BIAS OF AIR VOID SYSTEM DATA FROM FLY ASH CONCRETES

by

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Research Petrographer

(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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BACKGROUND

Fly ash is a by-product from the combustion of coal. It is the fused ash particles and unburned granules of coal that can be collected from the stack of a coal-burning electric generating plant. It "consists for the large part of solid or hollow spherical particles of siliceous and aluminous glass...called cenospheres."* Small amounts of multifaced polyhedrons of glass and irregularly shaped coal or carbon coated particles are usually present. The amounts of the various particle types vary with the source of the coal, the temperature in the furnace, and the length of the firing time.

This report deals only with the hollow cenospheres whose walls are so thin that when they appear transected on a polished slab of concrete they are indistinguishable from transected air void spheres. Such cenospheres are lighter than water, colorless, and between 10 μm and 500 μm in size. Only such particles will be mistaken for air voids by an alert linear traverse operator. If they occur in sufficient quantities, and they are counted as air voids in a linear traverse analysis, the parameters determined for the air void system would be biased towards a high specific surface and percentage of air voids, and a small spacing factor. Thus, it has been thought that what might really be a marginal or unsatisfactory air void system could, with sufficient cenospheres of appropriate shell structure and size, be mistakenly determined to be a completely satisfactory system. The study reported here was undertaken to ascertain the seriousness and complexity of this problem.

PROCEDURES

Eleven specimens of fly ash from ten electric generating plants were obtained and examined. Each specimen was examined for color and

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*ABDUN-NUR, E. A., "Fly Ash in Concrete," Highway Research Board Bulletin No. 284, Washington, D. C., 1961.

the relative quantity of colorless floating cenospheres. The six lightest colored specimens were also the ones with the most floating cenospheres. These six were examined semiquantitatively.

It was found that fly ash segregates in the dry state when stored in a bag or can. The light cenospheres work their way to the top of the container under vibrations during transport and are slower in settling than the other constituents after mixing with air. One such specimen of fly ash from the top of a container was examined semiquantitatively for cenospheres.

The amount of cenospheres was determined by floatation from 100g of fly ash in distilled water in a separatory funnel. The best separation was achieved by mixing the fly ash and water, allowing the mixture to soak for two hours to loosen adhering particles from the fly ash, and adding the mixture to the funnel in small increments. Heavier-than-water portions were drawn off by stopcock before new increments were added. After the last increment, all utensils and the sides of the funnel were washed down and the floating portion was flushed onto a filter paper to be dried and weighed. After weighing, the cenospheres were sieved and examined for size, color, and wall thickness.

RESULTS

In all cases, except for the segregated specimen, the floating cenospheres were less than 1% by weight of the fly ash, and generally were 0.3% or less. The mean size was estimated at 0.003 inch.

There is no inexpensive way to determine the specific gravity of solids that float on water. Because of the height at which these cenospheres floated, it was estimated that the mean specific gravity was probably about 0.7. One percent of the fly ash calculated to approximately 0.1% by volume of the concrete.

It can be seen that the apparent increase in the volume of air voids and the apparent increase in specific surface are within acceptable limits of error, if the diameter of the individual particles of fly ash average about .075 mm (.003 in.). The decrease calculated for the spacing factor of air voids was only .005 mm (0.0002 in.) and need only be considered where the spacing factor is close to the acceptable size for the class of concrete under study.

In addition, it was found that some fly ashes which did have particles that floated did not necessarily have many clear cenospheres that could be mistaken for air voids. The surfaces were sometimes dark, or had dark spots, and sometimes the shell was frothy and thick and would not look like an air void wall when in cement paste.

The cenosphere-rich portion of the specimen which had segregated during shipping and storage was found to contain 3.3% cenospheres by weight. If it is assumed that this is the upper limit of the amount of cenospheres apt to occur in fly ash with present processing procedures, then it can be assumed that 0.4% by volume of cenospheres in the concrete is the maximum amount likely to occur. Such an amount may result in a determination of 0.4% excess air, an increase of 50 in the specific surface, and a possible decrease of 0.025 mm (0.001 in.) in the spacing factor.

Thus, the presence of even relatively large amounts of cenospheres need be considered during the interpretation of linear traverse data only in marginal cases.

SUGGESTED PRECAUTIONS

1. The operator of the linear traverse equipment should be aware of the appearance of fly ash and alert to avoid counting as air voids those transected fly ash cenospheres that are thick walled, dark colored, or frothy in appearance.

2. In cases where the air void parameters are barely within the specification and fly ash cenospheres are present, small allowances should be made for the bias caused by the fly ash.

3. If it is suggested that the particular concrete specimen is exceedingly rich in cenospheres which appear to be air voids, the lapped specimen of concrete can, after the air voids determination has been completed, be etched in a 0.3 N solution of HCl for about 10 seconds to etch away the paste and reveal the glass shells of the cenospheres in relief.

   A second determination by linear traverse can then be made to count and measure only those fly ash cenospheres that could have been mistaken for air voids.

   The raw data on the cenospheres is subtracted from the total raw data before the air void parameters are calculated.

This procedure is necessary only when the air void data are marginally within specification and it is suspected that clear, confusing cenospheres occur on the traverse line more frequently than one for every 50 mm (2 in.) of traverse.