Proactive Pre-Drainage Criteria for Hybrid Ash Basin Closure

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ABSTRACT

As regulatory compliance drives owners to close ash basins, safe and effective management of CCR is a critical issue. Dewatering or removal of interstitial water from ash is a proven method of stabilizing ash during the closure process. Dewatering supports closure activity by imparting stability to the ash, allowing it to stand at slopes and to support loads that would otherwise not be safe or sustainable. However, relying on this benefit requires the phreatic surface in the ash to be established and maintained several feet or more below the slope or working surface. For applications where an excavated ash slope must remain in place for a substantial period of time, such as hybrid closures or for beneficiation, identification of key ash properties and the required phreatic surface are critical to define safe ash slopes. Pre-drainage techniques, including wellpoints, wells, and ejectors, have proven to be effective in achieving this for significant slope cuts, stacked ash fills, and for conventional excavations. The ability to monitor the phreatic surface in the work area is also a key component to pre-drainage and maintenance. Some project owners have found it advantageous to specify a depth or elevation to which the water level must be lowered prior to closure activity. This ensures that the water will be lowered to an acceptable level without putting the owner in the position of being the dewatering system designer or infringing on the contractor’s means and methods. This presentation will discuss potential methods and rationales for specifying maximum long-term ash slopes under a variety of conditions, a required dewatering result, as well as the pros and cons of doing so.

BACKGROUND

Closure of CCR impoundments are generally regulatory-driven, but more frequently litigation and legislation determine not only the timing of impoundment closure but the method of closure as well. With the maximum 15-year closure window available for CCR impoundment closure (including all available extensions), uncertainty regarding the initiation of closure, the method of closure approved by regulatory agencies, and the likelihood of legal challenges, the time available to utilities to effectively close
impoundments will be limited. This is an especially acute challenge for closure by removal and hybrid closure of large basins.

Safe and effective removal and stacking of sluiced CCR requires that the CCR be stabilized prior to excavation and hauling as well as beneath future stacking. Schedule pressures, driven by regulatory compliance, litigation, or the shear mass of CCR to be removed, can result in unsafe conditions if adequate time is not permitted for proper stabilization of the ash.

The most effective means to stabilize sluiced CCR to facilitate access, excavation, slope cuts, and stacking is by dramatically increasing the shear strength of the ash with dewatering. Dewatering can be accomplished by a variety of methods; all of which can be effective if properly planned and implemented. Implementation begins during the design phase when engineers analyze each stage of closure construction which includes both temporary and permanent conditions anticipated during closure. For the sake of maintaining safe conditions and meeting project schedule, it may be best for the design engineer to assign the depth and aerial extent of dewatering prior to equipment access, CCR excavation and stacking for the sake of what we will refer to as geotechnical stability.

**WET AND DRY SLUICED CCR**

Typically, sluiced fly ash in place at or below the normal pool elevation of the impoundment is saturated. Saturated fly ash typically has very low shear strength and will exhibit instability if not improved. Improvement of CCR can be achieved by mixing in place with a stabilizing agent, but this demands access for large, heavy equipment. The most common and in most cases the only practical means to stabilize sluiced fly ash is by dewatering.

From a geotechnical engineering standpoint, the behavior of fly ash (including the safety and stability of fly ash during excavation) is a close function of whether the CCR is drained or undrained. Fly ash in a drained condition has reasonably good shear strength and can be stable at relatively steep slopes for extended periods of time. Fly ash in the undrained condition will seek a very flat angle of repose and is highly prone to instability when disturbed due to excess pore pressure (Figure 1). The activities we need to undertake to complete closure can result in instability. Road construction, excavation, stockpiling, hauling, and loading into trucks or railcars can result in sudden disturbance of fly ash during closure. It is important to investigate, test, and monitor the behavior of fly ash site by site.
There is a zone, several feet above the phreatic surface, where the degree of saturation of the ash is between what we have called “wet” and “dry”. In this zone, the strength and behavior of the ash is changeable and potentially unstable due to capillary action, delayed drainage, or re-wetting of the ash by precipitation. Any water level criteria that may be specified should take into consideration these changeable conditions several feet above the phreatic surface.

