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Although the articles in MATES are usually generated from within the Materials and Technology Division, we are not reluctant to step outside for something that we feel to be particularly pertinent. The NCHRP Synthesis 134, "D-Cracking of Concrete Pavements," is an important compilation of information on this subject. We could see no way that the summary of the information in the above report that appeared in CONCRETE CONSTRUCTION could be improved upon, and are pleased to offer it to our readers. This article is reprinted, with permission, from the September 1988 issue of CONCRETE CONSTRUCTION magazine.

D-CRACKING PAVEMENTS

Causes Are Understood But Treatment Choices Are Few

Concrete pavement D-cracking is a terminal condition. Once it starts, there's no known cure. The cause is known — coarse aggregates susceptible to freezing and thawing deterioration. But the only way to prevent D-cracking is to avoid using these aggregates in concrete pavements. Even that isn't as simple as it sounds. How do you identify susceptible aggregates? And what do you do when the only economically available aggregates in the area cause D-cracking?

Some of the answers are in a just-published report from the National Cooperative Highway Research Program. It explores the causes and potential ways of avoiding or treating D-cracking distress.

Causes and Symptoms

Aggregates that cause D-cracking absorb moisture from the pavement base and from surface water entering through cracks and joints. If aggregate pores are full when freezing occurs, internal pore pressure cracks the particles causing the mortar to crack as well. More cracks develop with repeated freezing and thawing cycles.

The cracks usually begin in the lower portion of the slab and move upward, but they may also start at the top or in the interior. They always start along cracks, joints, or free edges.

Eventually a pattern of cracks forms at the pavement wearing surface. This pattern appears as a series of closely spaced fine cracks. These cracks are generally adjacent and parallel to joints and cracks and to the free edges of the pavement slab. Black, blue, white, and gray deposits of calcium carbonate and dirt often fill the cracks.

Because D-cracks usually start at the bottom and progress upward, the bottom of the slab may be badly deteriorated before cracks appear on the pavement surface. Taking full-depth cores from the area of joints and cracks is the only way to detect the first stages of D-cracking.

Factors Influencing D-Cracking Development

Coarse aggregates that cause D-cracking are nearly always sedimentary materials: limestone, dolomite, shale, sandstone, and graywacke. But not all sedimentary aggregates cause the problem. Aggregates with low permeability, high porosity, and small pore size are most likely to cause D-cracking.

D-cracking usually doesn't occur in concrete that dries periodically because drying prevents aggregate saturation. Continuous moisture availability is needed. Bridge decks

don't develop D-cracking because the underside dries and aggregates don't become saturated.

In general, terrain features have little bearing on degree of pavement saturation. It makes little difference whether the pavement is on a tangent, at or above existing grade, on the crest of a hill, in a low area, under a bridge, or in an open area.

Frequent freezing and thawing cycles are most harmful. The D-cracking problem isn't as prevalent in very cold regions where fewer freeze-thaw cycles occur.

Several factors have little influence on D-cracking: fine aggregate properties, type and amount of cement, pavement design, and traffic. Surprisingly, a positive underdrain system isn't sufficient to prevent D-cracking from developing. It can only postpone it.

Identifying Susceptible Aggregates

Field service records of aggregates from established quarries help highway agencies predict aggregate performance. For unproven aggregate sources, identifying poor performers requires testing the aggregate, either in concrete or by itself.

Some tests simulate the service environment for concrete containing the questionable aggregate. Freezing and thawing tests are most commonly used. Changes in specimen weight, length, or modulus of elasticity are used to predict field performance. These tests are the most reliable method for identifying problem aggregates, but they are expensive and time consuming. One test may last 6 months or more.

Tests on the aggregates alone are used to measure aggregate properties that correlate well with field performance. Tests that predict performance best measure properties related to pore size, continuity, and volume.

An absorption-adsorption test developed by the Portland Cement Association identifies sound and unsound aggregates but is too restrictive. It identifies some aggregates with satisfactory service records as being potentially nondurable. The test can be helpful, however, when used with the more reliable freezing and thawing tests. It can serve as an early warning of changes in absorption-adsorption characteristics for aggregate from an approved source. The source could then be reevaluated on the basis of freezing and thawing tests. Other tests in use include the Iowa pore index test and a mercury porosimeter test that determines pore size and volume.

Aggregate tests are quicker to run but less reliable than freezing and thawing tests on concrete containing the aggregate. They are better suited for preliminary screening tests.

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Making Poor Aggregates Better

If aggregate from a given source causes D-cracking, is there any way to upgrade the aggregate? Three techniques are being used today:

- Coarse aggregate particle size reduction
- Heavy media separation of harmful particles
- Blending harmful aggregates with more durable aggregates

Any one of these may improve some aggregates, but have no effect on others.

