Ash Development Association of Australia

USE OF COAL COMBUSTION PRODUCTS AS CONSTRUCTION MATERIAL COMPONENTS

Fly Ash Reference Data Sheet NO. 3
2013

1. INTRODUCTION

Coal Combustion Products (CCPs) are the by-products generated from the combustion of pulverised coal in coal-fired boilers used for power generation. These products include a finer component called fly ash and a coarse component called furnace bottom ash. Furnace bottom ash is collected from the bottom of the combustion chamber whilst fly ash is separated from the flue gas by either electrostatic precipitation or fabric filtration prior to the discharge of the clean flue gas into the atmosphere. Therefore CCPs generally fall into two broad categories.

In Australia, the use of CCPs has increased over time. The most common beneficial use of fly ash is as a Supplementary Cementitious Material (SCM) in blended cement and concrete manufacture [1, 2]. During 2011, approximately 14 million tonnes of CCPs were produced in Australia of which approximately 2 million tonnes of fly ash was used as supplementary cementitious materials in cement based and concrete applications. Another 4 million tonnes was used in various civil and structural applications not specifically addressed in Australian Standards or in State Road Authority Specifications.

This reference data sheet considers the types of CCPs that are currently produced at coal fired power stations and the types of applications where they provide beneficial use opportunities as components of construction materials.

2. COAL COMBUSTION PRODUCTS (CCPS)

2.1 TYPES AND CLASSIFICATION

As indicated, CCPs fall into two broad groups of materials, fly ash and furnace bottom ash.

Fly ash is described in Australian Standard AS 3582.1 [3] as a 'solid material extracted from the flue gases of a boiler fired with pulverized coal'. Whilst typically used as an SCM, this definition also applies to materials not specifically complying with the requirements of AS 3582.1.

Fly ash is composed of mostly silica and aluminium oxide species, being a fine material ranging in size between 1 µm and 300 µm, with a rounded rather than angular shape. Its colour is generally light to mid-grey with an amorphous (glassy and non-crystalline) structure resulting in the material having pozzolanic properties meaning that it will react with calcium hydroxide produced by the reaction of lime or cement and water, to produce additional cementitious or binding compounds. The composition of these particles is not crystalline and is termed amorphous (glass, non-crystalline). These amorphous particles contribute to the fly ash having pozzolanic properties [1, 2].

Furnace bottom ash comprises mainly agglomerated or fused particles that are too large to be carried in the flue gases. These particles instead fall to an ash collection point at the bottom of the furnace. Furnace bottom ashes have a similar chemical composition to fly ash.

There are a number of sub-classifications or grades for fly ash and furnace bottom ash. These are:-

- Fly Ash Grades
  - » Graded (AS 3582.1)
  - » Ungraded or Run of Station
- Furnace Bottom Ash
  - » Graded
  - » Ungraded or Run of Station

The terms 'Graded' and 'Ungraded' are described below:

- Graded - a material that has been processed, selected or classified to meet specific grading and property requirements
- Ungraded - a material that has not been processed/ classified or selected to meet specific grading and property requirements

Ash from each power station will have unique properties that are generally suitable for use as construction material components. Significant quantities of material are available for further processing, blending and application. These materials are available from a number of sources and in the forms described below.

2.2 FLY ASH MATERIAL AVAILABILITY

Ungraded fly ash is separated from flue gasses by electrostatic precipitation or fabric filtration prior to transport to processing facilities or ash storage silos where it becomes available for collection and transport. Ash from each power station will generally exhibit specific characteristics that also makes it useful as a construction material component.

Fly ash that is not immediately required for beneficial use is also routinely transported to dedicated ash storage facilities of different types located adjacent to the power station.

These include:

1. Dry Placement: Ungraded fly ash is conditioned with water and conveyed by truck or conveyor for placement
2. Dense Phase Placement: Ungraded fly ash is mixed with water to create a dense phase materials prior to pumping to a final storage location

Coal fired power stations have traditionally used dense phase placement systems due to simplicity and low operating costs. Stored materials can be recovered for beneficial reuse but properties may need to be re-assessed prior to use.

Graded fly ash, as discussed previously, is extensively used in the manufacture of blended cements and as an SCM in concrete [1, 2]. Australian Standard AS 3582.1 sets out the specification requirements for fine, medium and coarse grade as shown in Table 1 below.

