Field Experience with Alkali-Aggregate Reaction in Concrete: Eastern United States

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● THIS paper covers the failure of concrete pavements and bridges in the Eastern United States due to a chemical reaction between alkali (Na_2O and K_2O) in the cement and soluble silica in the aggregate. The reaction, customarily known as the alkali-aggregate reaction, promotes excessive expansion and cracking of concrete. In itself, the cracking is more disfiguring than dangerous, but it does permit ready access of water to the interior of the concrete mass. Then the failure of the concrete by freezing and thawing, or by wetting and drying, may be greatly accelerated.

As early as 1930, concern was expressed over the number of concrete pavements and bridges in some of the southeastern states which showed expansion and multiple cracking. Several independent studies of the problem were made, but these were directed mainly toward the influence of magnesia in the cement on the soundness of the concrete. The reason for this association had been furnished by the performance of concrete pavement on the Travelers Rest Road in South Carolina. Within two years after this pavement was laid, excessive expansion and a well-defined crazing of the concrete built with one brand of cement was found. Analyses of the cement showed the magnesia content to be high, as much as 8 or 9 percent being found in some tests. As three other brands of cement had been used in this pavement with satisfactory results, and these cements contained low to moderate amounts of magnesia, it was believed that the magnesia content of cement was definitely associated with the durability of the concrete.

Figure 1. Cracking of concrete pavement in Georgia.

In 1934, the Bureau of Public Roads, with the assistance of the interested state highway departments, began an extensive study of the durability of concrete pavements and associated structures in the Southeastern States. Although only 8 percent of the 1,077 miles of concrete pavement inspected showed distress, many pronounced failures were found (see Figure 1). In the summary of the data collected, it was found that the failure of concrete was associated with the brand of cement used, or the combination of cement and aggregate. Efforts were made to determine whether the chemical analysis of the cement could furnish information as to the reason for the distress of the concrete. No complete analyses could be found. Usually, determinations were made for magnesia, sulfur trioxide, and loss on ignition, and occasionally for silica, lime, alumina, and iron oxide. No connection between these chemical determinations and the failure of the concrete was found other than that for the one plant which furnished cement with a high magnesia content.

When Stanton published his report of the effect of alkali in cement, analyses for alkali content were made of cement from all mills which furnished cement used in the

Figure 2. Failure of concrete on US 1 in Dumfries, Virginia.

concrete studied. It was found that the brands of cement which were associated with failure of concrete invariably had an alkali content of over 0.6 percent. Those used to prepare concrete in which little or no failure occurred had alkali contents of less than 0.5 percent.

Identification by source of all aggregates used was not entirely successful because in many cases a word was used to designate the aggregate and this word could denote either the name of a producer or the name of a town near several sources of aggregate produced by different companies. However, it soon became apparent that quartz gravels produced near the geographical center of Alabama were more definitely associated with distress of concrete than gravels from any other source. Concrete prepared with crushed stone showed little distress except when used with a high-magnesia cement. Blast furnace slag had the poorest record of all coarse aggregates; inasmuch as slag was usually used with high-alkali cements, the concrete prepared with these materials had the greatest possibilities of failure.

Reduction of the alkali content of the cement used in the Southeastern States has caused a great increase in the durability of concrete. It is now possible to state that the concrete placed during the last 10 years is of comparable quality with that in any other section of the country.

During the last few years, some concern has been given to reported failures of concrete prepared with low-alkali cement. In 1955 a survey was made of major bridge structures in Georgia which had been prepared with reactive aggregate and low-alkali cement. All of these bridges were six to seven years old, and it was expected that the concrete, if subject to an alkali-aggregate reaction, would show evidence of this. Although some portions of different bridges did show some faint pattern cracking, in no case could the cracking be stated to identify concrete subject to the alkali-aggregate reaction.

During this survey, failure of a bridge in Toccoa, Georgia, due to the alkali-aggregate reaction was observed. The aggregate was gravel from the Savannah River. Previously this aggregate had been considered nonreactive. In this bridge, high-slump concrete was used to permit its transportation in pipes for a considerable distance. It is believed that the alkali-aggregate reaction was promoted not only by the high-alkali cement but also by the wetness of the concrete.

Other than the failures of concrete in the highways, principally in Alabama, Georgia, and South Carolina, which are interrelated by use of similar cements and aggregates, no extensive failure of concrete in the Eastern States due to the alkali-aggregate reaction is known. Several individual structures might be mentioned, such as the Tuscaloosa Lock in Alabama, and the Buck hydroelectric plant in Virginia. The concrete in the Tuscaloosa Lock was reported (1) to have failed due to a chemical reaction between alkalies in the cement and chalcedonic chert aggregate. The Buck plant (2) was built in 1912 of concrete prepared with crushed phyllite (intermediate between slate and schist) and, presumably, a high-alkali cement. It is interesting that the report states the concrete was poured wet according to common practice at the time of construction.

