



# MATES

## MATERIALS AND TECHNOLOGY ENGINEERING AND SCIENCE

Published by the Materials and Technology Division of the Michigan Department of Transportation

Issue No. 7

May 1987

### D-CRACKING OF CONCRETE PAVEMENTS

One of the most serious problems encountered, in Michigan, in the performance of concrete pavements is that of so-called 'D-cracking.' Although it has been experienced since the 1930's when concrete pavements first came into general use, there is little agreement on the term's origin or the meaning of the 'D' which variously denotes 'distress, discoloration, or deterioration,' or the shape of the pieces that break off from the pavement.

**What is it?** - D-cracking in a concrete slab is a progressive structural deterioration of the concrete beginning in certain types of susceptible coarse aggregate, caused by repeated freezing and thawing after absorbing moisture. The problem, which is more significant in larger sized particles, starts well out of sight at the base of the slab near the joints. Generally, it takes several years to progress upward to the top of the slab where it first becomes visible as a series of small cracks, often preceded and accompanied by dark discoloration of the concrete surface. D-cracking usually is not detected in the early stages except by core drilling. Figure 1 shows the cross-section of a drilled core exhibiting initial stages of D-cracking at its base.

**Where is it generally found?** - D-cracking is generally found initially at longitudinal and transverse joint intersections and later at transverse cracks. Figure 2 shows D-cracking at a joint intersection and at a transverse joint. The deterioration starts in the corners and progresses along the joints with transverse joints usually exhibiting the most rapid damage.

**How does it start and progress?** - D-cracking is initiated by moisture, usually at the bottom of a slab, where contact with the base inhibits drying. It is accentuated by cracks and joints providing paths for water to the base and by the presence of poor drainage. The moisture penetrates the tiny pores in the particles of certain types of coarse aggregate.

