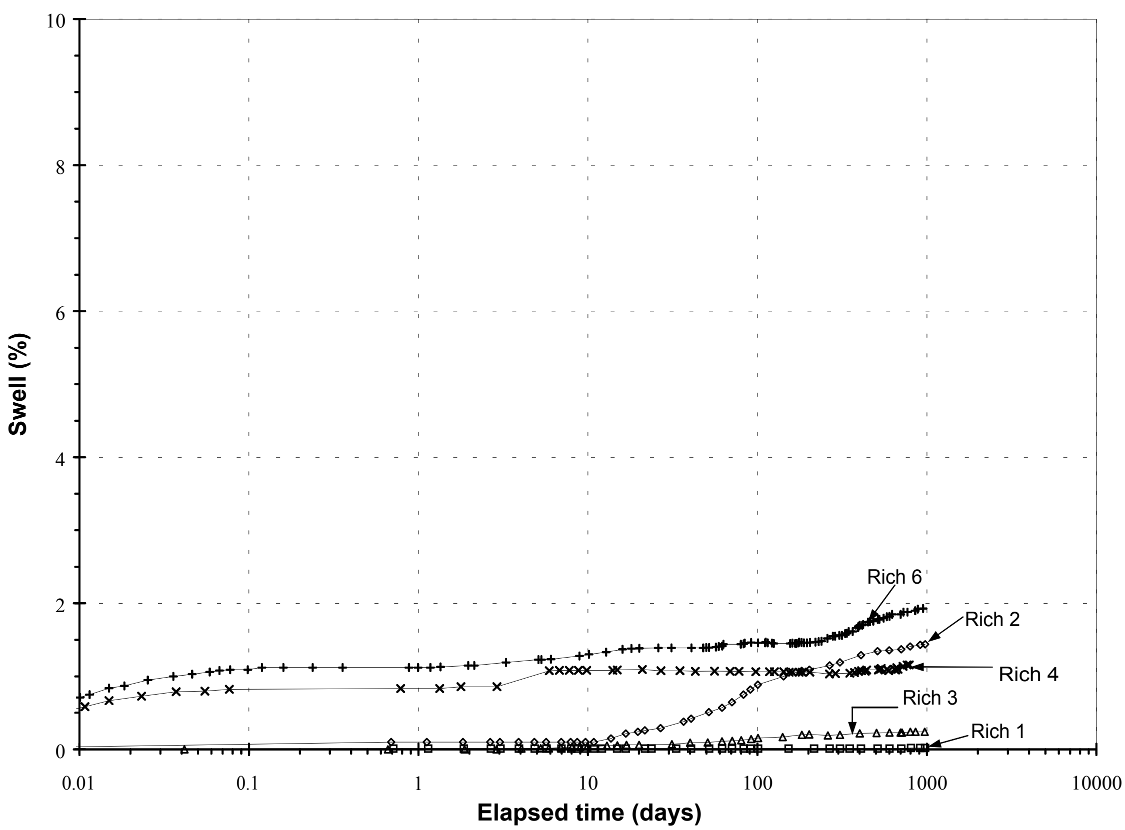


Figure 1. Long term Swell Test Results on Compacted Ash Samples

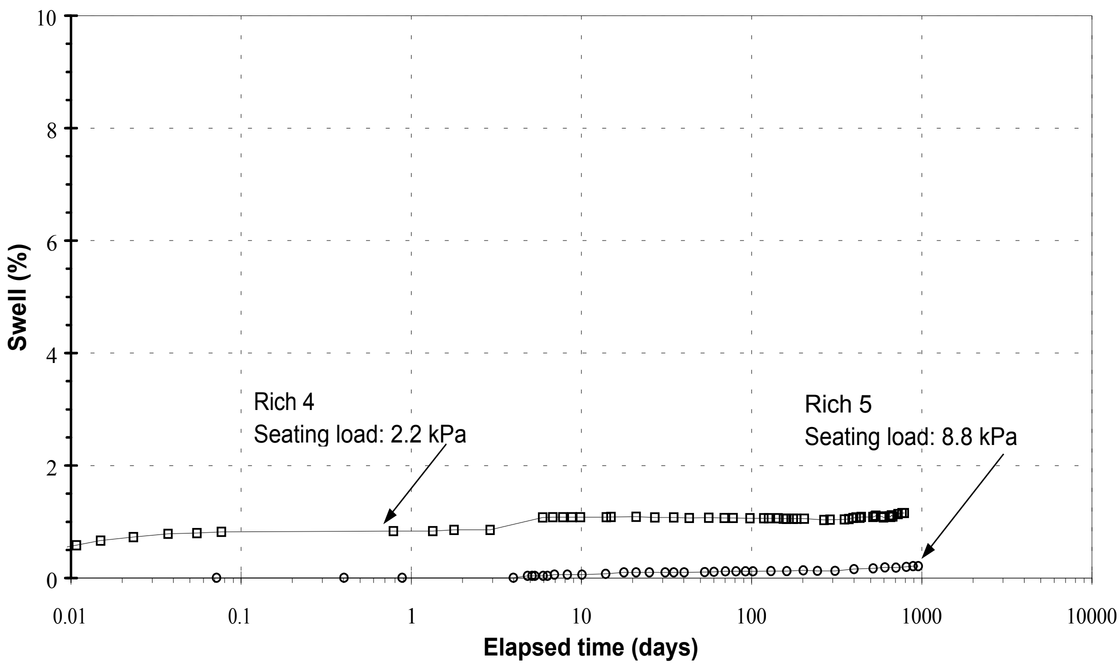


Figure 2. Long Term Swell Tests on Compacted Ash Samples at Two Nominal Seating Loads

## DISCUSSION

Soil collected from the shopping center site included bulk samples, geoprobe cores and undisturbed samples in thin walled Shelby tubes. One dimensional consolidation and swell tests were performed on Shelby tube samples of the ash fill as well as the supporting soil immediately below the ash. The results of swell tests on two intact ash samples are presented in Figure 3. The data show no significant tendency for volume change in the compacted ash (less than 1.5% swell). Figure 4 presents the results of one dimensional consolidation tests on intact samples of the ash and the supporting soil. The ash sample, collected at the base of the fill, shows some tendency to compress under applied load (approximately 1% compression at the design column load). The clay recovered from immediately beneath the tested ash sample compressed approximately 4% for the same applied load. These tests combined with visual observations made during several field investigations indicate the presence of compressible clays under the CCP fill. The field geotechnical inspection reports that recorded construction activity beginning with clearing and grubbing through placing the CCP structural fill to paving the parking lots indicate these soft, compressible clays are present throughout the site. The area wide extent of these unsuitable materials is suggested in Figure 5, which is a plot of the undercuts recorded during construction of the various structures on the site. It is noted that the vast majority of the recorded undercutting was performed in the areas where the CCPs had not been placed.

