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JOINT HIGHWAY RESEARCH PROJECT

Executive Summary

FHWA/IN/JHRP-90/6

THE PHYSICAL DURABILITY AND ELECTRICAL RESISTIVITY OF INDIANA BOTTOM ASH

Te-Chih Ke

PURDUE UNIVERSITY

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To: H. L. Michael, Director
Joint Highway Research Project

April 26, 1990

Project: C-36-50J

From: C. W. Lovell and J. E. Lovell
Joint Highway Research Project

File: 6-19-10

Attached is the Final Report of the JHRP project entitled "The Physical Durability and Electrical Resistivity of Indiana Bottom Ash". The report was prepared by Mr. Te-Chih Ke, Graduate Research Assistant, under our direction.

The results of the study will be useful in determining the durability and corrosiveness of bottom ashes used as a highway construction material. The suggested testing methods and evaluation criteria are included. A total of four Indiana bottom ashes were selected, sampled, and tested. To increase the data base for evaluation, additional tests were conducted on the other 7 ashes sampled earlier. The comparison of the test results and the established evaluation criteria shows that Indiana bottom ashes are durable but may be corrosive.

The report is submitted for review, comment and acceptance in fulfillment of the referenced study.

Respectfully submitted,

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THE PHYSICAL DURABILITY AND ELECTRICAL RESISTIVITY OF INDIANA BOTTOM ASH

by

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16. Abstract

This research assessed the long-term performance (durability) and the environmental effect (corrosiveness to adjacent metal structures) of Indiana bottom ashes, based mainly on laboratory investigation. The 5-cycle sodium sulfate soundness tests and the 50-cycle freeze-thaw tests were conducted to examine the physical durability. Four electrochemical characteristics (electrical resistivity, pH, soluble chloride, and soluble sulfate) were used to estimate the corrosion potential of Indiana bottom ashes.

Evaluation criteria for durability and corrosiveness of bottom ash, based on appropriate specifications for aggregates and past experiences for soils, were developed. The comparison of test results and the above criteria shows that Indiana bottom ashes are durable but may be corrosive. The bottom ashes with a high corrosion potential should not be utilized in highway construction where metal structures are involved.

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Introduction

A decreasing supply of natural high-quality aggregates has motivated the search for innovative materials. On the other hand, every year a huge quantity of industrial by-products is produced. Disposal of these by-products is costly and may cause an environmental hazard. If the utilization of industrial by-products as a construction material is feasible, it not only solves a potential solid waste disposal problem but also provides an economic alternative construction material. In this study, bottom ash - one kind of coal ash - is the material of interest.

However, prior to extensive utilization, chemical and physical properties and mechanical behavior of bottom ash should be investigated to meet the existing requirements of commonly used aggregates. In the past, much of the available research has focused on the properties of fly ash - another kind of coal ash. This is understandable because fly ash represents approximately two-thirds of the total ash production, and is applied largely to soil stabilization and cement replacement in concrete.

In 1972, Seals et al. [1], based on their study of the general properties, chemical composition, and mechanical behavior of West Virginia bottom ashes, proposed that bottom ash could be an engineering material used in fill and pavement construction. Recently, Huang and Lovell [2] extended the study of bottom ash to include environmental aspects. Based on the testing results from Indiana bottom ashes, they concluded that bottom ash has mechanical behavior comparable to natural sands; is nonhazardous; and has minimal effects on the quality of ground water. These extensive studies truly reveal that bottom ash will be an excellent alternative construction material. However, they did not comprehensively cover the topics of physical durability and corrosiveness of bottom ash, which influence the long-term performance of both itself and any adjacent metal structures.

Durability is one of the most substantial properties of a material, and is the ability to retain an initial state when subjected to the conditions of the service environment. A lack of durability of bottom ash would produce deterioration with time, and would thus prevent any large scale utilization. Corrosiveness is the property of a medium to cause corrosion of an enclosed or adjacent metal structure. If bottom ashes are used as backfills for reinforced earth structures or backfills adjacent to other metal structures, potential corrosion caused by interactions among bottom ashes, metal structures, and the environment is of concern. Those bottom ashes having a high corrosion potential tend to damage the adjacent metal structures. The main goal of this study was to provide simple testing procedures to assess the durability and corrosiveness of bottom ash.

Experimental Program

Four candidate bottom ashes from three utility stations of Indiana were selected to be examined, based on the recently completed work of Huang [3]. They are Perry K ash, Gibson ash, Schahfer 14 ash, and Schahfer 17 ash. The dominant criterion for this selection was the separate storage of bottom ash from fly ash in the ash pond of the power plants. Among four candidate ashes, Schahfer 14 ash is the only wet bottom ash.

In most power plants, bottom ash is transported to a disposal lagoon as a slurry flowing through closed conduits. The closed ash transport and handling systems are seldom equipped with sampling ports at convenient locations. In such cases, bottom ashes had to be collected as grab specimens from ash deposits at the outlet of sluice pipes. The sampling of four candidate bottom ashes was made in the spring of 1989. At the time of sampling, determinations of resistivity and pH were also conducted, except for the Perry K ash. The field resistivities of these ashes measured were all greater than 4000 Ohm-cm.

