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CHARACTERISTICS AND UTILIZATION OF FLY ASH

Produced by

FAIRBANKS AREA POWER PLANTS

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ABSTRACT

Fly ash produced by four power plants in Fairbanks and vicinity was collected and analyzed. Current fly ash specification and potential users of fly ash in general and in the Fairbanks area in particular were evaluated. A detailed bibliography on utilization of fly ash is appended for reference by producers and potential users of fly ash.

I. INTRODUCTION

Fly ash is a new mineral commodity which is a by-product obtained from burning pulverized coal in a power plant. It has the physical and chemical properties of pozzolan, a siliceous and/or siliceous-aluminous material with no inherent cementing character, but which, in the presence of water, will combine with calcium oxide at ordinary temperatures to form cement compounds. It largely consists of solid or hollow spherical particles of siliceous and aluminous glass, with small amounts of thin-walled, multi-faced polyhedrons of high iron content and irregularly shaped, relatively porous carbon or carbon-coated particles. Other minor components of fly ash include: magnesium oxide, calcium oxide, alkalies, sulfur trioxide, and other elements in minor quantities.

II. SAMPLE COLLECTION AND ANALYSIS

Samples of fly ash were collected from four power plants serving Fairbanks and the general vicinity. All four power plants receive coal from the Nenana coal fields. The four plants are: Golden Valley Electric Association, Mine Mouth Power Plant at Healy; University of Alaska Power Plant; City of Fairbanks, Municipal Utilities Power Plant; and the Fort Wainwright Power Plant. The samples were analyzed for SiO_2 , $\text{Al}_2\text{O}_3\text{Fe}_2\text{O}_3$, Mg O , S O_3 , moisture, loss on ignition and surface area. Table 1 shows the analysis of the four samples.

TABLE I
 ANALYSIS OF FLY ASH PRODUCED
 IN THE
 FAIRBANKS AREA

CONSTITUENT	G.V.E.A.	M.U.S.	U. OF A.	FT. WAINWRIGHT
SiO ₂ %	48.34	39.70	50.42	51.92
Al ₂ O ₃ %	20.44	20.40	21.76	18.36
Fe ₂ O ₃ %	6.00	7.20	6.60	5.20
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ Min%	77.78	67.30	78.78	75.48
MgO	3.68	5.08	2.78	2.66
SO ₃	0.38	1.17	2.24	0.59
Moisture	0.03	0.10	0.14	0.13
Loss on ignition	1.65	5.90	1.23	0.44
Fineness Min. Cm ² /gm	2045	288	671	275

III. FLY ASH SPECIFICATION AND UTILIZATION

Due to the differences in physical and chemical properties of fly ash from different sources, individual specifications have been set up by various organizations. For example, Philadelphia, Chicago, Detroit, New York, and Flint have their own fly ash specifications; and State Highway Departments, the U.S. Bureau of Public Roads, and the U.S. Bureau of Reclamation have their own specifications for fly ash used as construction materials. Other organizations such as the American Society for Testing Materials (ASTM), U.S. Army Engineers, Veteran's Administration, Edison Electric Institute (EEI), and various consulting firms currently are working on new specifications and codes applicable to fly ash.

Alabama, Connecticut, Georgia, and Kentucky have specifications for the use of fly ash in Portland cement concrete used for highway purposes. Illinois, Indiana, Kansas, Maryland, Michigan, New Jersey, North Carolina, and South Carolina have specifications for the use of fly ash as a mineral filler in bituminous mixtures. Virginia and Pennsylvania, since they forbid the use of fly ash, have no specifications. Illinois and Virginia permit the use of fly ash in lime-fly ash-aggregate mixture for soil stabilization of bituminous roads.

ASTM has two committees (C-7 and C-9) dealing with the specifications of fly ash used as pozzolan and as fine aggregate. There are presently seven specifications designated by ASTM.