Size reduction is the most promising approach. Reducing the maximum size from 1-1/2 inches to 1 inch or 1/2 inch can significantly improve freezing and thawing resistance of some materials. For gravels this can be done three ways:

- Screening and discarding oversize material
- Screening and crushing the oversize, then blending it back in
- Screening and crushing the oversize to produce a separate coarse aggregate composed only of crushed particles

The second option involves the least waste, but in some cases crushed particles aren't as durable as uncrushed particles. Tests may be needed to confirm which option produces the most durable aggregate. For crushed stone material there's only one option: further crushing material to a smaller maximum size.

Heavy media separation methods use heavy liquids to float off materials with low specific gravities. Because specific gravity doesn't always correlate well with D-cracking susceptibility, this method isn't as reliable as size reduction.

Blending poor-performing aggregate with a more durable aggregate is the least desirable upgrading method. Marginal aggregates may benefit from the technique, but for poor aggregates, blending probably only postpones distress.

Preventing or Minimizing D-Cracking

To avoid using D-cracking-susceptible aggregates, some states take a source acceptance approach. Acceptance criteria include performance histories and results of extensive testing. Besides approving general source locations,

highway agencies may even identify specific acceptable ledges within a source for crushed stone.

Using locally available aggregate costs less, so attempts are made to improve marginal sources by size reduction methods. An across-the-board maximum size reduction may be too restrictive, unnecessarily increasing production costs. The best approach is testing a range of maximum sizes from each source. This determines the largest acceptable maximum size from each source.

Little can be done to minimize damage if D-cracking-susceptible aggregates are used. Slowing the rate of deterioration is the best that can be hoped for. Increasing sand content of the concrete and blending durable with nondurable aggregates dilutes the harmful material. Installing a positive drainage system can also help reduce the rate of deterioration when marginal aggregates are used. Longitudinal pipe underdrains do this well.

Further Research Needed

More information is needed on maintaining and rehabilitating D-cracked pavements. Needed information includes the following:

- Procedures to slow the rate of D-cracking and extend pavement service life
- Procedures for evaluating the pavement structural condition and extent of distress
- Guidelines for deciding whether to repair or rebuild
- Procedures for choosing the best rehabilitation method for a specific project

Procedures that permit custom designing pavement rehabilitation on a project-by-project basis are most likely to yield maximum returns on repair dollars invested.

Acknowledgment

This information was taken from "D-Cracking of Concrete Pavements," prepared by Donald Schwartz as NCHRP Synthesis 134. A copy of the report is available for \$7.60 from the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

TECHADVISORIES

The brief information items that follow here are intended to aid MDOT technologists by advising or clarifying, for them, current technical developments, changes or other activities that may affect their technical duties or responsibilities.

SPECIFICATION UPDATE

Steel Chain Link Fence, 6.21(1), dated 7-18-88. This specification updates the requirements for chain link fence.

Plastic Drum Alternates for Type II Barricades, 6.31(8e), dated 8-4-88. The approved plastic drums have been deleted from the specifications and added to the Materials Sampling Guide under Prequalified Materials.

Determination of Concrete Pavement Thickness Placed Over Open-Graded Aggregate, 4.50(11b), dated 8-5-88. This revision expanded the specification to require that this particular method of measurement be used on all open-graded aggregate, rather than just open-graded drainage course.

Schedule of Liquidated Damages, 1.08(3), dated 8-17-88. This revision was required in order to be in compliance

with a new FHWA regulation which requires each state highway agency (SHA) to keep liquidated damage provisions current so that the amounts recovered through contractor assessments would, at a minimum, cover the SHA's average daily construction engineering costs attributable to the contract time overrun.

Guard Rail Anchorage, Cable-Departing End, 6.13(4b), dated 8-23-88. The words "Guard Rail" were removed from the pay item for Thrie Beam Anchorage, Cable-Departing End. This change makes the pay item read the same as shown on Standard Plan III-58J.

Filler Walls for Bridge Pins, 5.03(11c), dated 8-25-88. Dowel bars with expansion caps have been deleted from the specification. They are replaced with expansion anchored bolts in accordance with the approved Special Detail 5, dated 7-19-88.

This document is disseminated as an element of MDOT's technical transfer program. It is intended primarily as a means for timely transfer of technical information to those MDOT technologists engaged in transportation design, construction, maintenance, operation, and program development. Suggestions or questions from district or central office technologists concerning MATES subjects are invited and should be directed to M&T's Technology Transfer Unit.

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