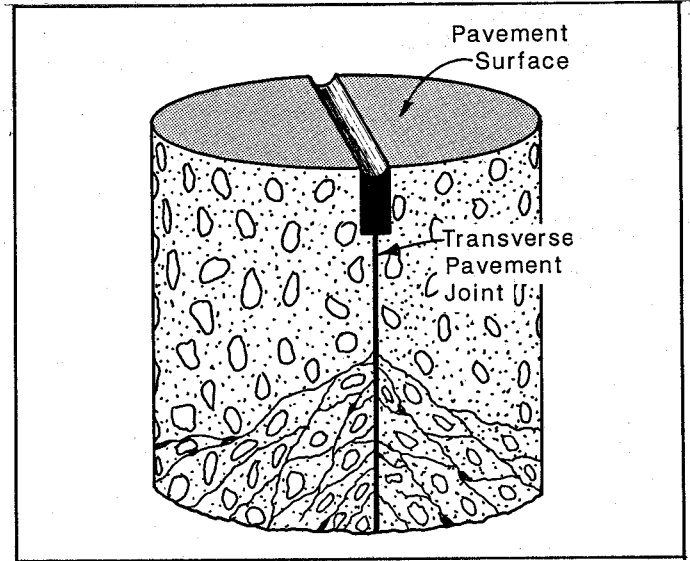


Figure 1

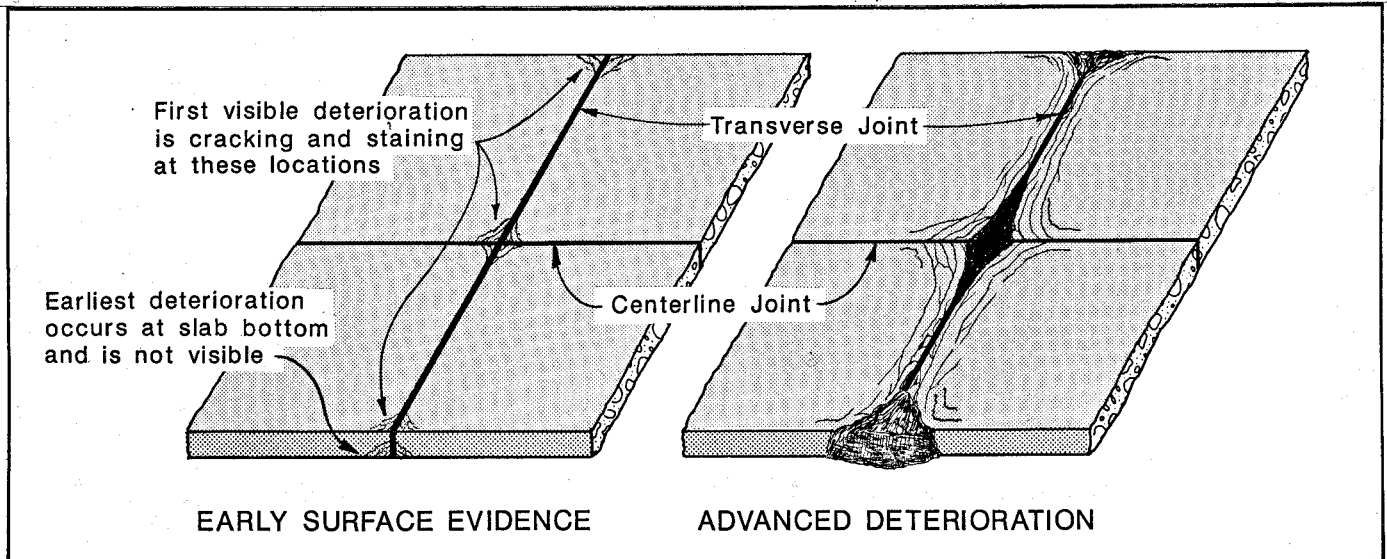


Figure 2

Testing Laboratory  
U of M 1913

Research Laboratory  
MSU 1939

Investigation and Research Division  
1924

Testing and Research Division  
1933

Materials and Technology Division  
1985

When frozen, the trapped moisture expands to form ice. As thawing occurs, more moisture is able to penetrate the newly formed cracks created by the destructive expansion of the previous freeze. The next freeze then produces more destructive cracking, and so on. This cracking begins near joints where adjacent material is not present to resist the expansive forces, and first of all at intersections of longitudinal and transverse joints, where restraining forces are at minimum across the corner.

Eventually, the deterioration at the base of the slab progresses to the stage of rubble formation, while the phenomenon itself moves upward toward the top surface and away from the joint. Larger pieces of the susceptible materials are broken down smaller and, if all the coarse aggregate in the mix is of the susceptible type, the appearance of the remnants after longer exposures gives the impression that no large particles had been used in the mix to begin with.

What conditions promote it? - Three basic conditions are needed to produce D-cracking. First, moisture must be present and available so that the particles are more than 91 percent saturated. This condition often involves a poorly draining base or, in past years, steel base plates under the joint. Second, the particles of coarse aggregate must be susceptible to cracking—certain types of aggregate (some limestones and fine-grained sedimentary rocks) are notorious for having planes-of-weakness and deleterious pore sizes (0.4 to 2.0 microns). The larger the particle the longer the water path, and the more cracks will form, since the water cannot escape during freezing. Therefore, in the same material, smaller sizes perform better than larger ones. Third, there must be freezing and thawing—the problem is less prevalent in very cold regions where fewer cycles of freezing occur. However, when salt is frequently used on the roadway, more freeze-thaw cycles occur.

The presence of substantial and heavy traffic does not cause D-cracking; however, it does accelerate its progression by removing the pieces loosened by the cracking and exposing new layers of aggregate, thus requiring earlier attention by maintenance forces.