1. ASTM C311-53T Methods of sampling and testing fly ash for use as an admixture in Portland cement concrete.
2. ASTM C311-61T Tentative methods of sampling and testing fly ash for use as an admixture in Portland cement concrete (Revision of ASTM C311-53T).
3. ASTM C340-55T Specification for Portland-pozzolan cement.
4. ASTM C350-54T Specification for fly ash for use as an admixture in Portland cement concrete.
5. ASTM C350-60T Tentative specification for fly ash for use as an admixture in Portland cement concrete (Revision of ASTM C350-54T).
6. ASTM C379-56T Tentative specification for fly ash for use as Pozzolanic material with lime.
7. ASTM C379-65T Tentative specifications for fly ash for use as pozzolanic material with lime (Revision of ASTM C379-56T).

Most of the specifications mentioned in the above paragraph are for fly ash used in the cement and concrete markets. Fly ash as a pozzolanic additive is required to have a minimum of 40 per cent silica and three per cent magnesium oxide, a maximum of five per cent weight loss on ignition, a two to three per cent maximum moisture content, 0-12 per cent retained on #325 sieve, and a 2800-3000 cm^2/gm Blaine Specific Surface rating. Table 2 lists the important specifications designed by ASTM and the Bureau of Reclamation.

TABLE 2

SPECIFICATIONS FOR FLY ASH AS USED AS AN
ADMIXTURE IN PORTLAND CEMENT CONCRETE

		Specification A	Specification B
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃	(Minimum)	70 %	75 %
Magnesium as MgO	(Maximum)	5 %	5 %
Sulfur Trioxide	(Maximum)	5 %	4 %
Alkalies as Na ₂ O	(Maximum)	1.5 %	2 %
Loss on ignition @ 750° C	(Maximum)	12 %	5 %
Moisture Content @ 105° C	(Maximum)	3 %	Not specified
Mean particle diameter, microns	(Maximum)	9 %	Not specified

SOURCE: Specification - A, ASTM C-350-60T, 1964.

Specification - B, Bureau of Reclamation Specifications

Therefore, if fly ash is to partially replace cement in the major concrete market, it should contain 70 to 75 per cent of combined silica, alumina, and iron oxides in order to meet the fly ash specifications in road paving, structural concrete, and concrete products.

Research efforts on the utilization of fly ash have not as yet developed all of the facts necessary to state the proper specification for fly ash in various markets. Specifications should represent a compromise between the desire of the purchaser for a product that meets his specifications, and the type of fly ash available. This problem has been examined by Snyder: (1, p. 35-1, 38)

"Although it is possible for producers and consumers of fly ash to reach agreement concerning the suitability of a given fly ash for a given use on the basis of present specifications, neither party's interests are fully served by present specifications.

From the viewpoint of the purchaser, there is an unknown degree of risk that a fly ash which meets specifications may not prove to be satisfactory in service.

From the viewpoint of the producers, the specifications may well be more restrictive than is warranted leading to the rejection of fly ash that would have been performed satisfactorily in service—"

IV. POTENTIAL MARKETS FOR FLY ASH IN VARIOUS INDUSTRIES

The following is a comprehensive list of industrial markets for fly ash from current literature, although very few of these are applicable to the Fairbanks area at this time.

1. Mineral Industries
 - a. Iron and steel industry
 - 1) Slag-fly ash aggregate
 - 2) Raw material of iron oxide
 - 3) Mild abrasive in metal polishing
 - 4) Foundry sand
 - 5) Binder in pelletizing iron ore, replacing some bentonite.
 - b. Aluminum Industry
 - 1) Raw materials for alumina
 - 2) Foundry Sand
 - 3) Abrasive for polishing aluminum products
 - c. Refractory Industry
 - 1) Brick
 - 2) Tile
 - 3) Other ceramic products
 - d. Glass Industry
 - 1) Raw material for colored glass and containers
 - 2) Abrasive in glass finishing
 - e. Cement Industry
 - 1) Raw material in cement manufacturing
 - 2) Pozzolanic additive
 - f. Petroleum Industry
 - 1) Pressure grouting
 - 2) Cementing of oil well casings
 - g. Minor metal industry
 - 1) Raw material for Germanium
 - 2) Raw material for Gallium
 - h. Coal Mining
 - 1) Mine dusting, prevention of explosions and fires
 - 2) Neutralizing acidic mine water
 - i. Miscellaneous
 - 1) Heavy media separation agent
 - 2) Mineral fillers
 - 3) Mineral wool
2. Chemical Industry
 - a. Paper Manufacturing
 - 1) Mineral filler
 - 2) Neutralizing acid waste liquids
 - b. Rubber manufacturing
 - 1) Mineral filler
 - c. Plastics and paints
 - 1) Mineral filler
 - d. Others
 - 1) Filtration agent
 - 2) Neutralizing agent