Grade	Fineness % passing 45 µm sieve	Loss on ignition Max %	Moisture content Max %	SO3 content Max %
Fine	75	4.0	1.0	3.0
Medium	65	5.0	1.0	3.0
Coarse	55	6.0	1.0	3.0
Ref. Test Method (AS)	3583.1	3583.3	3583.2	3583.8

Table 1: Fly Ash as defined in AS 3582.1

In addition to the properties listed in Table 1, there are a number of other characteristics relevant to SCM performance including:

- Available alkali content
- Relative density
- Relative water requirement
- Relative strength

2.3 FURNACE (BOTTOM) ASH

Furnace (bottom) ash (FBA) is composed of agglomerated ash particles collected at the base of the furnace or combustion chamber of the power station boiler. Furnace bottom ash can be collected wet or dry, depending on the power station configuration and transferred to dedicated storage locations. This material is often grey to black in colour (although some materials can be white), with angular shaped particles and a porous surface structure. The grain size of furnace bottom ash ranges from fine sand to fine gravel (greater than 5 mm size). Typically, the particle size for FBA is typically 0.1 mm to 30 mm although most commonly less than 20 mm in size [4, 5, 6].

Furnace bottom ash can be collected and processed from the ash repository. The method of collection will depend on the actual beneficial use. Following collection, the required characteristics applicable to the proposed final beneficial use may need to be reconfirmed.

3. APPLICATION OF CCPS

3.1 GENERAL

As previously indicated, fly ash is most commonly used in SCM applications while furnace bottom ash is mainly used in construction applications as fine and course aggregate. Due to the properties and characteristics of these materials, various other applications in other fields have been reported [7, 8, 9, 10, 11].

Some of these include:-

- Oil well cement (for application in the drilling of oil wells where high temperatures prevail)
- Decorative glass
- Ceramic fibres
- Tiles
- Synthetic marble
- Reflective material
- Continuous casting mould powder
- Domestic cleaning powder
- Synthetic wood
- Alumina, magnetite, iron, carbon and cenospheres in mineral extraction
- Glass ceramics
- Foam insulation products
- Anti-corrosion coatings
- Synthetic zeolites
- Agriculture and soil amendment
- Potassium silicate fertilizer
- Manufactured aggregates

Whilst the list of potential applications for CCPs are extensive, the focus of this data sheet relates specifically to construction materials as this area is considered to have the greatest bulk usage potential for such materials. Currently in Australia, other than as cementitious binders in concrete, CCPs have had limited use as construction materials in:-

- Structural fills, aggregates and mine rehabilitation
- Mineral fillers
- Waste stabilization and solidification
- Road and pavement materials

In the following sections, detailed information relating to the following applications is described as these areas present the most potential for significant beneficial use:-

- Road and pavement construction
- Manufactured aggregates
- Filler and grout applications, and
- Structural fills

3.2 ROAD AND PAVEMENT CONSTRUCTION

CCPs are used worldwide in pavement and road construction. For these applications, the ADAA can provide information relating to pavement construction [4] and road stabilisation [12, 13]. Due to the consistent particle size relative to other pavement material components, these products can be used in most pavement layers [4, 13] with some roads and pavement construction applications for each summarised below:-

- Fly ash
  - » Ingredient in soil modification and/or stabilisation
  - » Component in road bases, sub bases, and pavement
  - » Ingredient in waste stabilisation and/or solidification

- Furnace bottom ash
  - » Where settlement of the sub grade is of concern in embankments on soft or poor ground conditions
  - » Aggregate in road bases, sub bases, and pavement

There are a large number of industrial pavement applications requiring sub base and sub grade layers used to support traffic loads within distribution and warehouse type facilities. CCPs can enhance such pavement layers by modifying the structure of such layer blends and also in the case of fly ash, its pozzolanic nature can be used to increase bearing capacity. Importantly, fly ash does not necessarily need to conform to the requirements of AS 3582.1 to be effective in such applications.

In the last few decades, due to increasing traffic loads, roads have required increasing levels of rehabilitation and maintenance, and thus increased cost. Using CCPs not only helps to reduce

maintenance costs through product improvements, but also is environmentally beneficial as the use of CCPs contributes to the conservation of natural resources which would otherwise be used.

3.3 MANUFACTURED (AGGLOMERATED) AGGREGATES

CCPs can also be used as manufactured aggregates or in combination with natural aggregates. Generally, coarser CCPs, specifically furnace bottom ash, are used for this purpose. Due to the particle size of furnace bottom ash, it can be used as a replacement for aggregate and is usually sufficiently well-graded in size to avoid the need for blending with other fine aggregates to meet grading requirements. Furnace bottom ash particles have a porous surface structure and are less dense than conventional natural aggregate. It is generally beneficial to use FBA in base course and shoulder material blends or in cold mix applications for pavement construction. Furnace bottom ash is also potentially beneficial as a lightweight concrete aggregate.

3.4 FILLERS AND GROUTS (INCLUDING STRUCTURAL FILL)

Coal combustion products are used as fillers within slurried material mixes and in grouts. These applications have traditionally had specified graded (fine) fly ash as referenced in AS 3582.1. However in many filler and grout applications it is not necessary to use specially selected material conforming to AS 3582.1 as ungraded fly ash described earlier would be directly applicable and could potentially fit such applications more closely with having the presence of coarser particle fractions.

