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Standard Guide for Use of Coal Combustion Products (CCPs) for Surface Mine Reclamation: Re-contouring and Highwall Reclamation[1]

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1. Scope

1.1 This guide covers the use of coal combustion products (CCPs) for surface coal mine reclamation applications, as in beneficial use for reestablishing land contours, highwall reclamation, and other reclamation activities requiring fills or soil replacement. The purpose of this standard is to provide guidance on identification of CCPs with appropriate engineering and environmental performance appropriate for surface mine re-contouring and highwall reclamation applications. It does not apply to underground mine reclamation applications. There are many important differences in physical and chemical characteristics among the various types of CCPs available for use in mine reclamation. CCPs proposed for each project must be investigated thoroughly to design CCP placement activities to meet the project objectives. This guide provides procedures for consideration of engineering, economic, and environmental factors in the development of such applications, and should be used in conjunction with professional judgement. This guide is not intended to replace the standard of care by which the adequacy of a given professional service must be judged, nor should this guide be applied without consideration of a project's unique aspects.

1.2 The utilization of CCPs under this guide is a component of a pollution prevention program; Guide E1609 describes pollution prevention activities in more detail. Utilization of CCPs in this manner conserves land, natural resources, and energy.

1.3 This guide applies to CCPs produced primarily from the combustion of coal.

1.4 The testing, engineering, and construction practices for using CCPs in mine reclamation are similar to generally accepted practices for using other materials, including cement and soils, in mine reclamation. For guidance on structural fills to be constructed at mine sites, see applicable ASTM guide for coal ash structural fills.

1.5 Regulations governing the use of CCPs vary by state. The user of this standard guide has the responsibility to determine and comply with applicable regulations.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C188 Test Method for Density of Hydraulic Cement
C311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
D75 Practice for Sampling Aggregates
D420 Guide to Site Characterization for Engineering Design and Construction Purposes (Withdrawn 2011)[3]
D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))
D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1195 Test Method for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements
D1196 Test Method for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

Use in Evaluation and Design of Airport and Highway Pavements

D1452 Practice for Soil Exploration and Sampling by Auger Borings

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils

D1883 Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils

D2166 Test Method for Unconfined Compressive Strength of Cohesive Soil

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading

D3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

D3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures

D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table

D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density

D4429 Test Method for CBR (California Bearing Ratio) of Soils in Place

D4448 Guide for Sampling Ground-Water Monitoring Wells

D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils

D4972 Test Method for pH of Soils

D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

D5239 Practice for Characterizing Fly Ash for Use in Soil Stabilization

D5851 Guide for Planning and Implementing a Water Monitoring Program

E1609 Guide for Development and Implementation of a Pollution Prevention Program (Withdrawn 2010)[3]

E2201 Terminology for Coal Combustion Products

2.2 *AASHTO (American Association of State Highway and Transportation Officials) Standards:*[4]

T 288 Determining Minimum Laboratory Soil Resistivity

T 289 Determining pH of Soil for Use in Corrosion Testing

T 290 Determining Water Soluble Sulfate Ion Content in Soil

T 291 Determining Water Soluble Chloride Ion Content in Soil

2.3 *Other Methods*():

EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP) **(1)**[5]

EPA Method 1320 Multiple Extraction Procedure (MEP) **(2)**

EPA Method Monofill Waste Extraction Procedure (MWEP) **(3)**

Synthetic Ground water Leaching Procedure (SGLP) **(4)**

Long-Term Leaching Procedure (LTL) **(4)**

3. Terminology

3.1 *Definitions*—For definitions related to coal combustion products, see Terminology E2201. For definitions related to geotechnical properties, see Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *internal erosion*—piping; the progressive removal of soil particles from a mass by percolating water, leading to the development of channels.

3.2.2 *permeability*—the capacity to conduct liquid or gas. It is measured as the proportionality constant, k, between flow velocity, v, and hydraulic gradient, i; $v = ki$.

4. Background

4.1 *Significance and Use*—CCPs can be effective materials for use for reclamation of surface mines. Following are key scenarios in which CCPs may be utilized beneficially in a mined setting:

Structural fill
Road construction
Soil modification or amendment for revegetation **(5-9)**
Isolation of acid forming materials **(5)**
Reduction of acid mine drainage (AMD) **(5,10-15)**
Highwall mining **(16,17)**

4.1.1 These options represent most, but not all, scenarios under which CCPs would be returned to the mine. This guide discusses issues related to highwall mining and recontouring. Because of the chemical and physical characteristics of CCPs and the benefits derived from the use of CCPs in these applications, placement of CCPs in a surface mine setting qualifies as a beneficial use as defined in Terminology E2201.

