PennDOT RECYCLING MATERIAL FACT SHEET

Coal Combustion By-Products (CCP)

Coal Flyash

Introduction and Background

Coal flyash is produced from burning pulverized coal in a coal-fired boiler. Coal flyash is a fine-grained, lightweight, powdery particulate material that is usually collected from the flue gas by means of electrostatic precipitators, baghouses, or mechanical collection devices such as cyclones(1,5). When pulverized coal is combusted as much as 80 percent or as little as 20 percent of the ash is entrained in the flue gas depending on the type of coal-fired boiler furnace is used, and captured with the afore mentioned particulate collection devices. The captured dry flyash is either pneumatically conveyed to a hopper/storage silo (dry management), or mixed with water, sluiced through a series of pipes to an on-site impoundment (wet management)(1,5).

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The Electric Power Research Institute (EPRI) reported in a 2009 technical update document that coal-fired power plants in the United States produce more than 92 million tons of coal ash per year. About 40% is beneficially used in a variety of applications, and about 60% is managed in storage and disposal sites(5). While the American Coal Ash Association (ACAA) reported in 2007, the United States produced 131 million tons of coal combustion products (CCP). Approximately 43 percent being used beneficially, and nearly 75 million tons disposed of as waste. By using coal ash instead of disposing of it in landfills, environmental degradation and energy costs associated with mining virgin materials are avoided. This beneficial reuse saves taxpayer dollars and reduces environmental impacts. As an example, for every ton of flyash used in place of Portland cement, about a ton of carbon dioxide is prevented from entering the Earth's atmosphere*2).

Among other beneficial reuse applications (see Application section for document links), flyash is used as(1)

- mineral filler in hot mix asphalt paving applications
- in Portland cement concrete (PCC) as a mineral admixture
- as structural fill or embankment material for highway construction projects (Great Britain pioneered the use flyash use as a structural fill or embankment material during the 1950's where it is still bid as an alternate borrow material on roadway fill projects where available.
- component of stabilized base and subbase mixtures, an
- flowable fill (also called controlled low strength material, or CLSM)

This fact sheet provides information on the recycling of flyash including the geotechnical properties, chemical composition, and applications for the Pennsylvania Department of Transportation (PennDOT) use in civil engineering applications. The fact sheet is divided into the following sections:

Material Properties – describes typical Flyash properties
- Geotechnical Engineering properties
- Chemical composition

Applications –
- Selected construction flyash applications
- Descriptions of flyash Highway applications.

Specifications – Present existing PennDOT specifications.
Conclusions – Presents conclusions and discusses implementation issues.

Material Properties

Table 1. Typical range of geotechnical properties[4]	
Property	Flyash
Specific Gravity	2.1 - 2.9
Bulk Density (compacted), lbs/ft^3	65 - 110
Optimum Moisture Content,%	10 - 35
Hydraulic Conductivity, cm/s	10^{-4} - 10^{-6}
Porosity	0.40-0.50
Angle of Internal Friction, degrees	25 - 40
Source: CP-INFOnDatabase. EPRI: August 5, 2009	

Table 2. Normal range of chemical composition for flyash produced from different coal types (expressed as percent by weight)[1]

Component	Bituminous	Subbituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10
Na_2O	0-4	0-2	0-6
K_2O	0-3	0-4	0-4
LOI	0-15	0-3	0-5

Applications :

Table 3. Coal Flyash selected construction-related applications (2011)[3]			
Application	Million Metric Tons	Million Tons	Percent of Total Used
1. Concrete/Concrete Products /Grout	13.05	11.76	66%
2. Blended Cement/ Raw Feed for Clinker	2.25	2.03	11%
3. Flowable Fill	0.15	0.14	0.8%
4. Structural Fills/Embankments	3.62	3.26	18%
5. Road Base/Sub-base	0.13	0.11	1%
6. Soil Modification/Stabilization	0.63	0.57	3%
13. Aggregate	0.01	0.005	0.03%
Approximate Total	19.84	17.87	1.00
Source: after American Coal Ash Association 2011 CCP Production & Use Survey			

Selected construction related applications for Coal Flyash are listed in Table 3 above. Descriptions of Highway applications for Coal Flyash (follow document link below) include[3]:

- *Asphalt Concrete*
- *Portland Cement Concrete*
- *Embankment or Fill*
- *Stabilized Base*
- *Flowable Fill*

Specifications

Currently the Pennsylvania Department of Transportation uses Coal Flyash in highway construction.

