Fly ash Reclamation and Beneficiation using a Triboelectric Belt Separator

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ABSTRACT

Tribo-electrostatic separation has been used for the commercial beneficiation of coal combustion fly ash to produce a low carbon product for use as a cement replacement in concrete for twenty-five years. With 24 separators in 18 coal-fired power plants and cement plants across the world, Separation Technologies' (ST) patented electrostatic separator has been used to produce over 20 million tons of low carbon product that has been recycled for use in concrete or cement production.

To date, commercial tribo-electrostatic beneficiation of fly ash has used primarily dry "fresh" or "production" ash. Reductions in the quantity of dry fly ash generated and requirements to empty historical ash landfills and ponds has created the need to develop a process to reclaim and beneficiate landfilled or ponded ash.

ST has developed and commercialized a new process for beneficiation of reclaimed fly ash from landfills and ponds that utilizes fly ash drying and deagglomeration technology together with the ST tribo-electrostatic carbon separation technology. ST has installed a demonstration of this new process at the Talen Energy Brunner Island power station near York PA. The ST fly ash beneficiation process offers both utility and cementitious materials customers an environmentally friendly, low-carbon emission, fly ash recycling technology which enables cost effective landfill and pond reclamation.

INTRODUCTION

The American Coal Ash Association (ACAA) annual survey of production and use of coal fly ash reports that between 2000 and 2017, over 1.1 billion short tons of fly ash have been produced by coal-fired utility boilers in the United States.[1] Of this amount, approximately 460 million tons have been beneficially used, mostly for cement and concrete production. However, the remaining 640 million tons are primarily found in landfills or filled ponded impoundments. While utilization rates for freshly generated fly ash have increased considerably over recent years, with current rates above 60%, approximately 14 million tons of fly ash continue to be disposed of annually. While utilization rates in Europe have been reported higher than in the US, considerable volumes of fly ash have still been stored in landfills and impoundments in some European countries.

Recently, interest in recovering this disposed material has increased, partially due to the demand for high-quality fly ash for concrete and cement production during a period of reduced production as coal-fired power generation has decreased in Europe and North America. Concerns about the long-term environmental impact of such impoundments are also prompting utilities to find beneficial use applications for this stored ash.

LAND FILLED ASH QUALITY AND REQUIRED BENEFICIATION

Stored fly ash will require some processing to meet quality standards for cement or concrete production. Since the material has been typically wetted to enable handling and compaction while avoiding airborne dust generation, drying and deagglomeration is a necessary requirement. A greater challenge is assuring the chemical composition of the ash meets specifications, most notably the carbon content measured as loss-on-ignition (LOI). As fly ash utilization has increased in the last 20+ years, most "in-spec" ash has been beneficially used, and the off-quality ash disposed. Thus, LOI reduction will be a requirement for utilizing the vast majority of fly ash recoverable from utility impoundments.