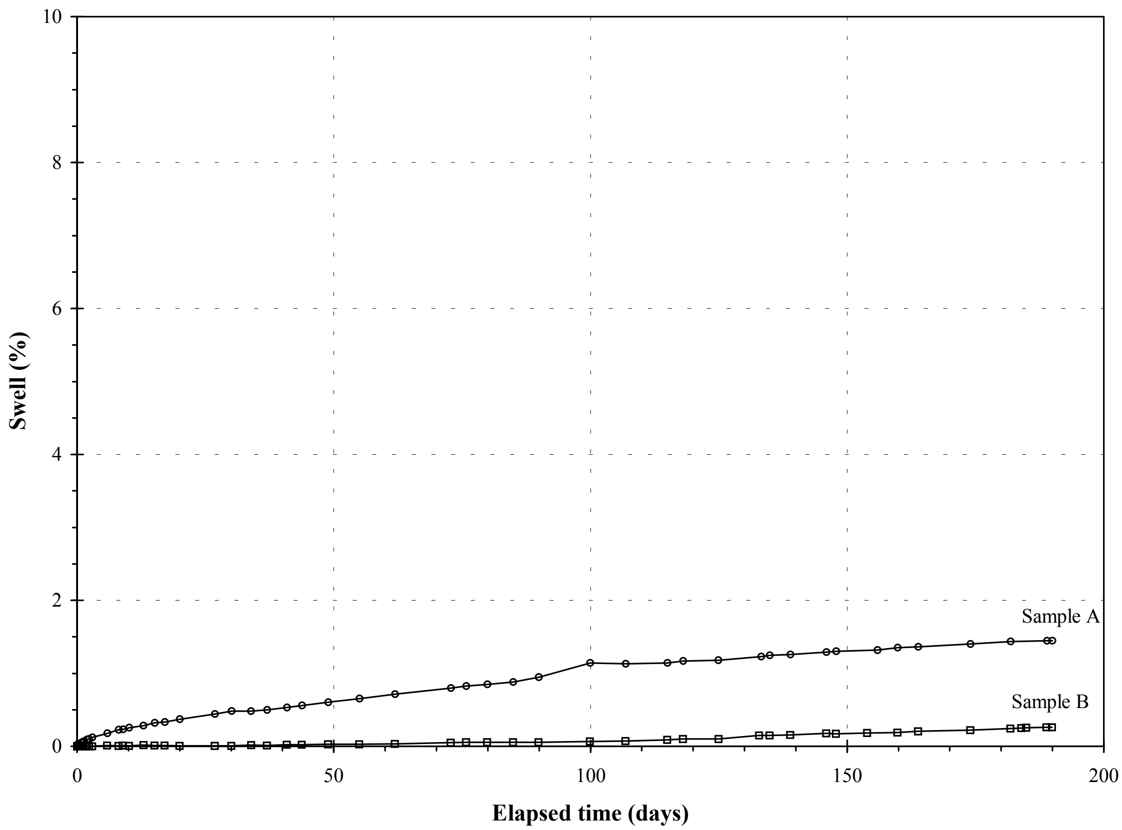


Figure 3. One Dimensional Swell Tests on Two Intact Ash Samples

## CONCLUSIONS

The amount of swelling recorded in laboratory tests conducted on samples retrieved from the CCP structural fill as well as samples of the CCPs taken from the supplier and compacted in accordance with standard procedures is not sufficient to have been the cause of the structural distress documented at the subject site. The damage observed was however consistent with settlement of the underlying clays. The laboratory tests as well as the available field information indicate that the observed damage to the shopping center buildings was likely the result of differential settlement caused by an incompetent subgrade.