Considering the wide array of possible sources, generation, placement, storage, loading and saturation conditions of fly ash within an ash basin, the range of shear strengths identified through in-place or laboratory testing is remarkably narrow. “Wet” (undrained) fly ash exhibits generally low shear strength in-place and is highly prone to instability when loaded, as described previously. As geotechnical engineers, we try to identify shear strength parameters for fly ash that are representative of the in situ conditions as well as the anticipated conditions during closure. To complete closure activities, some or all of the fly ash has to be improved to the extent that safe and stable conditions can be established. In general terms, “wet” fly ash has to be improved to “dry” fly ash in order to complete access, excavation, hauling and stockpiling activities. When we analyze the conditions required to achieve adequate factors of safety against slope instability, the assumed shear strength parameters and the location of the phreatic surface are the key variables.

A large body of knowledge exists on wet and dry (undrained and drained) shear strengths and does not need to be discussed further herein.
CONSTRUCTION CONDITIONS, CONTRACTOR’S MEANS & METHODS

The construction conditions that are typically the contractor’s responsibility are access improvements for construction equipment, excavations which do not have the potential to adversely affect permanent features of the work, working platform stability for specialized equipment that may be part of a contractor’s unique approach to the work, stockpiling of ash, and hauling. The contractor is typically responsible for controlling water levels for worker safety (as opposed to geotechnical stability).

Access improvement for heavy equipment obviously needs to be early in the game. A sufficiently thick dry crust may be suitable enough for access if the water level in the pond is relatively deep. The rule of thumb is that a 10-ft (3 m) dry crust is sufficient for typical earthwork equipment. In reality, it varies and depends upon a number of factors including the type of coal, completeness of burning, ash gradation and consistency, density, etc., as well as the construction activity.

Where the water level is closer to the surface, the contractor may choose to create a dry crust with dewatering, improve access with floating roads, or just work the site with the water within several feet of the surface. Dewatering may not be the best option where discharge permits may be a constraint, dewatering prematurely triggers closure, or it is simply not the contractor’s preferred approach. Floating roads may also be necessary in the finest corner of the pond in ash that visually appears clay-like and has no free water (specific yield is zero). Where floating roads are constructed, this typically is done with geogrid, perhaps in several layers. This area may be necessary for 10 to 20 percent of the pond area. This is an area of the pond that can only be dewatered if there is significant layering of more typical ash within the finer clay-like material, and a sufficiently strong dry crust may not be achievable.

Excavations which do not have the potential to adversely affect permanent features of the work are typically up to the contractor’s means and methods. The contractor should have the freedom to sequence and dewater the work provided the means and methods do not compromise worker safety or permanent elements of the closure.

Temporarily stockpiling of CCR is a necessary step in many ash basin closure projects. Stockpiling CCR over low shear strength saturated sluiced fly ash can result in instability ranging from surface bearing capacity type failures to larger scale foundation and slope failures. Foundation CCR material may have to be stabilized by dewatering in advance of stockpiling. The rate that the foundation CCR materials are loaded should be assessed in the design phase and pore pressures should be monitored during stockpile development. In addition, CCR that is excavated from below the phreatic surface will have to be processed to lower the moisture content to facilitate subsequent stacking. Stockpile and processing areas should be included in the planning of ash basin closures. This critical element of the closure is often overlooked, which can negatively impact schedule and costs.

