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

This standard is issued under the fixed designation E2243; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 for Site Characterization for Engineering Design and Construction Purposes
D422 Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)[3]
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

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.03 on Beneficial Use.

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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.

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 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 Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1883 Test Method for California Bearing Ratio (CBR) 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 (Withdrawn 2017)[3]
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 (Withdrawn 2018)[3]
D4448 Guide for Sampling Ground-Water Monitoring Wells
D4767 Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
D4972 Test Methods 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

[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.

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.

4.2 *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**).