Geotechnical Characteristics and Safety Considerations for Wet Ash Basin Closure

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ABSTRACT

In response to the massive slope stability failure of a coal combustion residuals (CCRs) dredge cell at the Tennessee Valley Authority (TVA) Kingston Fossil Plant in 2008, several failure investigations and geotechnical evaluations have been completed. The "Root Cause Analysis Report, TVA Kingston Dredge Pond Failure," AECOM, June 2009, and the "Geotechnical Properties of Fly Ash and Potential for Static Liquefaction," EPRI, 2012, provide valuable information on the characteristics of ponded fly ash and the liquid flow properties of partially saturated fly ash. The authors of this technical paper have been actively engaged in the field-testing, geotechnical evaluation, and safety evaluation of several recent CCR impoundment closure projects. This experience has provided additional information about the geotechnical characteristics of fly ash as it pertains to subgrade stability of ponded ash, and the construction of access roads for excavation and fill placement. This paper will provide information on the following:

- How layering of different types of fly ash materials in ash basins, and variations in moisture content, contribute to instability when subjected to surcharge loading and equipment vibrations.
- What constitutes a "stable crust" for building of access roads, and for the support of construction equipment for excavation and removal.
- Practical field-testing utilizing the hand-held vane shear device and different types of surface proofing methods for assessing ash basin stability during construction.
- Use of "real time" porewater pressure monitoring devices to measure the buildup excess porewater pressure.
- Practical guidelines for developing safety Work Plans and Go/No Go decision processes when working over and around soft/saturated fly ash materials.
- Best Management Guidelines (BMGs) for assessing the geotechnical characteristics of wet ash to develop safety guidelines for construction.

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INTRODUCTION

The authors of this technical paper have been closely involved with contractors and field engineers who were actively engaged in the construction, and safety evaluation of several recent CCR impoundment closure construction projects. To address the safety concerns of ash basin owners, and the technical requirements of the design engineer, several new and practical field tests and interim geotechnical evaluation methods were developed. This practical and site specific experience has provided additional information about the geotechnical characteristics of fly ash, as it pertains to the stability of ponded ash, and the constructability of ash basin closure projects.

This technical paper and presention provides several practical guidelines and safety monitoring methods that should be useful for a wide variety of wet ash basin construction projects. These guidelines include:

- **Ash Basin Layers:** Identifying the influence of layering in ash basins. This would include recognizing different types of ash, and changes in moisture content changes that need to be accounted for in the design and closure construction process.
- **Crust Stability:** Consideration of what constitutes a “stable crust” for building access roads and a safe platform for the support of ash basin closure construction equipment. This would include explanation of methods used by field engineers and contractors for making an evaluation of crust stability and changes in subsurface conditions.
- **Basin Stability:** Practical methods for evaluating the stability of ash basin including hand-held vane shear devices, surface proofing methods with construction equipment, and “real-time” time porewater pressure measurements for challenging areas.
- **Safety Work Plans:** How to develop and implement Safety Work Plans and guidelines for Go/No Go decision making
- **Best Management Guidelines (BMGs):** These guidelines were developed by the UNC Charlotte, Energy Production Infrastructure Center (EPIC) Coal Ash and Liquid Management (CALM) Office for ash basin owners, design engineers, and closure contractors.

GEOTECHNICAL CHARACTERISTICS AND BASICS OF A STABLE CRUST

The geotechnical characteristic of ash basins vary from site to site, and are influenced by several factors including layering of different types of fly ash materials, pore geochemistry, variations in moisture content and a wide variety of surface drainage conditions. Recent presentations by respected contractors and geotechnical engineers (Hardin, 2016 and Hebeler, 2016) and academic researchers (Jewell, 2016) indicate that the primary defining characteristics are: a) that each ash basin is different, b) the ash basins often have a complex deposition and placement of sluiced materials, and c) the heterogeneity of the saturated ash basin materials both horizontally and vertically in the ash basin. Another important geotechnical characteristic that must be considered for ash basin design and construction is that the water -- porewater and changing water levels in ash basins -- can contribute significantly to the instability and inconsistent strength characteristics of fly ash in ash basins. Addressing these conditions is often matter of contractor experience and skill that is necessary to mitigate a variety of challenging field conditions that are encountered during construction. Figures 1 and 2 show evidence of layering in a typical wet ash basin closure project.