It is well understood that when saturated fly ash is loaded into trucks, it experiences loss of strength and can be variously described as “soup”, “muck”, “goop” and other less
sophisticated but equally descriptive engineering terms. This may not be a safety issue as much as an environmental issue if the CCR spills onto areas outside the ash basin or is subsequently tracked onto public roads. For closure by removal projects, a target moisture content should be identified for CCR that is hauled off site. A moisture content range of 30 to 35% is a typical target for off-site hauling or placement into landfills. Higher moisture contents may be acceptable for hauling within the ash basin.

**CONSTRUCTION CONDITIONS, KNOWN TEMPORARY AND PERMANENT CONDITIONS**

The typical hybrid closure involves at least one slope cut where ash is excavated below the water level and stacked further upslope. This slope probably represents the greatest potential for a catastrophic failure in ash if the water is not controlled and ash remains wet or drained ash is rewetted by precipitation or dewatering system failure.

Pre-drainage dewatering is a necessity as the slope stability analyses require water levels to be well below the interim excavation surfaces. These analyses also dictate that the pre-drained water levels be lowered as the stack height increases. The engineering analyses are critical and must dictate acceptable staging and sequencing of the work.

**GEOTECHNICAL ANALYSES**

For purposes of this paper, the construction conditions are broken into two general groups:

- CCR Stacking
- CCR Excavation

Stacking of CCR includes placement of fill over saturated sluiced CCR to construct temporary or permanent berms, dikes, pond bifurcations, placement of CCR in temporary stockpiles and placement of CCR in controlled compacted lifts to support ash basin consolidation. Geotechnical evaluation of the foundation materials can determine where it is safe to stack ash or construct a stockpile, the rate of CCR placement, and the overall height that can be developed.

An example is provided in Figure 2 which shows a slope stability analysis of a proposed ash stockpile area to be developed within an ash basin containing sluiced ash. This is a typical scenario for many ash basins to be closed by removal or hybrid closure since stockpiling of CCR outside the ash basin limits is prohibited by federal and most state regulations. The example stockpile is to be developed by placement of CCR from another portion of the ash basin. It has been determined by experience that stockpile development must be limited to no thicker than 8-ft (2.4m) lifts where the foundation materials are comprised mainly of fly ash. Subsequent lifts can only be placed once pore pressures in the foundation CCR return to pre-development levels.
Figure 2. A stable condition where 8 ft (2.4 m) of ash is stacked upon dewatered sluiced ash beneath.

In Figure 2, slope stability analyses were conducted assuming the foundation CCR was in the drained condition. Analyses indicated a suitable minimum factor of safety.

If the foundation material is fly ash and the stockpiling is to commence before the phreatic surface could be lowered, undrained conditions have to be assumed. In this scenario, free water remains in the ash basin, which would be consistent with pre-construction testing of the CCR showing that it is saturated to within 2 ft (0.6 m) of the surface.

As can be seen in Figure 3, the nature of the slope failure is similar to that identified in the drained analyses, but the minimum factor of safety is much less than 1.0, and this condition would be considered unsafe.

Figure 3. An unsafe condition where 8 ft (2.4 m) of ash is stockpiled upon saturated sluiced ash.

To support the stockpile placement and maintain the overall project schedule, active dewatering of the foundation is required. In this case, wells or wellpoints could be utilized to lower and maintain the phreatic surface beneath the stockpile a minimum of 8 ft (2.4 m). The area to be dewatered extended a minimum of 50 ft (152 m) outside the stockpile footprint. The minimum factor of safety (see Figure 4) was determined to be acceptable for temporary conditions for the initial 8-ft (2.4 m) lift and no time limits were placed on stockpile development.
Analyses completed to support placement of a second lift indicate that with suitable setbacks from the limits of the initial lift, the minimum factor of safety is marginally acceptable, see Figure 5. In the event a second lift is required, dewatering can be extended to a 12-ft (3.6 m) depth. Subsequent subsurface exploration can be conducted to measure any strength gain in the foundation due to dewatering and placement of the initial stockpile lift. These mitigation and verification measures could be applied as needed throughout closure construction.