LOI REDUCTION BY TRIBOELECTRIC SEPARATION

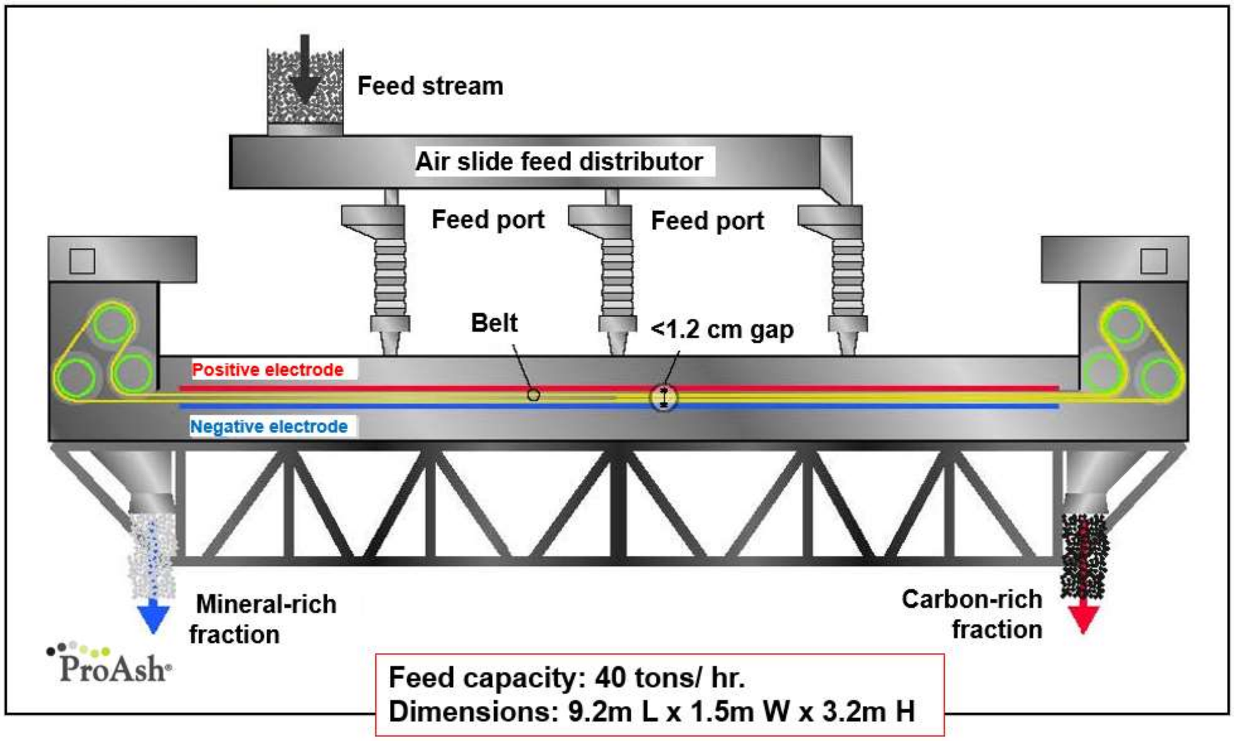
While other researchers have used combustion techniques and flotation processes for LOI reduction of recovered landfilled and ponded fly ash, STET has found that its unique tribo-electrostatic belt separation system, long used for beneficiation of freshly generated fly ash, is also effective on recovered ash after suitable drying and deagglomeration.

STET researchers have tested the tribo-electrostatic separation behavior of dried landfilled ash from several fly ash landfills in the Americas and Europe. This recovered ash separated very similarly to freshly generated ash with one surprising difference: the particle charging was reversed from that of fresh ash with the carbon charging negative in relation to the mineral. [2] Other researchers of electrostatic separation of fly ash carbon have also observed this phenomena.[3,4,5] The polarity of the STET tribo-electrostatic separator can easily be adjusted to allow rejection of negatively charged carbon from dried landfilled fly ash sources. No special modifications to the separator design or controls are necessary to accommodate this phenomena.

TECHNOLOGY OVERVIEW – FLY ASH CARBON SEPARATION

In the STET carbon separator (Figure 1), material is fed into the thin gap between two parallel planar electrodes. The particles are triboelectrically charged by interparticle contact. The positively charged carbon and the negatively charged mineral (in freshly generated ash that has not been wetted and dried) are attracted to opposite electrodes. The particles are then swept up by a continuous moving belt and conveyed in opposite directions. The belt moves the particles adjacent to each electrode toward opposite ends of the separator. The high belt speed also enables very high throughputs, up to 40 tons per hour on a single separator. The small gap, high voltage field, counter current flow, vigorous particle-particle agitation and self-cleaning action of the belt on the electrodes are the critical features of the STET separator. By controlling various process parameters, such as belt speed, feed point, and feed rate, the STET process produces low LOI fly ash at carbon contents of less than 1.5 to 4.5% from feed fly ashes ranging in LOI from 4% to over 25%.

Fig. 1 STET Separator processing dried, landfilled fly ash



The separator design is relatively simple and compact. A machine designed to process 40 tons per hour feed is approximately 30 ft. (9.2 m.) long, 5 ft. (1.5 m.) wide, and 10.5 ft. (3.2 m.) high. The belt and associated rollers are the only moving parts. The electrodes are stationary and composed of an appropriately durable material. The belt is made of non-conductive plastic. The separator's power consumption is about 1 kilowatt-hour per tonne of material processed with most of the power consumed by two motors driving the belt.

