ABOUT FLY ASH AND OTHER RESIDUES FROM BURNING COAL

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

This report has been prepared for the benefit of those persons involved in highway construction who are not familiar with coal ash terminology. The information presented will, it is hoped, assist them in avoiding confusion relating to the general characteristics and potential uses of the various types and classes of ash.

The report covers, very briefly, some of the definitions applicable to the ash from coal burned in electric-generating plants. Major differences between "high lime" (Class C) and "low lime" (Class F) fly ash, and the need to distinguish between the two types in conducting research or experimental construction with these materials, are discussed. A broad review of potential uses of the types of ash for highway construction is given with references to papers in each area.

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INTRODUCTION

There is renewed interest in the use of the ash from coal-burning power plants in highway construction and maintenance because of the increasing use of coal by the utilities. Because of earlier interest in the 1950s and 1960s, there is considerable literature concerning the merits of such ash in various applications. In particular, fly ash has been shown to be useful in fills, embankments, and soil stabilization, and as an ingredient in portland cement concrete, usually as a replacement for part of the cement. Recent reports by Texas and some western states have shown the usefulness of fly ash in stabilization projects and even for filling potholes. However, for this latter work the material used is a "high lime" or Class C fly ash that is quite different from the "low lime" or Class F fly ash used in earlier research in Virginia and that is now available on the East Coast. Consequently, in considering the potential uses of fly ash it is extremely important that one be aware that at least two different classes of fly ash are involved and that all the reported benefits do not apply for both classes. In addition, all fly ashes, even if of the same class, do not have the same properties. Bottom ashes are also useable for some purposes, and while they are similar to fly ash in their elemental chemical composition, their physical properties and the manner in which their chemical elements are combined are quite different.

For those not completely familiar with the technology, the following brief review of definitions and major areas of potential use should be helpful.

DEFINITIONS

The residue from burning coal at a power plant is termed either bottom ash which is further classified as "dry" or "wet", or fly ash.

Dry Bottom Ash

Dry bottom ash is the residue from coal burned in dry-bottom boilers. It generally is a well-graded aggregate ranging in size between the 3/4 in. (19 mm) and the standard U. S. No. 200 sieve. It is characterized as being porous and susceptible to degradation under compaction and loading. Its specific gravity ranges between 2.10 and 2.40. The major chemical constituents are silica (SiO_2), ferric oxide (Fe_2O_3), and alumina (Al_2O_3). The percentage of each elemental oxide in a given ash will depend on the source of the coal burned.

Wet Bottom Ash

Wet bottom ash is produced when the molten residue in a wet-bottom boiler is discharged into a water-filled hopper. It is smaller in maximum size than dry bottom ash and the particles are glassy and very hard and brittle. The specific gravity is usually around 2.7, but can be higher with high iron contents (Fe_2O_3). The elemental oxides present are generally the same as those in dry bottom ash, but the amount of each will vary depending upon the source of the coal.

A good summary of the potential for use of these materials for highway construction and maintenance is found in several reports prepared for the Federal Highway Administration. These are summarized in reference 1.

Fly Ash

Fly ash is the material collected in the precipitators that remove particulate matter from the exhaust gases of power plants to reduce air pollution. It is generally finer than portland cement and consists mostly of small spheres of glassy compounds of complex combinations of silica, ferric oxide, and alumina.

Most of the earlier literature (1950-75) recognized that the composition of fly ashes varied with the source of coal, but essentially all the available materials were from the burning of bituminous coal. Fly ash of this type has no self-hardening or setting properties but has pozzolanic properties. This means that in the presence of water the fly ash particles react with calcium hydroxide (lime) to form cementitious products. The cementitious products so formed are chemically very similar to those present in hydrated portland cement. Such reactions occur slowly at normal atmospheric temperatures.

Fly ashes resulting from the burning of subbituminous coals and lignite such as are found in some of the midwestern states may have some pozzolanic properties but they also are self-hardening. That is, when mixed with water they can harden by hydration much the same way portland cement hardens. In most cases the initial hardening occurs very rapidly. This type fly ash has become available in large quantities in the United States only in the last few years as the western coal fields have been opened.

CHEMICAL DIFFERENCES

The chief difference in the way the fly ashes from the two types of coal react is attributable to the amount of calcium present and the manner in which it is combined with other elements. The total calcium, expressed as calcium oxide (CaO), has been reported to range between 1% and 12% in ashes from bituminous coals. The median value would probably be in the 5% to 8% range. No general statement as to how the calcium is combined in these materials can be made. For some ashes a substantial amount of the calcium can be shown to be present as calcium sulfate (gypsum), calcium hydroxide (hydrated lime), and calcium oxide (free lime), but in others most of the calcium is combined with silica and alumina as part of the glassy components.

