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

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●THE sixteen states considered in the Central United States are Arkansas, Colorado, Illinois, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Wisconsin and Wyoming. A questionnaire prepared and sent out to the states by the Highway Research Board Committee on Durability of Concrete—Chemical Aspects in 1953, revealed the following: Four states did not reply; eight states replied that they had no alkali reaction in concrete; two replied that possibly they may have alkali-reactive aggregates; and two replied that they did have alkali-aggregate reaction or cement-aggregate reaction in concrete. Therefore, these remarks are confined to the aggregate problem in the states of Iowa, Kansas, Missouri, and Nebraska, with emphasis on Kansas and Nebraska inasmuch as they replied that they had such a problem.

Probably the Kimball, Nebraska, aggregate is best known in this area for producing severe cracking, expansion, and loss in strength when used in concrete construction. This aggregate has been used in three concrete paving projects and one concrete railroad overpass in Kimball. The three paving projects had developed severe cracking and expansion, and the railroad overpass had visible cracking at five years of age. The records indicate at least three different brands of cement were used in the Kimball projects; however, no records seem to be available regarding the alkali contents of these cements.

In a study of special concrete problems in Kansas, Nebraska, Iowa, and Missouri, carried out as a cooperative project between the Portland Cement Association and Kansas State College, the Kimball aggregate was studied. In this study Kimball aggregate was used to mold a 24- by 24- by 6- in. concrete specimen using a low-alkali cement (0.55 percent Na_2O equivalent) for natural outside weathering. This specimen containing Kimball aggregate and low-alkali cement has severe cracking after fourteen years of natural outside weathering.

Aggregate from the Platte River in Nebraska has been used extensively in concrete pavements and structures in Nebraska. This aggregate has also been used in Iowa, Missouri, and Kansas. The service record of Platte River aggregate in concrete has varied from moderate cracking to severe cracking in the four-state area.

Aggregate from the Republican River in Kansas and Nebraska has produced severe cracking, expansion, and loss of strength when used as a single total aggregate in concrete. Concrete pavements and structure containing Republican River aggregate have been constructed in the Republican River watershed from Junction City, to St. Francis, Kansas. This aggregate has produced more severe cracking, expansion, loss of strength, and deterioration when used in concrete than any other aggregate in the state of Kansas to date. In this respect, it ranks next to the Kimball aggregate.

The bridge across the Republican River at St. Francis was constructed from aggregate adjacent to the bridge site. In a few years the bridge floor had expanded until it closed the expansion joints, crushed the bridge floor, and tore loose some of the steel diaphragm connectors between the steel girders. The concrete piers and pier caps cracked so badly that a repair job was necessary. The repairs to this bridge consisted of cutting and chipping the cracked, disintegrated concrete from the piers and pier caps and then guniting. The expansion joint and the bridge floor adjacent to the expansion joint was cut out and replaced. This bridge was constructed with no shear connectors between the bridge floor and the steel girders: to measure the expansion of the concrete relative to the steel girders it was necessary to find a point where a form tie wire had scratched the paint along the top of the steel girder. The bridge, constructed in 1936, showed the concrete expansion relative to that of the steel girders was over 0.22 percent by 1946.

The city of St. Francis, Kansas, built a water pumping plant using Republican River

aggregate in the concrete foundation for the engines. In approximately three years after the engine foundations had been placed, the concrete cracked, expanded, and warped until the engines were pushed out of line, causing damage to the engines. The original unreinforced foundations were taken out and replaced with reinforced concrete.

The railroad overpass at Almena, Kansas, was built with local aggregate from a dry pit near that town. The concrete pier caps on this structure cracked and deteriorated until it was necessary for the Kansas State Highway Commission to make repairs.

The Republican River aggregate has produced severe cracking in the concrete of the bridges across the Republican River at Scandia, Concordia, and Clay Center, Kansas. This aggregate, when used as a single aggregate in concrete construction with cements having an alkali content of less than 0.60 percent, has produced severe cracking, loss of strength, and warping where the concrete is exposed to outside natural wetting and drying. Republican River aggregate used as a single aggregate in construction of concrete culverts has not produced cracking or deterioration in the barrels of the culverts. Severe cracking occurs in the wingwalls and handrails of bridges and culverts in which this aggregate has been used. This condition also exists with Platte River, Kaw River, and Arkansas River aggregates, and with a number of aggregates from dry pits in this area. The only place where these reactive aggregates have produced severe cracking, loss of strength, and deterioration in concrete has been in that portion of the pavement or structure subjected to wetting and drying. The author has never seen this type of severe cracking in concrete pipe installed underground when the pipe was constructed with the aggregates from this area that have produced serious cracking in concrete pavements.

The Kaw River aggregate has produced severe cracking, expansion, and loss of strength when used in concrete construction from Junction City to Kansas City, Kansas, and the Arkansas River aggregate has a similar service record from Great Bend to Arkansas City, Kansas.

The State Highway Commission of Kansas was aware of this problem more than 25 years ago, and by field service records and laboratory wetting and drying tests has separated the servicable aggregates from the unservicable ones. Full-scale field projects, laboratory pilot projects, and laboratory specimens of concrete containing cements with less than 0.60 percent Na_2O equivalent have been built. After seven years of natural weathering, the concrete has severe cracking and loss of strength. Therefore, it appears that a specification limiting the alkali content of cements in this area to 0.60 percent Na_2O equivalent would not be a guarantee to stop this type of cracking. These results have led to the general conclusion that the expansive reaction with these aggregates differs from that for the aggregates on the West Coast and have led to the use of the term cement-aggregate reaction rather than alkali-aggregate. Kansas experience has been that use of the two present ASTM procedures, C 227-52 T and C 289-54T, did not enable separation of the servicable aggregates from the unservicable aggregates.

The most economical and satisfactory method the Kansas State Highway Commission has found to stop this severe map cracking and loss of strength with these reactive aggregates is the addition of 30 percent durable, absorptive crushed limestone having a maximum size of 1 in. and a minimum size of No. 4 mesh.

A number of full-scale projects, pilot projects, and laboratory specimens in which the concrete aggregate consisted of 70 to 75 percent reactive aggregates and 25 to 30 percent crushed limestone by weight have been built. After 17 to 20 years the concrete has good strength (600 psi modulus of rupture), no map cracking, and a change in length of 0.025 per expansion.

The Supplemental Specification 45-256 prepared in 1946 is now incorporated in the Kansas Highway Commission Standard Specifications for State Road and Bridge Construction, Addition 1955, and appears under Section 93 of the 1955 Kansas Standard Specifications. It stipulates the requirements and test procedure covering the aggregates that have produced reactivity in concrete.