In what regions is it most prevalent? - Generally, states that experience frequent freezing and thawing cycles and damp winters, and have readily available sources of susceptible aggregates, are more likely to find D-cracking in their concrete pavements. This includes most northern states. D-cracking is less prevalent in regions that freeze infrequently and in regions where the ground stays hard-frozen for most

of the winter. Michigan, Ohio, Indiana, Illinois, Minnesota, Kansas, Missouri, and Iowa all experience significant D-cracking problems.

How can we control it? - It is important to use a high quality durable aggregate; or if use of moderately susceptible sources is necessary, use a suitably small maximum particle size. Some aggregates, such as high quality dolomite and rocks of igneous origin are not so prone to such cracking, while aggregates with high proportions of chert and certain types of limestones are very poor risks. Some marginal materials can be made to perform adequately by limiting the maximum particle size to about 1/2-in. Improvement in drainage of the base and sealing of joints pay significant dividends in performance, but cannot prevent deterioration of susceptible aggregates. Experiments have shown that susceptible aggregates will become saturated just by contact with damp ground. Even the presence of 15 percent of a poor material can cause deterioration of the concrete. Therefore, the basic preventive measure against D-cracking is the selection of durable materials.

Can aggregates be tested for potential D-cracking? - The positive way to evaluate the durability of the aggregate is to conduct freeze-thaw tests of saturated aggregate in concrete. As the freeze-thaw process is repeated over several hundred freeze-thaw cycles, the rate and extent of the concrete's expansion is measured, providing a realistic indication of the aggregate durability under freeze-thaw conditions. Although such tests are time consuming, they are reliable indicators and are routinely used by the M&T Division to evaluate most coarse aggregates used in concrete. A quick indication of the potential ability of a coarse aggregate to resist D-cracking may be measured by the "Iowa Pore Index Test" which measures the amount of water that can be injected into oven-dried aggregate between one and 15 minutes after application of a pressure of 35 psi. The test is quite effective in identifying aggregates with pore systems predominantly in the range of 0.4 to 2.0 microns in diameter, and correlates quite well with actual service observations for most types of homogeneous materials, such as quarried stone. However, there are problems associated with application of this type of test to gravels, which are mixtures of rock types.

Efforts are continuing at the national level, and here at the laboratory to determine faster methods of testing for D-crack susceptibility. In the meantime, the freeze-thaw evaluation is an effective, though slow process.

John O'Doherty

#### 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.

#### PERSONNEL CHANGES

The M&T Division has recently lost three long-time employees through retirement, and gained three newcomers. **Marv Janson** retired after 32 years with the the Division's Research Laboratory Section, where he was head of the Spectrochemistry and Photometry areas. **Jack Sachse**, who joined the Division in 1970, is retiring as a structural fabrications inspector in the Testing Laboratory Section. And, also from that Section, **John Kolar** has retired as a sign fabrication inspector after being with the Department since 1960. We wish all three of these dedicated employees a busy and happy retirement, and thank them for their years of service.

The new employees are **Kim Elias**, who's been hired as a geologist in the Geotechnical Services Unit of the District Support Section; **Sonny Jadun**, an engineer in the Structures Research Unit of the Research Laboratory, and **Jim Schafer**, engineering tech in the Testing Laboratory's Bituminous

Technical Services Unit. Kim graduated from MSU in 1985 with a degree in Geology, and since then has been working for the Department of Natural Resources. Her duties there included field investigation and data interpretation relative to ground water quality. Sonny obtained his BS Degree in Civil Engineering at NWFP University in Pakistan in 1981 and his Masters in Civil Engineering at MSU in 1984. He has been working for MDOT since graduation - first for two years in Bridge Design, then for a year in the Engineering Development Program in the Construction Division. Jim is our choice to fill the large shoes of Mike Reeves as the Traveling Bituminous Mix Specialist for the southwestern part of the state. He has long experience in M&T having worked in materials testing, on our soils boring crews, as a density supervisor, and for the past 9 years, as a materials sampling and testing technician in District 7. We welcome all three to the Division, and pleasantly anticipate the contributions that they will be making to the Division and the Department.

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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