4.1.2 CCPs are ideally suited for use in numerous fill applications. Structural fills and other high-volume fills are significant opportunities for placement of CCPs in mine situations for reclamation, recontouring, and stabilizing slopes. These applications are the focus of this guide.

4.1.3 Any type of CCP may be evaluated for use in mine reclamation, even fly ash with high carbon content. Project-specific testing is necessary to ensure that the CCPs selected for use on a given project will meet the project objectives. The use of CCPs can be cost effective because they are available in bulk quantities and reduce expenditures for the manufacture and purchase of borrow material, Portland cement, or quicklime. Large-scale use of CCPs for mine reclamation conserves landfill space by recycling a valuable product, provided that the CCP is environmentally and technically suitable for the desired use.

[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

[5] The boldface numbers in parentheses refer to the list of references at the end of this guide.

4.2 *Use of CCPs for Mine Reclamation*—E2201 the Standard on Fly ash, bottom ash, boiler slag, FGD material, and FBC ash or combinations thereof can be used for mine reclamation. Each of these materials typically exhibits general physical and chemical properties that must be considered in the design of a mine reclamation project using CCPs. The specific properties of these materials vary from source to source, so environmental and engineering performance testing is recommended for the material(s) or combinations to be used in mine reclamation projects. Guidance in evaluating the physical, engineering, and chemical properties of CCPs is given in Sections 6 and 7.

4.3 *Engineering Properties and Behavior*—Depending on the mine reclamation application, fly ash, bottom ash, boiler slag, FGD material, FBC fly ash, FBC bottom ash, or combinations thereof may have suitable and/or advantageous properties. Each of these materials typically exhibits general engineering properties that must be considered in engineering applications. These general engineering properties are discussed in the following subsections; however, it should be noted that the specific engineering properties of these materials can vary greatly from source to source and must be evaluated for each material, or combination of materials, to be utilized for a structural fill.

4.3.1 *Unit Weight*—Many CCPs have relatively low unit weights. This is sometimes referred to as "bulk density" in the literature. The low unit weight of these materials can be advantageous for some structural fill applications. The lighter-weight material will reduce the load on weak layers or zones of soft foundation soils such as poorly consolidated or landslide-prone soils. Additionally, the low unit weight of these materials may reduce transportation costs, since less tonnage of material is hauled to fill a given volume. Lower density fills of equal internal angle of friction will exert less lateral pressure on retaining structures.

4.3.1.1 Fly ash is typically lighter than the fill soil it replaces, with unit weight ranging from about 50 to 100 pcf (8 to 16 kN/m^3).

4.3.1.2 Bottom ash is also typically less dense than coarse-grained soils of similar gradation, with unit weight ranging from about 70 to 90 pcf (11 to 14 kN/m^3).

4.3.1.3 Boiler slag is typically as heavy as, if not heavier than, natural soils of similar gradation, with unit weight ranging from about 90 to 110 pcf (14 to 18 kN/m^3).

4.3.1.4 Oxidized and/or fixated FGD materials are also relatively lightweight, with unit weights ranging from about 50 to 100 pcf (8 to 16 kN/m^3).

4.3.2 *Compaction Characteristics*—Most CCPs can be placed and compacted in a manner very similar to soil and aggregate fill materials. In fact, most CCPs exhibit very little cohesion and are not as sensitive to variations in moisture content as are natural soils.

4.3.2.1 Fly ash, FGD material, and FBC ash are typically placed and compacted in a manner similar to noncohesive fine-grained soils. Smooth-drum vibratory rollers or pneumatic tired rollers typically compact these materials most effectively. Although not always, fly ash and FGD material typically exhibit a measurable moisture-density relationship that can be utilized for compaction quality control. To take full advantage of the self-hardening properties of some fly ash, FGD material, and FBC ash, compaction soon after the addition of water is recommended. If hardening or cementation has occurred prior to compaction, cementitious bonds may need to be disrupted to relocate the grains into a more dense state (**18**). Strength and permeability will not be the same for self-hardening materials compacted before cementation has occurred as for those compacted after cementation has occurred. Compaction criteria are usually not specified for FGD material that exhibits thixotropic properties.