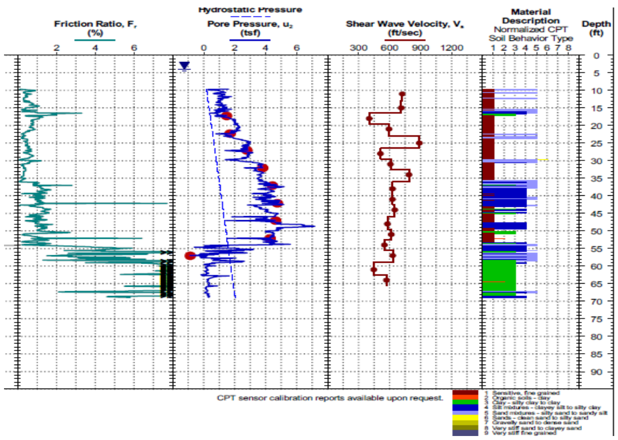

Figure 1: Typical CPT Probe Layered Ash and Pore Pressures

Figure 2: Sample of Layered Ash Basin Less Drainable and More Drainable Ash

One challenging aspect of ash basin construction projects is determining when the crust is stable enough for access by workers and different types of construction equipment. Crust stability is influenced by the moisture content of ash materials, the degree of layering in the ash basin, and the potential for changing water levels in the ash basin. Another key component is addressing how and when the fly ash in the basin is influenced by vibrations from construction equipment. To account for inconsistent and/or changing conditions influenced by vibration, many contractors have started utilizing hand-held vane shear testing equipment both before and after construction has started. The hand-held vane shear devices are used to check the undrained strength of the ash in the upper 5 to 10 feet of the ash basin. Another useful tool for quality control and safety monitoring is using vibrating wire, porewater pressure transducers and readout devices to provide “real time” measurement of the changes that occur. These devices allow the contractor and field engineers to combine qualitative observations of the ash basin surface, and quantitive measurements of the ash basin subsurface to provide field assessment of the crust stability. The following “rules of thumb” are frequently used for assessing when a crust is stable for access by workers or construction equipment:

- **Approximate Minimum Thickness to Support Construction Equipment:** This approximate minimum crust thickness is typically developed on a site specific basis by conducting several test sections and/or proof rolls to see if the ash crust cracks or fails in the presence of construction equipment and “floating access” roads. The test sections can be used by observing shallow penetration with a track hoe bucket called a “thump test” or by observing the action of equipment over a “floating access” road. These type of specialty cross sections are often made from geosynthetic underlayment that is covered with a free draining material like shot rock or bottom ash. A typical minimum crust thickness above a softer zone is 5 to 7 feet. (See Figures 3 and 4.)
- **Compare Undrained Shear Strength versus Equipment Ground Pressure:** Most low ground pressure (LGP) equipment has track pressures in the range of 4 to 5 psi corresponding to 500 to 700 psf. This can be compared to an undrained shear strength measured in the field with a hand held vane shear device ranging from 500 to 750 psf. For safe operation of construction equipment, a suitable crust thickness of 5 to 7 feet with a minimum undrained shear strength of 700 psf is frequently used. This field evaluation typically requires measurement by an experienced technician using a hand head vane shear test device. The field evaluation must take into consideration the near surface drainage characteristics, and the influence of construction equipment vibrations.
- **Continously Monitor Crust Stability:** The stability of the crust is influenced by trapped water and equipment vibrations. Experienced contractors and equipment operators are aware that porewater trapped in subsurface layers of finer ash, and/or equipment vibrations can cause rapid changes to the integrity or stability of an ash basin crust. Measurements of porewater pressures and observations by experienced operators are some of the ways that field engineers and contractors conduct “real time” assessment of a crust stability.
- **Create a Work Plan that Institutes Clear Go/No Go Procedures:** To effectively coordinate the field observations, quality control measurements, and the skill of equipment operators, many contractors have defined Go/No Go procedures that are are incorporated into the project Work Plan and health and safety guidelines. Many of these Work Plan have guidelines giving the ash crust or construction area a “time-out” by stopping work in an area until excess porewater pressure dissipates or minimum undrained shear strength values are re-established.
- **Coordinate the Construction Monitoring with the Design Engineer:** Since most ash basin closure projects are constructed in accordance with stringent engineering design and regulatory requirements it is important that any construction monitoring and field measurements of the shear strength of the wet ash materials be coordinated with the design developed by the design engineer and expectations of the ash basin owner. Some modifications to the field placement procedures and near surface drainage layers of partially saturated ash can have positive and negative impacts on the final grades, and the settlement characteristics of the fly ash materials.