In contrast to the 5% to 8% median range for CaO in fly ashes from bituminous coal, the usual range in the fly ash from subbituminous coal and lignite is from 25% to 30%, but may be as high as 41% or as low as 10%. Very little of this calcium is actually present as CaO (free lime). It is combined with silica and/or alumina to form the cementitious compounds that hydrate and harden when water is added.

Because of the general differences in the amount of calcium expressed as CaO, the fly ash from bituminous coal is often referred to as a "low lime" fly ash and that from subbituminous coal or lignite as a "high lime" material. However, it is important to keep in mind that there are significant differences in how the calcium is combined. One cannot simply add more lime ($Ca(OH)_2$ or CaO) to a low-lime fly ash and obtain the same properties provided by a high-lime fly ash of the same calcium oxide content.

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FLY ASH SPECIFICATIONS

Various states establish their own specifications for fly ash based on their own needs and, to some extent, on the characteristics of the materials available to them. However, most of these are similar to the ASTM specifications, which are generally considered the standards. The ASTM has two specifications relating to fly ash. One, ASTM C618, recognizes fly ash as a class of pozzolan for use as a mineral admixture in portland cement concrete and the other, C593, applies to fly ash and other pozzolans for use with lime. Specification C618 identifies two classes of fly ash: Class F and Class C. Class F is the "low lime" material derived from bituminous (or anthracite) coal as previously discussed, and Class C is the high lime material derived from subbituminous coal or lignite. The classification does not depend solely on the source of the burned material. The ash must also meet specific requirements for composition, fineness, and pozzolanic activity. Specification C593 is primarily used for materials suitable for soil stabilization with lime. No distinction is made in this specification on the basis of the type of coal burned. Generally speaking, C618 is a more stringent specification than C593. It should be kept in mind that materials from different sources, even though of the same class, may have significantly different characteristics and would behave differently in combinations with other materials. Thus, each source needs to be tested for suitability for a specific application.

POTENTIAL USES

Considerable literature is available concerning potential uses of bottom ash and fly ash in highway construction and maintenance. Accordingly, no attempt will be made in this short presentation to identify these in any detail. However, some of the broad potential fields of application are noted below. In each case a valuable lead-in reference is listed for those desiring further information. These lead-in references include further references of interest in each field and generally cite both advantages and disadvantages in using ash. Anyone interested in a detailed study of the literature concerning coal ash should obtain copies of the proceedings of the five symposia listed under references 1-5.

1. Black base and bituminous surfaces — Some bottom ashes can be used as portions of the aggregates in this type construction. However, their usefulness will vary depending upon their characteristics; for example, whether they are derived from wet or dry

bottom furnaces. The presence of pyrites and sulfates is highly detrimental, and ashes containing appreciable amounts of these constituents should be avoided. (See reference 6.)

2. Asphaltic concretes — Fly ash can be successfully used as a filler in areas where the usually desired types of materials are not available. Handling problems and relative transportation costs appear to be the limiting factors in the use of fly ash for this purpose. (See reference 7.)

3. Stabilized bases, subbases, embankments, fills — Fly ash mixed with cement and/or lime is used in a number of ways for these applications. Reference 8 summarizes the techniques involved in six related applications. Fly ashes complying with ASTM C593 would normally be specified for these uses, and they could be from bituminous coal or from subbituminous coal or lignite.

   The presence or absence of self-hardening properties in the fly ash would have an important effect on the proportioning of materials and design of the projects. Some techniques using self-hardening materials (Class C) are entirely unsuitable when using ash with pozzolanic properties only (Class F). In early experimental projects in Virginia to show the feasibility of fly ash and lime stabilization, Class F fly ashes were used. (See reference 8.)

4. Portland cement concrete — Fly ash is used as an admixture in portland cement concrete or as an ingredient in blended cement used in lieu of portland cement. Although Class C materials have been used to a limited extent for this purpose, Class F materials from bituminous coal are normally used, and most research and experimental construction with fly ash concrete utilizes this type of fly ash. Usually, when used as an admixture a portion of the portland cement is replaced by the fly ash. (See reference 9.)

AVAILABILITY IN VIRGINIA

Several companies market fly ash in Virginia for use as a pozzolan. The ash is from bituminous coals and generally conforms to ASTM C618, Class F. Such fly ash is kept dry at the power plant and is not combined with the bottom ash. No Class C or high lime materials with significant self-hardening properties are now commercially available in Virginia.

It is understood that increased interest is being shown by VEPCO and perhaps others in finding markets for fly ash heretofore disposed of in settlement basins or stockpiled in combination with bottom ash. Such materials may be uneconomical and difficult to use because they are likely to show wide variations in the relative amounts of fly ash and bottom ash, and they are extremely difficult to dry. Consequently, experimental construction with these materials should be approached with caution. Most power companies interested in marketing their ash residues will use dry methods of removal and storage and will keep the fly ash and bottom ash separated.

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