4.3.2.2 Bottom ash is generally placed and compacted in a manner similar to noncohesive coarse-grained soils or fine aggregate. Smooth-drum vibratory rollers typically are most effective for the compaction of these materials. Bottom ash may or may not exhibit consistent moisture-density relationships. Bottom ash typically compacts best when saturated. Bottom ash should be compacted to a specified density.

4.3.2.3 Boiler slag is generally placed and compacted in a manner similar to noncohesive coarse-grained soils or fine aggregate. Smooth-drum vibratory rollers typically are most effective for the compaction of these materials. As with bottom ash, boiler slag may or may not exhibit consistent moisture-density relationships. Boiler slag typically compacts best when saturated.

4.3.3 *Strength:*

4.3.3.1 *Shear Strength*—For non-self-hardening fly ash and bottom ash, shear strength is derived primarily from internal friction. Typical values for angles of internal friction for non-self-hardening fly ash are higher than those for many natural soils. These ashes are non-cohesive, and although the ash may appear cohesive in a partially saturated state, this effect is lost when the material is either completely dried or saturated.

(1) Because of its angular shape, the shear strength of bottom ash is typically greater than that of fly ash and is similar to the shear strength of natural materials of similar gradation. However, friable bottom ash may exhibit lower shear strength than natural materials of similar gradation.

(2) The shear strength of boiler slag may be higher than that of natural materials of similar gradation, owing in part to the typically angular shape and hardness of the particles.

4.3.3.2 *Compressive Strength*—Self-hardening CCPs and stabilized FGD material undergo a cementing process that increases with time. Hydration of dry self-hardening CCPs commences immediately upon exposure to water and can cement the CCP particles in a loose state, reducing the compacted density and strength. High compressive strengths can be achieved if the CCPs are compacted immediately after incorporation of water. Unconfined compressive strengths greater than 2000 psi have been reported for a cementitious ash-water mixture after 248 days (**18**).

4.3.4 *Consolidation Characteristics*—Structural fills constructed of fly ash or FGD material typically exhibit small amounts of time-dependent, postconstruction consolidation. This is because excess pore water pressures dissipate relatively rapidly, and thus most of the embankment settlement or deformation occurs as a result of elastic deformation of the material rather than by classical consolidation. Most deformation due to the mass of the fill or structure thereof generally occurs during construction.

4.3.4.1 Bottom ash and boiler slag are free-draining materials that can be compacted into a relatively dense, incompressible mass. For this reason, structural fills constructed of bottom ash or boiler slag also typically exhibit small amounts of time-dependent, postconstruction consolidation or deformation, with the most deformation occurring during construction.

4.3.4.2 Self-hardening fly ash and FGD material typically exhibit minimal postconstruction consolidation or deformation because of cementing and solidification of the CCPs.

4.3.5 *Permeability*—The values for permeability of CCPs range greatly depending on the type of CCP, the degree of compaction, and other placement variables.

4.3.5.1 The permeability values for non-self-hardening fly ash are similar to those observed for natural silty soils.

4.3.5.2 Self-hardening fly ash and FGD material are relatively impermeable, with permeability values similar to those for natural clays. Self-hardening fly ash and some FGD material may be susceptible to cracking in the environment. Cracking can produce a conduit for liquids through the placed material and change the measured permeability.

4.3.5.3 Bottom ash and boiler slag are typically as permeable as granular soils of similar gradation.

4.3.6 *Erosion Characteristics:*

4.3.6.1 *Internal Erosion (Piping)*—Non-self-hardening fly ash is subject to internal erosion because of its fine-grained, noncohesive nature. Internal erosion can be controlled by providing adequate surface water controls to minimize infiltration and by providing internal drainage when warranted.

(1) Bottom ash and boiler slag typically are well graded and capable of being compacted to a stable mass. These attributes usually preclude any problems arising from internal piping of material.

(2) Self-hardening fly ash and FGD material are usually not subject to internal erosion.

4.3.6.2 *Surface Erosion*—All CCPs may be eroded by wind or water and require use of erosion controls similar to those commonly used on earthwork construction projects. Wind erosion may be controlled by use of wind breaks. Dusting may be controlled by addition of water, or conditioning, to non-self-hardening materials. Water erosion can be limited by controlling water at the site by using sedimentation, sloping, and run-off controls meeting regulatory requirements. These controls should be put in place under the supervision of a qualified professional.

4.3.7 *Swelling*—Some self-hardening CCPs may swell with time. Paragraph 6.3.8 provides guidance on evaluating the swelling potential of CCPs.