Figure 3: Access Road Underlain By Failing Soft Layer

Figure 4: Track Hoe Bucket Penetration Test Located Near Porewater Transducer

PRACTICAL METHODS FOR THE TESTING AND EVALUATION OF ASH BASINS

To assist with the stability evaluation of partially saturated ash basins for construction and safety monitoring, the UNC Charlotte CALM Office has developed several methods for measuring the undrained shear strength and porewater pressure of fly ash on challenging ash basin projects. These methods include pre-construction testing and field measurements on soft, partially saturated fly ash materials. In addition to the test methods, guidelines have been developed for interpretation and use of these methods as part of a planned field testing and safety monitoring program for workers and heavy equipment operators. The use of the vane shear test device and porewater pressure transducers provides the following to ash basin owners, design engineers and contractors:

- Measurements in difficult-to-access areas about the depth and undrained shear strength of wet ash materials.
- In-place measurement of undrained shear strength and changes in porewater to allow the design engineer to plan ahead and design field access roads and subsurface drainage.
- Information about localized soft/saturated zones that could liquefy when subjected to dynamic loads from construction equipment.
- Placement of porewater pressure devices in soft layers that tend to have the greatest potential to trap excess porewater pressure. (See Figures 5 and 6).

Figure 5 : Typical "real-time" porewater pressure reading device

Figure :6 Hand held vane shear test readings safely obtained over geogrid

BEST MANAGEMENT GUIDELINES AND SAFETY WORK PLANS

To address the safety requirement of the electric power companies and other owners of wet ash basins, the UNC Charlotte EPIC CALM Office has developed several Best Management Guideliness (BMGs). These BMGs provide useful information about how to test soft subgrades using the hand held vane shear devices, where to locate porewater pressure monitoring devices, and how to develop a Safety Work Plan that accounts for a wide variety of changing conditions. One of the most important aspects of a Safety Work Plan is to provide guidelines to the project superintendents and equipment operators about when it is not safe to work on partially saturated ash, and when work should be temporarily stopped. Other considerations include:

- Roles, responsibilities and responsible parties for the main construction and field engineering activities.
- Applicable geotechnical engineering reports, design drawings and specifications that are applicable to the development of the ash basin closure construction means and methods.
- Guidelines for material selection and placement based on site specific health and safety requirements and the closure design.
- Documentation for the technical basis for Go/No Go Decisions and the Job Hazard Assessment for a variety of construction and field monitoring activities.
- Procedures for the use of the vane shear tests and porewater pressure monitoring to inform equipment operators and the Project Superintendent of potential problem conditions.
- Guidelines for addressing changes in site conditions and/or identifying when Work Plan updates are required.

- Guidelines for developing safety Work Plans and Go/No Go decision processes when working over and around soft/saturated fly ash materials.
- Guidelines for interaction and coordination between the design engineer, the field engineer and the general constractor so that the ash basin owner's overall project objectives are accomplished.

SUMMARY AND CONCLUSIONS

The technical and construction experience that is needed to design and construct an ash basin closure has developed rapidly since the promulgation of the Final CCR Rule on April 16, 2016 The explanation and guidelines provided in this technical report are offered to provide ash basin owners, design engineers and contractor practical guidelines for evaluating the geotechnical characteristics of ash basins and developing safety monitoring practices.

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