3. Construction Industry
 - a. Concrete for road paving and mass concrete projects (dams and bridges)
 - b. Concrete blocks
 - c. Concrete pipe, tile and other concrete products
 - d. Bituminous concrete
 - e. Soil stabilization
 - f. Fly ash-lime aggregate
 - g. Fly ash-slag aggregate
 - h. Fly ash lightweight aggregate
 - i. Grout
 - j. Filler in wall board, putty, and roofing materials
 - k. Land fill
4. Agriculture
 - a. Fertilizer
 - b. Filler
 - c. Insecticides
 - d. Trace element source

V. MARKETABILITY OF FLY ASH

Many research efforts have demonstrated that fly ash has a wide variety of applications in the various industries. Fly ash has qualified as a raw material, additive, substitute or for other form of utilization in the construction, iron and steel, aluminum, ceramic and chemical industries, and in agriculture. The major reasons for using fly ash in the above fields are the diversified nature of by-product ash, and low cost of ash which will eventually make it marketable.

The advantages of fly ash thus can be evaluated by both technological performance and economic rewards from fly ash products.

1. Fly ash is a by-product. There is no mining or quarrying required.
2. The particle size of fly ash is fine enough to eliminate crushing or grinding in mineral preparation.

3. Due to its pozzolanic property, fly ash can be widely used as a raw material in cement manufacture.
4. The wide range of composition of fly ash extends its uses in the metallic, ceramics and chemical industries as raw materials.
5. The unburnt carbon of fly ash could serve as "built-in" fuel and save cost in the manufacture of fly ash aggregates, bricks or tiles.
6. Fly ash may improve final products, giving such qualities as higher strength, lower porosity, stronger edges and corners in concrete blocks, less cracking, and resistance to salt and sulphate waters in grouting.
7. The fly ash markets are generally close to power plants since both are located in populated areas.
8. The high alkali characteristics of fly ash can be utilized as a low-cost neutralizing agent.
9. Some high silica fly ash may be used in mild abrasives, foundry sands and in glass manufacture.
10. The combined percentage of silica, alumina and iron oxide in fly ash is so high as to make it useful as a mineral filler, filtration agents, etc.
11. Fly ash is readily available in quantity.

V. FLY ASH PRODUCTION AND UTILIZATION IN THE FAIRBANKS AREA

The demand for electric power in Fairbanks has been growing steadily at the rate of about six per cent a year since the 1950's. At present, all the electricity in the area of study is supplied by coal-firing plants. There are four institutions supplying energy in the region, namely, Golden Valley Electric Association, (GVEA), Ft. Wainwright (military), Fairbanks Municipal Utility System (M.U.S.), and the University of Alaska. Table 3 shows the capacity of electric

power generation of each installment, type of fuel, location of power plant and approximate distance to the city center of Fairbanks.

TABLE 3

CHARACTERISTICS OF POWER PLANTS ANALYZED

Capacity (kw)	G.V.E.A. 22,000	M.U.S. 8,500	MILITARY 27,000	U. of A. 1,500
Mineral/Fuel	Coal, Mine Mouth	Coal	Coal	Coal
Location	Healy	Fairbanks	Ft. Wainwright	College
Distance to City Center	100	within	less than 10	less than 10

The production of fly ash is a function of the quantity and ash content of the coal burned, and the efficiency of ash collection. The recovery of fly ash is dependent upon the type of coal burner, the variation in burning process and the type of ash collection system, whether mechanical or electrical. Table 4 shows the estimated fly ash production per year of four power plants under study, the method of ash collection, relative efficiency in recovery of fly ash and ash disposal method and experience in utilization of each power plant.