4.3.8 *Liquefaction and Frost Heave*—Although fine-grained and noncohesive materials such as fly ash are susceptible to liquefaction and frost heave when saturated, these problems are readily controlled by design practices that allow for drainage away from the ash fill. Because of fly ash sensitivity to moisture, it is standard practice to design fills to be well drained. Typically, drainage blankets to provide internal drainage and serve as a capillary barrier are included at the base of fills. Also, locating fills in areas where they are not subject to saturation or infiltration by surface water or ground water is normally considered in design. Self-hardening and stabilized fly ash and FGD material are not susceptible to liquefaction. Non-stabilized wet FGD material is highly susceptible to frost heave.

4.3.8.1 Well-compacted bottom ash and boiler slag are not typically susceptible to either liquefaction or frost heave. However, some of the finer bottom ash materials may behave quite similarly to fly ash and would require the same consideration for design as fly ash embankments.

4.3.9 *Specific Gravity*—Specific gravity is the ratio of the weight in air of a given volume of solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature. The particle specific gravity of fly ash is relatively low compared to that of natural materials and generally ranges from 2.1 to 2.6 (**19**).

4.3.10 *Grain-Size Distribution*—Grain-size distribution describes the proportion of various particle sizes present in a material. Fly ash is a uniformly graded product with spherical, very fine-grained particles.

4.3.11 *Moisture Content*—Moisture content is the ratio of the mass of water contained in the pore spaces of soil or rock material to the solid mass of particles in that material, expressed as a percentage. Most CCPs have almost no moisture when first collected after the combustion of coal. Nonstabilized wet FGD material has a high moisture content. Power plant operators sometimes add moisture to facilitate transport and handling, a process termed conditioning.

4.3.12 *Thixotropy*—The property of some gels to become fluids when disturbed by energy events such as vibration. This property may be exhibited by some FGD materials.

4.4 *Chemical Properties:*

4.4.1 *Elemental Composition*—The major elemental components of CCPs are silicon, aluminum, iron, calcium, magnesium, sodium, potassium, and sulfur. These elements are present in various amounts and combinations dependent primarily on the coal type (bituminous, subbituminous, or lignite) and type of CCP (coal fly ash, FBC fly ash, FGD material, and so forth). Trace constituents may include trace elements such as arsenic, boron, cadmium, chromium, copper, chlorine, mercury, manganese, molybdenum, selenium, or zinc (**20**).

4.4.2 *Phase Associations*—The primary elemental constituents of CCPs are present either as amorphous (glassy) phases or crystalline phases. Coal combustion fly ash is typically 70+ % amorphous material. FGD and FBC products are primarily crystalline, and the crystalline phases typically include calcium-based minerals.

4.4.3 *Pozzolanic Activity*—Most fly ash is characterized as pozzolanic because of the presence of siliceous or siliceous and aluminous materials that in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

4.4.4 *Hygroscopy*—Most CCPs are captured and then handled in conditions that either create or preserve dehydrated conditions. Some CCPs have distinctive stable states of hydration. This stable hydration state needs to be considered in some applications of CCPs.

4.5 *Environmental Considerations:*

4.5.1 *Regulatory Framework:*

4.5.1.1 *Federal*—The U.S. Department of the Interior Office of Surface Mining (OSM) is charged with the responsibility of ensuring that the national requirements for protecting the environment during coal mining are met and making sure the land is reclaimed after it is mined. When the use of CCPs occurs at surface coal mines, state or federal coal-mining regulators are involved to the extent that SMCRA (Surface Mining Control and Reclamation Act) requires the mine operator to ensure that:

(1) All toxic materials are treated, buried, and compacted, or otherwise disposed of, in a manner designed to prevent contamination of ground or surface water (30 CFR 816/817.41).

(2) The proposed land use does not present any actual or probable threat of water pollution (30 CFR 816/817.133).

(3) The permit application contains a detailed description of the measures to be taken during mining and reclamation to assure the protection of the quality and quantity of surface and ground water systems, both on- and off-site, from adverse effects of the mining and reclamation process (30 CFR 780.21).

(4) The rights of present users of such water are protected (30 CFR 816/817.41).

(5) Any disposal of CCPs at mine sites must be in accordance with those standards and with applicable solid waste disposal requirements (30 CFR 816/817.89).