Excavation of CCR to support, removal, and subsequent stacking is a common challenge for hybrid closures. Temporary and permanent CCR slopes need to remain stable and the excavated CCR needs to be processed (mainly dried) before hauling or placement over the sluiced ash to support closure. The key to safe slopes on closure projects under schedule pressure is understanding and controlling the saturation conditions. Where is the phreatic surface? Where will it be at the time excavation begins? What is being done to control and monitor the phreatic surface within the slope and foundation of the excavation? These questions need to be addressed jointly by the owner, engineer and contractor in advance of construction. These stakeholders will have staff on the ground during implementation of closure and their safety is paramount. It is critical at the design stage to determine the water level criteria, at least to the greatest extent possible with the geotechnical data on hand. Should unanticipated conditions be revealed during the course of the work, appropriate modifications should
be made. The contracts with the engineer and contractor should be structured to permit this flexibility in the course of the work.

NEED FOR CLEAR CRITERIA

A number of ash basin closures have been successfully completed using passive dewatering methods (rim ditches and sumps) as well as active or pre-drainage dewatering methods (wellpoints, deep wells). The dewatering approach in conventional construction is typically left to the means and methods of the contractor. Many design engineers believe that establishing firm performance criteria for the dewatering is considered encroaching upon the contractor’s realm. With ash pond closures where relatively steep, stable, dry slopes are required by design, it is essential to have clear performance criteria that will dictate that pre-drainage dewatering is utilized, but leave the design and implementation of the predrainage system to the contractor.

Steeper slopes reduce material handling and excavation time, but the viability of a relatively steep slope would have to be demonstrated by analyses and monitoring of the phreatic surface. Flatter excavation slopes are generally safer and accommodate expected changes in field conditions, but could extend the construction schedule and generate more CCR to manage. For a hybrid closure where CCR must be removed from below the water level and stacked on top of sluiced ash, it is advantageous from both a construction schedule and overall cost perspective to limit the footprint of the closure area. This requires the ash to be cut and subsequently stacked on a relatively steep slope, such as a 4:1. This is where pre-drainage dewatering is absolutely essential. Dewatering with rim ditches and sumps would not prevent the movement of ground that is so characteristic of working in ash. The loss of the toe of a 100 ft (30 m) high slope of ash on a 4:1 slope would be a catastrophic failure.

In nearly every ash basin closure that contains saturated sluiced fly ash, the time to complete the closure is a direct function of unwatering the pond and dewatering the CCR. Experience on numerous closure projects indicates that dewatering using rim ditches alone is generally slow. This approach alone is not compatible with aggressive closure schedules or with large scale removal or relocation of CCR. Since ash basin closures are likely to be driven by the compliance schedule, analyses for stability and dewatering should commence well before construction is initiated.

A dewatering and monitoring plan should be developed prior to ground disturbance, with multiple series of piezometers to demonstrate that the dewatering targets are maintained. Piezometer screen placement should be consistent with the critical dimensions and depths from the slope stability analyses. It is highly recommended that the dewatering and associated monitoring begin well before excavation to maximize its effect and optimize the excavation and hauling process.

CONCLUSIONS

Dewatering is customarily a temporary construction method that is left completely up to the means and methods of the contractor. Dewatering imparts a significant increase in
shear strength to the ash. With construction activities on the typical pond closure, there are site work activities which should be performed totally at the discretion and means and methods of the contractor, but there are conditions where the design engineer should dictate water level criteria in order to ensure higher shear strength within the ash, necessary as part of the closure design. The most vulnerable phase in the closure of a hybrid pond is the excavation and stacking of ash, with a resulting slope in the pond. This slope must be engineered and will require water levels to be maintained at pre-determined levels below the ash surface, achieved by predrainage methods (i.e., the use of wells or wellpoints) and monitored over the life of the closure. If pre-drained, the slopes may be relatively steep which will optimize cut and stacked volumes.