The experimental program of this study consisted essentially of a laboratory investigation aimed at testing bottom ash samples by standard as well as nonstandard methods. Frost action is prevalent in the northern U.S., including Indiana, where the freeze and thaw process is the most dominant environmental agent causing deterioration of a material. Due to limited time and funding, it was not possible to conduct durability testing in actual service environments. Instead, the freeze and thaw test based on AASHTO T103 [4] and the sodium sulfate soundness test based on ASTM C88 [5] were chosen to predict the durability of candidate bottom ashes. Both of these tests determine a weighted loss, which is regarded as a durability indicator. Normally, the larger the weighted loss, the less durable the material.

Through a literature review of underground corrosion, those material parameters best related to corrosiveness were determined to be minimum resistivity, pH, soluble chloride, and soluble sulfate. Generally, the higher the soluble contents of chloride and sulfate and the lower the minimum resistivity and pH, the more corrosive the material. These four electrochemical characteristics, basically determined by California Test methods [6,7,8], were used to estimate the corrosiveness of bottom ash. Since they are not standard methods, a sensitivity study of California Test methods was also performed.

In addition, to increase the data base for evaluation, tests were conducted on the other 7 ashes sampled earlier by Huang [3]. Therefore, in total, 11 Indiana bottom ashes were examined in this study.

Testing Results

The major particles of the only wet bottom ash, the Schahfer 14 ash, had a smooth surface (non-porous) texture, were hard, and looked much like crushed glass. On the other hand, the dry bottom ashes had quite angular particles and a highly porous texture. In particular, the Perry K ash particles, produced in stoker furnaces, had a popcorn-like surface texture and were very friable.

In determining the durability of the four bottom ashes, it was found that both the 5-cycle sodium sulfate soundness test and the 50-cycle freeze-thaw test yielded comparable weighted losses. This implies that either test is satisfactory to predict the durability of bottom ash. Accordingly, only 5-cycle sodium sulfate soundness tests were performed on the additional 7 bottom ashes. Among 11 bottom ashes examined, the weighted losses varied from 1.25 to 8.12, and the Schahfer 14 ash had the lowest weighted loss (1.25).

The analysis of soluble salts showed that, among four candidate bottom ashes, the Gibson ash had the highest soluble sulfate content (greater than 1000 ppm); the Perry K had the highest soluble chloride content (52 ppm); and the Schahfer 14 ash had the lowest soluble contents of both chloride and sulfate.

In determining the minimum resistivity and pH values, some of the recommended testing procedures were modified. California Test 532 requires that only the ash aggregates finer than the No. 8 sieve be used in the test. Thus, it does not take into account the contribution of coarser aggregates to the measured values. Therefore, it is strongly suggested that the total ash samples be crushed into the pieces finer than the No.8 sieve, and then be used in the test. Thus the measured values (minimum resistivity and pH) obtained are more representative of the total ash. Among 11 bottom ashes examined, the minimum resistivities ranged from

6660+ to 980 Ohm-cm, and the pH values varied between 4.8 and 9.6. The Schahfer 14 ash had the highest minimum resistivity and pH values. Combining this with the lower soluble salts contents of the Schahfer 14 ash, wet bottom ash appeared to be less corrosive than dry bottom ash.

With an comparison of these four corrosiveness parameters of Indiana bottom ashes and those of the soils used by Reinforced Earth Company [9], it was found that Indiana bottom ashes have a lower minimum resistivity and a higher soluble sulfate content, but a similar pH and soluble chloride content. This indicates that Indiana bottom ashes are statistically more corrosive and may be unsatisfactory for use as backfills for reinforced earth structures.

Evaluation Criteria and Results

The evaluation criteria for the durability of bottom ash were established, mainly based on the ASTM and the AASHTO standard specifications for aggregates. The allowable maximum weighted loss in the established criteria depends upon the application, and upon the particle size of bottom ash. The most rigorous requirement is a maximum weighted loss of 10% for a fine aggregate to be used in concrete. Since the total 11 Indiana bottom ashes examined have weighted losses less than 10%, they are predicted to be very durable in a freeze-thaw service environment. If they also meet the requirements of strength and gradation for different applications, they can be extensively utilized in embankments, backfills, and pavements.

On the basis of the past experiences with soils in underground corrosion, evaluation criteria for the corrosiveness of bottom ash were established. The noncorrosive requirements are a minimum 'minimum resistivity' of 1500 Ohm-cm, a minimum pH of 5.5, a maximum soluble chloride content of 200 ppm, and a maximum soluble sulfate content of 1000 ppm. Comparing these criteria with the testing results of the 11 Indiana bottom ashes, 7 ashes were classified as being corrosive. This high percentage indicates that Indiana bottom ashes must be carefully examined if they are used in construction where metal structures are nearby.

Conclusions

Current disposal practices indicate that bottom ash is still considered by many power-generating companies as a waste material. However, with the decrease in high quality natural mineral aggregates and an improved understanding of bottom ash, one is encouraged to view bottom ash as a useful engineering material, rather than as burdensome waste.

Based on the results of laboratory evaluations of selected Indiana bottom ashes, it is concluded that Indiana bottom ashes are durable, but may be corrosive. The combination of the durable nature of Indiana bottom ashes with the other favorite properties reported by Huang [3] reveals Indiana bottom ashes to be suitable for various highway uses. However, those ashes, which are classified as being corrosive by the methods in this study, should not be placed in the near vicinity of metal structures unless field investigations have revealed them to be acceptable.

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