(a) SMCRA gives primary responsibility for regulating surface coal mine reclamation to the states, and 24 coal-producing states have chosen to exercise that responsibility. On federal lands and Indian reservations (Navajo, Hopi, and Crow) and in the coal states that have not set up their own regulatory programs (Tennessee and Washington), OSM issues the coal mine permits, conducts the inspections, and handles the enforcement responsibilities. As a result of the activities associated with the SMCRA, coal mine operators now reclaim as they mine, and mined lands are no longer abandoned without proper reclamation. OSM also collects and distributes funds from a tax on coal production to reclaim mined lands that were abandoned without being reclaimed before 1977. OSM has a Coal Combustion Residues Management Program that focuses on providing expert technical information on the use of CCPs in mine reclamation for the mining industry, regulatory agencies, and other stakeholders.

(b) In 1999, U.S. Environmental Protection Agency (EPA) completed a two-phased study of CCPs for the U.S. Congress as required by the Bevill Amendment to RCRA. At the conclusion of the first phase in 1993, EPA issued a formal regulatory determination that the characteristics and management of the four large-volume fossil fuel combustion waste streams (that is, fly ash, bottom ash, boiler slag, and flue gas emission control waste) do not warrant hazardous waste regulation under RCRA and that utilization practices for CCPs appear to be safe. In addition, EPA "encourage[d] the utilization of coal combustion byproducts and support[ed] State efforts to promote utilization in an environmentally beneficial manner." In the second phase of the study, EPA focused on the byproducts generated from FBC boiler units and the use of CCPs from FBC and conventional boiler units for mine reclamation, among other things. Following completion of the study, EPA issued a regulatory determination that again concluded that hazardous waste regulation of these combustion residues was not warranted. However, EPA also decided to develop national solid waste regulatory standards for CCPs, including standards for placement of CCPs in surface or underground mines, either under RCRA, SMCRA, or a combination of the two programs (65 CFR 32214, May 22, 2000).

4.5.1.2 *State and Local*—There is considerable variation in state-mandated permitting and other regulatory requirements for CCP utilization. Some states have specific beneficial use policies, while other states have no regulations or guidance addressing beneficial use. Although the NEPA (National Environmental Policy Act) strictly applies only to federally funded projects, many states have similar mechanisms for assessing the environmental impacts of non-Federal projects. These mechanisms may require state permits that address any or all of the following issues: wetlands/waterways, National Pollutant Discharge Elimination System (NPDES) discharge, underground injection, erosion and sediment control, air quality considerations, and storm water management.

4.5.2 *Water Quality*—When planning to use CCPs for mine reclamation, one should consider the potential impacts on ground water and surface water to ensure protection of human health and the environment.

4.5.2.1 *Ground Water*—The design and implementation of a mine reclamation project should consider the potential ground water impacts of CCPs to ensure the protection of human health and the environment. Considerable research has been conducted to assess and predict the potential impacts of CCP utilization on ground water quality. An assessment of ground water quality impacts should be performed by a qualified professional and should take into account project-specific considerations such as composition of CCPs, the typically limited leachability of CCPs, presence of acid forming materials or acid mine drainage, placement of CCPs relative to the ground water table, rates of infiltration, the type of placement used for the CCP, and constituent migration, attenuation in ground water, and location of sensitive receptors (that is, wells). Where protection of ground water is a special concern, the leaching characteristics of the CCP should be evaluated as part of the assessment of constituent migration and attenuation. Consideration should be given to the leachability of the CCP in the presence of AMD. Some states may require a groundwater protection plan be prepared outlining controls that will limit potential impact to groundwater.

4.5.2.2 *Surface Water*—CCPs may affect surface water bodies during and after placement activities as a result of erosion and sediment transport. The engineering and construction practices recommended to minimize these effects on surface waters include storing the CCPs in stockpiles employing effective storm water management controls to maximize runoff and minimize run-on.

4.5.3 *Air Quality*—When planning to use CCPs for mine reclamation, one should consider the potential impacts to air quality including dusting.

4.5.3.1 *Dust Control*—Dusting must be controlled during the transport and handling of CCPs in order to avoid fugitive dust and to ensure worker safety. Dust control measures routinely used on earthwork projects are effective in minimizing airborne particulates at CCP storage sites. Typical controls include appropriate hauling methods, use of windbreaks, moisture conditioning of the CCPs, storage in bins or silos, covering the CCPs with large tarpaulins, wetting or covering exposed CCP surfaces, and paving or wetting unpaved high-traffic haul roads with coarse materials.