TABLE 4

FLY ASH PRODUCTION AND COLLECTION SYSTEMS

	G.V.E.A.	M.U.S.	MILITARY	U. of A.
Fly Ash Prod. approx. (Estimated in short tons per year.)	10,000	2,200	650(?)	1,000
Type of Combustion System	pulverized fuel	stoker	stoker	stoker
Relative Recovery	average	low	low	low
Ash Collection System	mechanical	mechanical	mechanical (most bottom ash)	mechanical
Ash Disposal	wet	wet	truck	dump
Utilization	no	no	some inland fill	some inland fill and road maintenance

A very limited amount of fly ash is being used in the Fairbanks area for land or structural fill and road maintenance. The potential uses of fly ash, particularly for the fly ash produced by the G.V.E.A. Mine mouth power plant would be:

1. Concrete mixes
2. Soil stabilization
3. Highway construction
4. Structural fill
5. Mass concrete project (airport, dam and port facilities)
6. Grouting or well-casing cement.

As an ingredient in concrete mixes, fly ash can be used in amounts from 100-150 pounds per cubic yard of concrete. Ready-mixed concrete, concrete blocks, prestressed and precast concrete, mass concrete projects and highway construction and maintenance represent many attractive fields open to the utilization of fly ash.

Soil stabilization alone could probably absorb the major part of raw fly ash. A mile of road base may utilize about 500 tons of fly ash and in general highway construction, about 600 tons of fly ash could be put into the paving of each mile of single lane highway. Therefore, a two-lane highway for 100 miles could absorb about 220,000 tons of ash.

Fly ash is used in oil well casing cement in the lower states; its possible application to the Alaskan market is obvious.

Alaska imports over 20,000 tons of cement a year. If 20 per cent of cement is substituted by specified fly ash, it would mean a market for 4,000 tons of fly ash.

Other potential markets in the field of winter road stabilization and control of thawing streams in spring time, could only be evaluated by further research.

TABLE 5

PRODUCTION AND CONSUMPTION OF FLY ASH IN THE U. S.

	1966	1967	1968
Production (tons) fly ash	17,123,144	18,409,854	19,813,747
bottom ash	8,065,683	9,131,453	7,259,212
boiler slag	-----	-----	2,554,569
Total	25,188,827	27,541,307	29,627,528
Total Ash	3,050,669	3,794,714	5,194,016
Consumption (tons) fly ash	7.9%	8.2%	9.6%
% utilization bottom ash	27.0%	25.0%	25.0%
boiler slag	-----	-----	57.8
Total consumption to production	12.0	13.8	17.5

Source: National Coal Association

VII. SUMMARY AND CONCLUSIONS

Fly ash from four coal-firing power stations in the Fairbanks vicinity was investigated during the study. The power plants under study range from 1,500 kilowatts to 22,000 kilowatts, and consume more than 650,000 tons of coal annually.

The preliminary investigations showed that the compositions of fly ash collected from each of the plants, although they do not meet ASTM specifications, other potential uses of this fly ash are promising.

Total production of fly ash in the Fairbanks area is estimated at more than 13,000 tons per year. So far, very limited amounts of fly ash are utilized in the area; are for land or structural fill and a very little in road maintenance. However, there are many potential uses for fly ash such as ready-mix concrete, mass concrete projects, road construction and grouting.

Since fly ash is a by-product from coal firing power stations, the future of fly ash is closely tied to the continued use of coal as an energy source in power generation. The threat of competition from fuel oil or natural gas has been greater since the development of the North Slope oil fields.

Utilization of fly ash is determined by many factors such as quality and specifications, the effort devoted to market development, and sales promotion. In the immediate future, if any market develops in Fairbanks, it will be concentrated in the construction and industry.

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