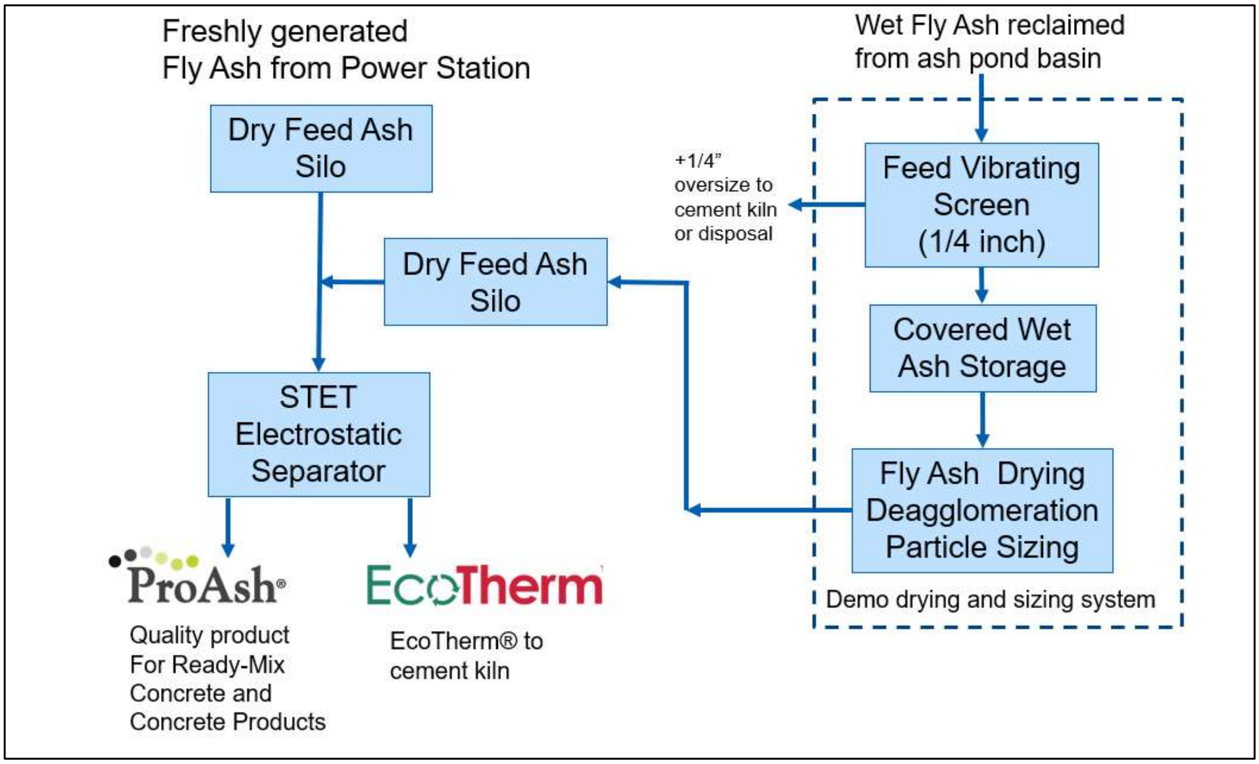
The process is entirely dry, requires no additional materials other than the fly ash and produces no wastewater or air emissions. The recovered materials consist of fly ash reduced in carbon content to levels suitable for use as a pozzolanic admixture in concrete, and a high carbon fraction useful as fuel. Utilization of both product streams provides a 100% solution for fly ash disposal.

DEMONSTRATION OF RECLAIM FLY ASH PROCESS AT BRUNNER ISLAND

The STET reclaim fly ash process has been demonstrated at the Talen Energy Brunner Island power station near York PA USA. ST has operated two tribo-electrostatic carbon separation systems for freshly generated fly ash at Brunner Island since 2006. The host utility has offered use of wet fly ash from their on-site ash basin 6 as a supplemental feed ash source for the ST facility, as the availability of freshly generated fly ash has decreased.

To prepare the samples for carbon separation, the large debris is removed by mechanical dry screening (6 mm) using a mobile screening unit located at Basin 6. The screened material is then loaded into trucks for transport to an ash storage structure. and the material is then transported to the feed hooper of the new process equipment where it is dried and deagglomerated. The dried feed material is stored in a new storage tank prior to conveyance to the existing STET system for carbon separation. Several methods for drying/deagglomeration have been evaluated at the pilot-scale to optimize the overall process. STET has selected an industrially proven, feed processing system that offers simultaneous drying and deagglomeration necessary for effective electrostatic separation. A general process flow sheet is presented in Figure 2.