4.5.3.2 *Radionuclides*—Coal and fly ash are not significantly enriched in radioactive elements or in associated radioactivity compared to common soils or rocks (**21**). Certain radioactive elements including radium and uranium are known to occur naturally in CCPs (**15**) and other fill materials. The U.S. Department of Energy estimated the radium concentration of fly ash to be no more than 3.0 pCi/g (**22**). Radon emissions from the CCPs are not likely to exceed the naturally occurring ambient emissions.

4.6 *Economic Benefits*—The use of CCPs for mine reclamation can have economic benefits. These benefits are affected by local and regional factors, including production rates, processing and handling costs, transportation costs, availability and cost of competing materials, environmental concerns, and the experience of materials specifiers, design engineers, purchasing agents, contractors, legislators, regulators, and other professionals. CCPs are competing as manufactured materials and not as waste products, however in the event that CCPs do not meet beneficial use requirements or cannot be utilized, they should be managed at an appropriate waste facility. Since CCPs are produced in the process of manufacturing electricity, these materials can present an advantage when utilized as raw products for finished goods. This is primarily due to the low overheads involved with the material production cost and the fact that some, but not all coal-fired power plants have immediate access to low-cost transportation. The transport of coal to the power plant can provide an excellent opportunity to return CCPs to a mine site to aid in mine reclamation projects.

5. Site Characterization

5.1 *General*—The siting and design of a mine reclamation project requires the identification and resolution of site access and environmental issues and completion of a geologic and hydrogeologic investigation to characterize the subsurface and mine conditions. The degree to which these activities are needed to support the engineering design will vary for each mine site, depending upon whether the sites are abandoned or active. In the case of surface coal mines, contemporaneous reclamation is required under the Surface Mining Law, and the reclamation plan is a required part of the permit granted either by the state or OSM.

5.2 *Geologic and Hydrogeologic Investigation*—The site conditions must be understood. This typically involves a review of mine maps and other available information to aid in understanding the site hydraulic conductivity, ground water flow and recharge, water table, and other pertinent information as determined by a qualified professional.

5.3 *Environmental Resources*—The water supply must be considered in evaluating environmental resources at a specific site. Additionally, many sensitive environmental resources such as wetlands, flood plains, surface water bodies, rare and endangered species, and cultural resource areas are afforded protection by federal, state, and local regulations and ordinances. Appropriate action should be taken to comply with the requirements of the regulatory agencies having jurisdiction at the mine site.

5.4 *Mine Characterization*—Two key components of site characterization for mine reclamation applications are (*1*) identification of the mine configuration and geometry and (*2*) evaluation of mine hydrology.

5.4.1 *Mine Configuration*—Typical surface-mining methods include area mining, contour mining, and mountaintop removal mining. Each of these methods requires specific types of reclamation activities.

5.4.1.1 Area mining is commonly used in flat or moderately rolling terrain. The overburden is excavated, and the mine is expanded horizontally. Topsoil and overburden need to be replaced as the mined area expands. CCPs can be used to augment overburden and/or topsoil.

5.4.1.2 Contour mining is typically used in mountainous terrain. A cut is made into the side of the hill or mountain, and the mine is expanded by further cuts into the mountain and around the perimeter of the mountain. Highwall areas result from the cuts into the mountain, and these are good candidate areas for reclaiming with CCPs. CCPs can also be used in stabilizing the slope of the reclaimed contour mine and in the preparation of the surface for ground cover required to minimize erosion.

5.4.1.3 Mountaintop removal mining is similar to area mining, except that the entire top of a mountain is mined. Topsoil and overburden need to be replaced as the mined area expands. CCPs can be used to augment overburden and/or topsoil.

5.4.2 *Mine Hydrology*—The hydrology of the mine must be understood so that reclamation can be optimized and water quantity and quality protected. The techniques used to characterize mine hydrology are similar to those for a geologic and hydrogeologic investigation.

5.5 *Environmental Monitoring*—Environmental monitoring provides a means of documenting whether the CCPs used in reclamation activities have impacted the site or surrounding area. Baseline monitoring should be conducted during site characterization activities and should include the parameters (metals and non-metals) attributable to CCPs. At a minimum, the monitoring should include the collection of precipitation quantity, mine drainage and surrounding surface water quality and quantity, and ground water elevation and quality. Guides D5851 and D4448 discuss sampling techniques. All water quality samples should be submitted for laboratory analysis of those chemical parameters deemed appropriate to characterize the baseline water quality of the mine and surrounding site. Monitoring should be conducted at the appropriate frequency