- Pennsylvania Department of Transportation Publication 408 2011[6;] (ftp://ftp.dot.state.pa.us/public/bureaus/design/pub408/pub%20408-2011.pdf)
    - Sections: 220, 322, and 724
- Pennsylvania Department of Transportation Standard Special Provisions[7] (http://www.dot14.state.pa.us/ECMS/SVSPPSearch?action=showResults)
- b03221 SECTION 322 - AGGREGATE-LIME-POZZOLAN BASE COURSE (SU)

Unresolved Issues[3]

Asphalt Concrete:

Although most flyash sources satisfy specification requirements (particle size) for asphalt mineral filler, not all flyash has performed satisfactorily in asphalt paving mixtures. The reasons for this are likely related to the fineness of the flyash, chemical composition, and affinity of the asphalt cement used. A better means of classifying flyash for use as mineral filler is needed.

A method for assessing the potential suitability of a given source of flyash as mineral filler in asphalt paving is needed. The loss on ignition (LOI) of flyash, especially flyash with low calcium content, may not be a significant factor affecting its performance as mineral filler. The calcium content, and in particular the free or available lime (CaO) content, of flyash with a high calcium content is believed to be instrumental in its performance as a filler, especially as an aid in the prevention of asphalt stripping. Additional field performance data are needed to draw valid conclusions regarding these factors.

Portland Cement Concrete (PCC):

An improved means of classifying and specifying flyash sources for use as a mineral admixture in PCC is needed. There are considerable laboratory and limited field data that indicate that high percentage (50 to 70 percent) Class F or Class C flyash, in combination with a high range water reducing admixture, produce concrete with exceptional compressive strength. Trial usage of high percentage flyash concrete mixes is needed in order to be able to evaluate the field performance of these mixes. Class F flyash may have cementitious ability when blended with other by-products such as cement kiln dust prior to being introduced into a concrete mix. Additional data are needed on the characteristics and long-term performance of concrete mixes in which a blend of flyash and other cementitious (or pozzolanic) by-products is used.

As a consequence of the Clean Air Act, many coal-fired power plants are being equipped with low NOx burners. The short-term effect of burning coal in a low NOx burner appears to be an increase in the LOI of the flyash. The coal ash industry is developing comparative information on the characteristics and engineering properties of ASTM C618 sources of flyash before and after installation of low NOx burners. Some flyash sources do not have acceptable LOI values once low NOx burners have been installed and put into operation.

Embankment or Fill:

Since coal flyash consists of predominantly silt-sized particles (< 0.075mm, No. 200 US Standard Sieve), there is a concern about frost susceptibility of flyash as an embankment or structural backfill material, especially in northern climates. Normally, earthen materials that are primarily in the silt grain size range are frost susceptible. However, some flyashes are frost susceptible while others are not. More testing of flyashes needs to be done to determine why this is so and to develop a more accurate predictor for frost susceptibility.

Bituminous (pozzolanic) flyash is more frequently used to construct embankments and structural backfills than subbituminous or lignite (self-cementing) flyash. This is due in part to the self-cementing characteristics of the latter type, which hardens almost immediately after the addition of water. Current practice is to lightly condition self-cementing flyashes with water, allow them to stockpile for a period of time, and then run the partially hardened flyash through a primary crusher before taking it to the project site. There is a need to develop more well-defined handling and preconditioning procedures for using self-cementing flyash as a fill material.

Stabilized Base:

Crack control has long been considered by many state transportation agencies as a prime concern associated with the use of pozzolan-stabilized base (PSB) mixtures. Although there have been a number of experimental projects related to joint placement for pozzolanic bases, there is still no universally accepted procedure for minimizing, or even possibly eliminating, shrinkage cracking in such mixtures. Addressing this issue may make possible greater acceptance and use of PSB mixtures by state transportation agencies.

Although the overwhelming majority of the PSB placed over the years has been with Class F flyash, there has been an increasing usage of Class C flyash in PSB mixtures. Because the handling characteristics of Class C flyash are so different from Class F flyash, more specific direction is needed on how to best handle Class C flyash when used as an activator in PSB mixtures. Information needed includes how to evaluate the extent of flash setting, how to select the proper conditioning technique for different degrees of reactivity, and when and how much retarder should be used.

Flowable Fill:

Although there are a wide variety of mix designs for flowable fill, some standardization of mix design methods is needed. The use of concrete admixtures (such as air-entraining agents) in flowable fill mixtures needs further investigation. More data are needed on long-term strength development of various flowable fill mix designs. More experience is needed in the setting time and rate of strength development of low flyash content mixes containing self-cementing flyash.

Conclusions

Coal Flyash, a Coal Combustion By-Products (CCP), has been used in numerous roadway construction projects throughout the U.S. The use of CCP has shown significant costs savings, environmental benefits, and has demonstrated performance comparable to conventional aggregates and earth material.

References: Ref (1) – Ref (5)