In 1934, the pattern and behavior of cracking of concrete on US 1 in Dumfries, Va., was found to resemble closely that of failed concrete pavement in Alabama and Georgia.

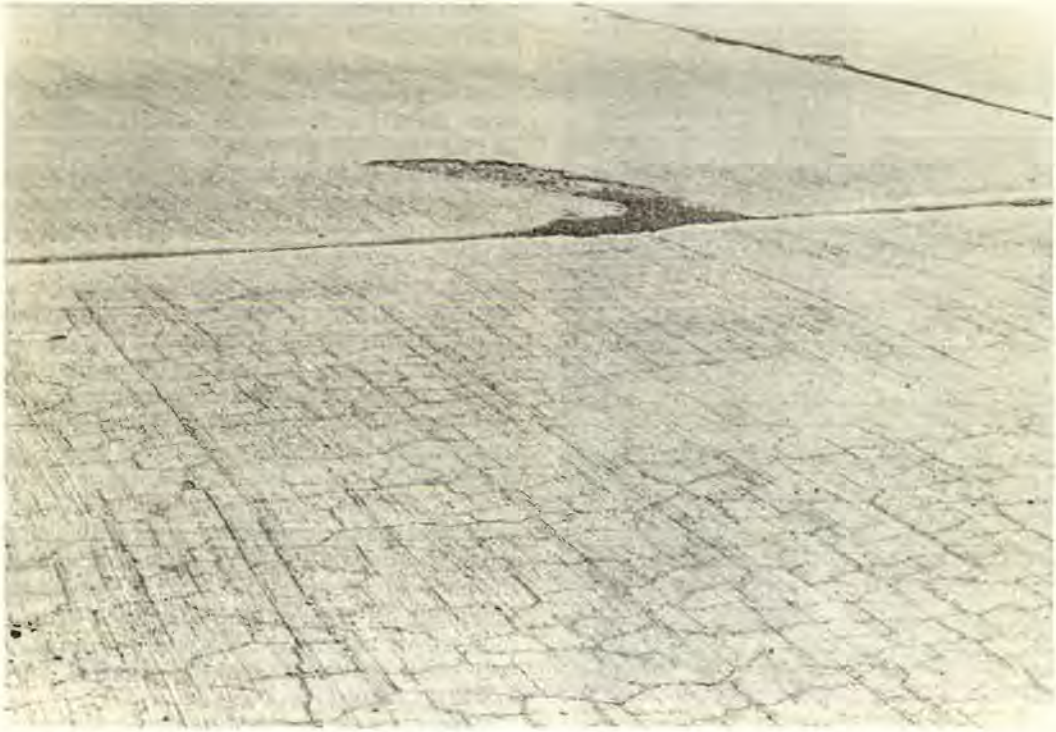

Figure 3. Failure due to alkali-aggregate reaction, Pentagon network.

This is shown in Figure 2. No samples of the concrete were obtained for examination, but it is believed that this concrete was subject to the alkali-aggregate reaction.

In 1957 cores were drilled from a badly cracked section (Figure 3) on the road network surrounding the Pentagon in Arlington, Va. The cores showed large amounts of gel present in the concrete, and it can be stated that the concrete failed due to the alkali-aggregate reaction. Although records fail to show the sources of the materials used, examination of the concrete showed the aggregate to be Potomac River gravel. The cement probably was from one of the mills in the vicinity of Washington, D.C., all of which produced cement with a fairly high alkali content. This is the first known instance of the positive identification of gel in concrete prepared with Potomac River gravel.

No other examples of the alkali-aggregate reaction are known in the Eastern States. In New Jersey many miles of concrete pavement built with dolomite coarse aggregate, quartz sand, and Lehigh Valley cements have developed a pattern of cracking similar to that in Alabama. Although many test specimens taken from this concrete have been examined, no positive evidence has been found that the alkali-aggregate reaction is involved. On Long Island, multiple cracking and great volume change have been found in concrete pavement containing local quartz sand and gravel. No studies of cores or samples from this concrete are known. It is believed, however, that this concrete would be much more liable to have been affected by the alkali-aggregate reaction than the dolomite concrete in New Jersey.

All along the Atlantic seaboard are many deposits of aggregate which are potentially reactive with the alkali in cement. It is possible that many occurrences of distress due to the alkali-aggregate reaction have not yet been identified. However, in many instances the concrete may be badly cracked but is still providing an adequate road surface for thousands of vehicles per day. It is suggested that ability to carry the imposed load without excessive repairs is far more important than the maintenance of an uncracked surface.

REFERENCES

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