Figure 2: Process flow sheet



The demonstration-scale system was designed for 5 Tph wet ash feed rate, with dried ash conveyed to the existing STET tribo-electrostatic carbon separation system which operates at 30 Tph. The new equipment was installed in summer 2020 with first load of wet ash processed in November 2020. Since startup, the system has operated reliably generating data necessary for full-scale plant design and equipment selection, and for generating fly ash product performance data necessary for permitting. Average ash quality data are presented in Table 1.

Table1 – ST Brunner Island reclaim fly ash process averages (Dec 2020-June 2021)

	Feed Ash	**ProAsh®**	**Ecotherm®**
Moisture	20.4%	0.15%	
LOI	7.1%	3.3%	25.8%
Dry Mass Yield	100%	84%	16%
+45-micron fineness		24%	
28-day strength activity index (% of control)		86.8%	

For the demonstration plant, propane was used as the drying fuel for convenience. Natural gas will be used as the drying fuel for the full-scale plant. Average specific dryer fuel usage was measured as 1875 BTU/lb. water evaporated (4.33 MJ/kg water evaporated). Full-scale dryer design will improve drying energy efficiency through use of stack gas recycling and reductions in ambient heat loss.

Concrete performance of the ProAsh® produced using feed ash reclaimed from BI basin 6 was compared to ProAsh® produced from freshly generated BI feed ash. Concrete strength development and initial setting time was found to be equivalent for the two sources. Results for concrete batch testing for both air entrained, and non-air entrained mixes are summarized in Table 2. Further testing also confirmed that the

ProAsh® from BI Basin 6 is effective in mitigating the deleterious effects of Alkali-Silica reactions in concrete structures.

Table 2 – Concrete performance for ST Brunner Island ProAsh®

Materials

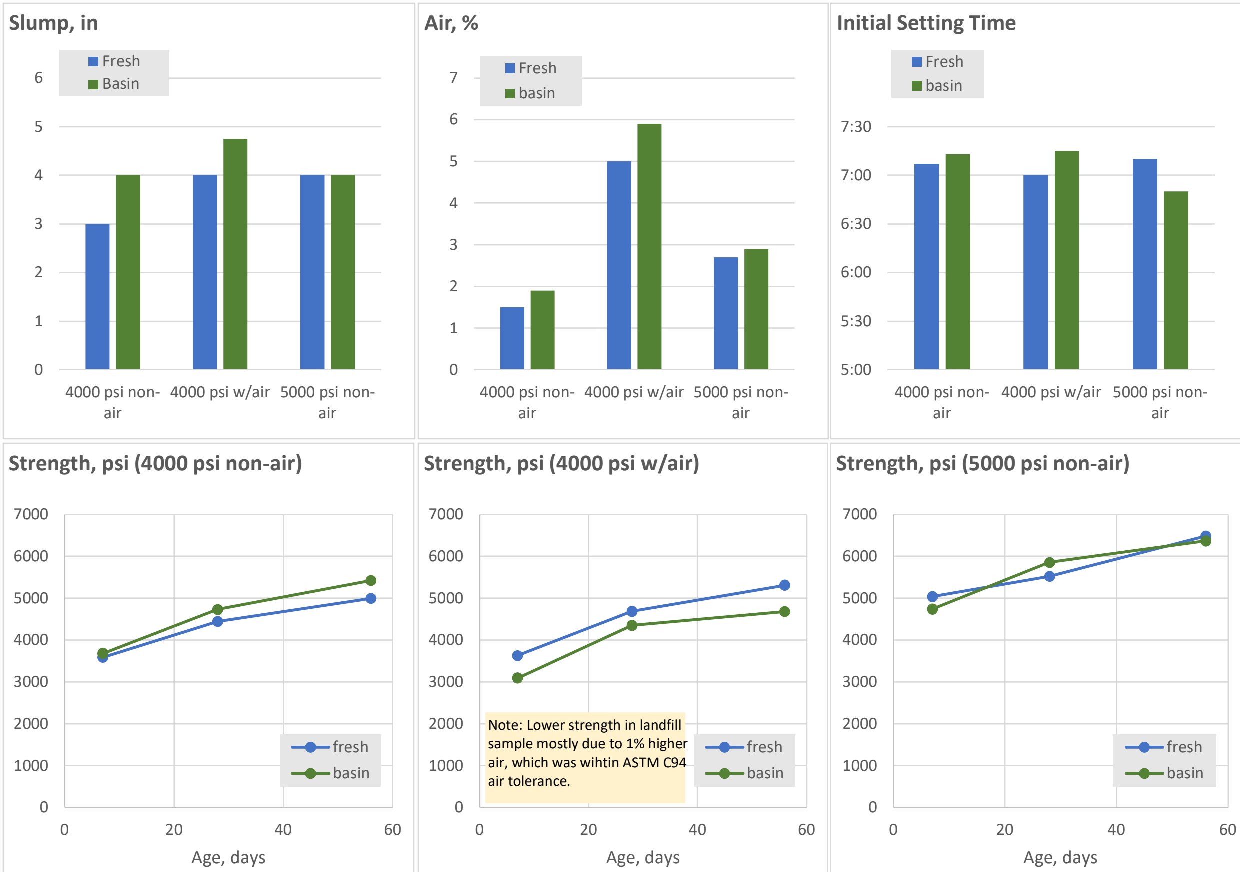
	LOI	Foam Index
	%	
Fresh ProAsh	3.5	0.38
Landfilled ProAsh	3.25	0.54