The incorporation of fly ash improves the fluidity of flowable fill and grouts. Specifically, the shape and particle size distribution of fly ash makes it a good mineral filler, for example in asphaltic concrete applications. The most common applications for CCP based fillers are found in building and road construction. These include:-

- Fly ash
  - » Component of flowable fill
  - » Fill material for structural applications and embankments [5]
  - » Mineral filler in asphalt

- Furnace bottom ash
  - » Fill material for structural applications and embankments [5]
  - » Concrete aggregate
  - » Aggregate for masonry unit manufacture
  - » Improvement of sub grade conditions where settlement is of concern in embankment construction

4. CONCLUSION

Whilst fly ash is extensively used in cement and concrete related applications, this reference data sheet explores many other potential applications for fly ash use in road construction, structural and non-structural fills and as fillers and in grout applications. Furnace bottom ash also has a range of uses in fine and coarse aggregate applications where natural aggregates are used. By utilizing CCPs in such applications, there are dual benefits of being able to provide construction materials having improved quality as well as having a positive influence on sustainability through reduced CO_2 emissions, reduced depletion of natural resources and reduced requirements for disposal and storage of material at power stations.

Fly ash and furnace bottom ash are available as graded or ungraded materials. Material sources across the power station include:-

- Classifiers
- Precipitators
- Ash hoppers
- Interim storage (bins)
- Ash repository (dam)

The Association recommends testing be conducted on each material source to ensure that its properties and characteristics are clearly known.

REFERENCES

1. Ash Development Association of Australia (ADAA), "Guide to the Use of Fly Ash in Concrete in Australia", Fly Ash Reference Data Sheet No. 1, Available from http://www.adaa.asn.au/refdatasheets.htm, August, 2009, 4p.

2. Ash Development Association of Australia (ADAA), "Australian Experience with Fly Ash in Concrete: Applications and Opportunities", Fly Ash Technical Note No. 8, Available from http://www.adaa.asn.au/technicalnotes.htm, November, 2009, 4p.

3. Standards Australia, Australian Standard AS 3582.1, "Supplementary Cementitious Materials for Use With Portland and Blended Cement – Part 1: Fly Ash", ISBN 0 7337 1688 1, SAI Global, 1998.

4. Ash Development Association of Australia (ADAA), "Pavement Construction and the Role of Coal Combustion Products", Technical Note No. 5, Available from http://www.adaa.asn.au/documents/Technical_Notes_5.pdf, 2012, 4p.

5. Ash Development Association of Australia (ADAA), "Structural Fills and the Role of Coal Combustion Products", Technical Note No. 6, Available from http://www.adaa.asn.au/documents/Technical_Notes_6.pdf, 2012, 4p.

6. Cement Concrete and Aggregates Australia, "Use of Recycled Aggregates in Construction", CCAA Technical Report, Available from www.ccaa.com.au, October, 2008, 26p.

7. Demirbas, A., "Potential applications of Renewable Energy Sources, Biomass Combustion Problems in Boiler Power Systems and Combustion Related Environmental Issues", Progress in Energy and Combustion Science, 2005. 31(2): p. 171-192.

8. Demirbas, A., "Potential Applications of Renewable Energy Sources, Biomass Combustion Problems in Boiler Power Systems and Combustion Related Environmental Issues". Fuel and Energy Abstracts, 2005. 46(6): p. 387-388.

9. Murarka, I.P and Erickson, J, "Use of Coal Combustion Products in Mine-Filling Applications: A Review of Available Literature and Case Studies", Final Report Reference DOE Award No: 99-CBRC, American Coal Ash Association, Oct, 2006.

10. Technology Information, Forecasting and Assessment Council (TIFAC), "High Value Added Products and Applications of Flyash", Department of Science and Technology, Government of India, Code No: TMS101, http://www.tifac.org.in, 2009.

11. Nebraska Department of Environmental Quality (NDEQ), "Beneficial Use of Coal Combustion By-Products, Steel Manufacturing By-Products, and Other Similar Materials", NDOE Environmental Guidance Document, 06-212, 2007.

12. Ash Development Association of Australia (ADAA), "Fly Ash Blended Binders for Road Stabilisation", Reference Data Sheet No. 7, Available from http://www.adaa.asn.au/documents/Ref_Data_Sheet_7.pdf, 2005, 2p.

13. Ash Development Association of Australia (ADAA), "Modified and Stabilised Construction Materials Incorporating Coal Combustion Products", Reference Data Sheet No 13.

14. Available from http://www.adaa.asn.au/documents/Ref_Data_Sheet_13.pdf, 2012, 5p.

ASH DEVELOPMENT ASSOCIATION OF AUSTRALIA (ADAA)

PO Box 1194 Wollongong NSW 2500 Australia
Telephone: +612 4228 1389 / Fax: +612 4258 0169
Email: adaa@adaa.asn.au / Web: www.adaa.asn.au