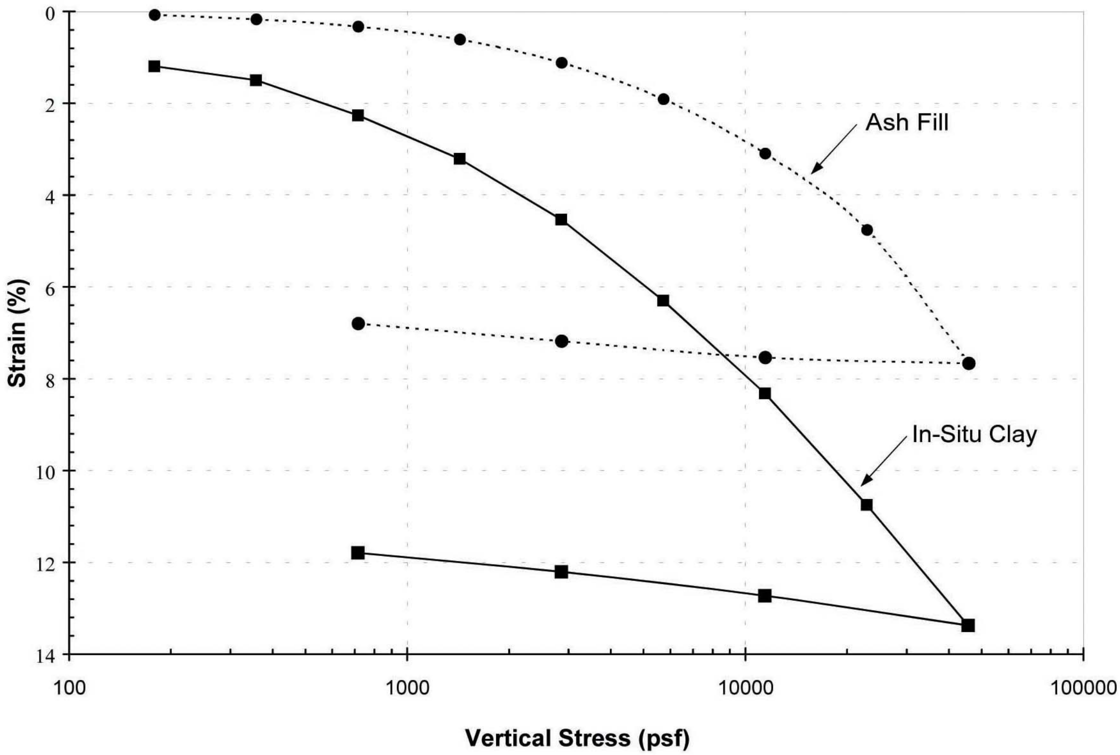


Figure 4. One Dimensional Consolidation Tests on Intact Samples of Ash Fill and the Underlying Clay

Figure 5. Extent of Undercutting Documented in Daily Reports

REFERENCES

[1] Collins, R.J., Aggregate-Related Applications for Residues from Fluidized Bed Combustion Boilers," Extending Aggregate Resources, ASTM STP 774, American Society for Testing and Materials, 1982, pp. 3-30.

[2] Nodjomian, S.M., 1994, Clean Coal Technology By-Products Used in a Highway Embankment Stabilization Demonstration Project, M.S. Thesis, The Ohio State University, Columbus, Ohio.

[3] Payette, R.M., W.E. Wolfe and J. Beeghly, 19s97, Use of Clean Coal Combustion By-Products in Highway Repairs, *Fuel*, V.76, p. 749-753.

[4] Dick, W., Stehouwer, R., Bigham, J., Wolfe., Adraino, D.C., Beeghly, J., and Murarka, I., 1997, Land Application Uses of Coal Combustion By-Products: Examples and Case Studies, ASA/CSSA/SSSA Annual Meeting, Anaheim, CA, October 26-31.

[5] Dick, W., J. Bigham, L. Forster, F. Hitzhusen, R. Lal, R. Stehouwer, S. Traina and W. Wolfe, R. Haefner, G. Rowe, 1999a, Land Application Uses of Dry FGD By-Product: Phase 3 Report, Electric Power Research Institute, EPRI TR-112916, 1999.

[6] Wolfe, W.E., Cline, J.H., 1995, A Field Demonstration of the Use of Wet and Dry Scrubber Sludges in Engineered Structures, Proceedings of 11$^{th}$ International Symposium on Use and Management of Coal Combustion By-Products (CCBs), Orlando, Florida, Jan 15-19, American Coal Ash Association and Electric Power Research Institute, EPRI TR-104657, V. 1, p. 17(1-10).

[7] Masashi K. M. and T. Katsumi, "Utilization of Coal Fly Ash from Fluidized Bed Combustion Systems Proc. ASCE Specialty Conf. Geoenvironment 2000, pp.1765-1779, 1995.

[8] Solem-Tishmack, J.K., G.J. McCarthy, B. Docktor, K.E. Eylands, J.S. Thompson and D.J. Hassett, "High Calcium Coal Combustion By-Products: Engineering Properties, Ettringite Formation, and Potential Application in Solidification and Stabilization of Selenium and Boron," Cement and Concrete Research, Vol 25,No. 3, pp.658-670. 1995.

[9] Deschamps, Richard J. "Using FBC and stoker ashes as roadway fill: A case study" Journal of Geotechnical and Geoenvironmental Engineering. v 124, n 11. Nov 1998, p 1120-1127.

[10] American Coal Ash Association, 1998, State Solid Waste Regulations Governing the Use of Coal Combustion Products (CCPs), Alexandria, Virginia, August,1998.

[11] Adams, D.A., 1992, Swelling Characteristics of Dry Sulfur Dioxide Removal Waste Products, M.S. Thesis, The Ohio State University, Columbus, Ohio.