Mix Designs

		4000 psi non-air	4000 psi w/air	5000 psi non-air
Cement	lb/cy	431	431	488
Fly Ash	lb/cy	144	144	162
Coarse Agg	lb/cy	1800	1800	1800
Fine Agg	lb/cy	1439	1251	1377
Water	lb/cy	309	280	281
Water reducer	oz/cwt	4	4	
HRWR	oz/cwt			4
AEA	oz/cwt	0	0.5	0

Test Results

Mix	Design	ProAsh Type	AEA	w/cm	Conc Temp	Unit Weight	Air	Slump	Initial Setting	Strength 7-day	Strength 28-day	Strength 56-day
			oz/cwt		F	lb/cf	%	in.	hh:mm	psi	psi	psi
1	4000 psi non-air	fresh	0	0.54	63	153.8	1.5	3	7:07	3590	4445	4998
2	4000 psi non-air	landfill	0	0.54	63	150.6	1.9	4	7:13	3684	4732	5426
3	4000 psi w/air	fresh	0.5	0.49	64	147.8	5	4	7:00	3632	4690	5313
4	4000 psi w/air	landfill	0.5	0.49	65	145.8	5.9	4.75	7:15	3095	4354	4682
5	5000 psi non-air	fresh	0	0.43	65	152.6	2.7	4	7:10	5040	5526	6486
6	5000 psi non-air	landfill	0	0.43	64	150.6	2.9	4	6:50	4741	5855	6372



CONCLUSIONS

ST Equipment & Technology (STET) offers a commercially proven processing technology for reducing the carbon (LOI) content of freshly generated dry fly ash. This proven tribo-electrostatic separation device has been used for the commercial beneficiation of coal combustion fly ash to produce a low carbon product for use as a cement replacement in concrete for over twenty-five years. Recent work by STET has demonstrated that this same commercially proven technology is suitable for processing recovered fly ash from ponds and landfills.

The STET reclaim fly ash process for landfilled and ponded fly ash has been demonstrated at the Talen Energy Brunner Island power station near York PA USA. ST has operated two tribo-electrostatic carbon separation systems for freshly generated fly ash at Brunner Island since 2006. The feed ash drying and de-agglomeration demonstration-scale system was installed in summer 2020 with first load of wet ash processed in November 2020. Since startup, the system has operated reliably generating data necessary for full-scale plant design and permitting. Concrete performance of the ProAsh® produced using feed ash reclaimed from BI basin 6 was compared to ProAsh® produced from freshly generated BI feed ash. Concrete strength development and initial setting time was found to be equivalent for the two sources.

The STET separation process with feed pre-processing equipment for drying and deagglomerating landfilled fly ash is an attractive option for ash beneficiation with significantly lower total cost and lower emissions compared to other options, such as fly ash carbon combustion processes.

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