Chip Seals for Improved Pavement Preservation

North Carolina's Approach

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Chip seals are used routinely in the maintenance and preservation of roadways. In the United States, emulsion-based chip seals, with emulsified asphalt binders and natural mineral aggregate chips, are commonly used.

The chip seal is constructed by spraying the asphalt emulsion onto the asphalt pavement, then spreading chips of aggregate into the emulsion, embedding the chips with pneumatic and rubber-tired rollers, and finally sweeping to remove the excess chips. Sometimes, the process is repeated—a double seal, with emulsion sprayed again and a second layer of chips added. The process seals fine cracks in the underlying pavement surface, reducing pavement deterioration by preventing water from intruding into the base and subgrade.

Problem

Despite the apparent benefits and widespread use of chip seals as a preservation treatment, some state departments of transportation (DOTs) have been reluctant to adopt the technology because of limited familiarity with chip seal practices. North Carolina DOT maintains an extensive network of low-volume roads—roads traveled by less than 3,000 vehicles per day; for these roads, chip seal is a logical preservation option and has been employed for many years. With tightening budgets, however, the department sought ways to improve chip seal performance by optimizing the material selection, mix design, and rolling equipment and pattern.

Rolling the chip-seal surface treatment.

PHOTO: NORTH CAROLINA DOT

Solution

Documentation and Research

North Carolina DOT personnel began to document chip seal practices and performance, to increase familiarity with the preservation treatment, to understand its performance and benefits, and to support targeted research to enhance its application. In particular, NCHRP Synthesis 342, *Chip Seal Best Practices (1)*, helped department staff increase familiarity with the technology. In addition to encouraging the use of chip seal as a preservation treatment, the synthesis led North Carolina DOT to sponsor a series of research projects to optimize the chip seal process and increase its benefits.

North Carolina DOT's in-house maintenance crews perform most of the state's chip sealing. Roadways are selected for treatment at the division or county level. The NCHRP synthesis report noted that every aspect of the chip seal process can be improved and optimized; North Carolina DOT therefore sponsored a series of research projects at North Carolina State University (NCSU) to evaluate and improve the various aspects of chip seal design and construction. A committee that included pavement management engineers, road maintenance engineers, and bituminous supervisors was appointed to oversee each project.

Projects and Findings

One project aimed at optimizing chip gradation. Researchers investigated the aggregate retention and frictional characteristics of lightweight and granite

Photo: North Carolina DOT

Preparation for sampling before placement of chip seal.

aggregates. The project demonstrated that lightweight aggregate with a 5/16-inch, or 7.5-millimeter (mm), nominal maximum aggregate size, a more cubical shape, and uniform gradation provided better aggregate retention than the fine-graded granite aggregate ranging from 12.5 to 2.36 mm in size. For both aggregate types, uniform gradation was most critical in minimizing aggregate loss. The research recommended using only material larger than 2.36 mm, with the amount of fines—or material smaller than 0.075 mm—not to exceed 1.5 percent.

Another project undertook a performance-based analysis of polymer-modified emulsions. The research evaluated the performance of single, double, and triple seals with unmodified and polymer-modified emulsions. The polymer modification was found to enhance rutting resistance—especially at high temperatures—as well as aggregate retention. A life-cycle cost analysis concluded that to be cost-effective, polymer-modified chip seals would need to last at least two years longer than unmodified chip seals—that is, for seven years.

A third project evaluated rolling methods to determine the optimal equipment, number of coverages, and rolling pattern (see photo, page 41). According to the findings, the best results were achieved when the rolling began with a pneumatic tire roller and finished with a combination roller; therefore, use of both the pneumatic roller and the combination roller was recommended.

Three coverages were found optimal, considering both the time for rolling and the aggregate retention. For multiple-layer chip seals, another key finding was that rolling the layer immediately below the top layer improved the aggregate retention in the top layer.

Other projects developed a mix design for chip seals with modified polymer and lightweight aggregate, a field test to predict the performance of recently placed chip seal, and methods for constructing samples in the field (see photo, left) that could be removed and tested in the laboratory (see photo, below, left). In addition, the most promising laboratory tests for chip seal performance were identified. An ongoing project is examining chip seal application on roadways with traffic volumes of more than 5,000 vehicles per day.

Photo: North Carolina DOT

North Carolina State University student carefully removes a sample for laboratory testing.

Application

The collaboration between NCSU and North Carolina DOT has led to implementation of several significant findings. For example, polymer-modified emulsions are now in use, and the department plans to acquire combination rollers when equipment is due for replacement. In addition, maintenance crews now have a better understanding of what makes a chip seal perform well and are testing new approaches to improve performance further.

All 14 divisions of North Carolina DOT have adopted the recommended chip gradation and are using lightweight aggregate and polymer-modified emulsions to some extent. All divisions have adopted the recommended number of coverages, and most are using either a pneumatic tire or combination roller.

Benefits

The program of research on surface treatments has produced obvious benefits. Better performing, longer-life chip seal is now in use. Although several years of operation are needed to quantify these benefits, positive improvements have occurred.

The use of lightweight aggregate has reduced tort claims for windshield damage. In one division, the annual tort claims associated with the preservation program have dropped from approximately 20 per season to none since the implementation of lightweight aggregate.

Adopting polymerized emulsions has improved aggregate retention—chip loss was reduced by 30 percent. The surface treatments are now being used on higher volume roadways. Although polymer-modified chip seals cost about 20 percent more than unmodified chip seals, other preservation treatment options for higher-volume roads—such as thin (1.25-inch) hot-mix asphalt overlays—cost nearly three times as much as the unmodified chip seals. The ongoing research will help quantify—in terms of performance and cost—the benefits of using polymer-modified chip seals on roads with higher traffic volumes.

North Carolina DOT maintenance crews have recognized their role in supporting a research effort that has improved performance and earned public satisfaction. The research provided university students with an opportunity to learn about pavement preservation and maintenance.

Although each road treatment is a relatively low-cost activity, North Carolina DOT's annual budget for chip seal was $63.2 million in 2010 and approximately $75 million in 2011. The cost savings accrued from the increased service life, improved performance, and increased public satisfaction, reduced tort liability, and increased safety will allow the preservation of more roadways with the same budget, compounding the benefits year after year.

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Reference

1. Gransberg, D., and D. M. B. James. *NCHRP Synthesis of Highway Practice, No. 342: Chip Seal Best Practices*, Transportation Research Board of the National Academies, Washington, D.C., 2005. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_342.pdf.

Resources

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Kim, Y. R. and J. Lee. *Performance-Based Analysis of Polymer-Modified Emulsions in Asphalt Surface Treatments*. Final report, FHWA/NC/2007-06, North Carolina DOT, Raleigh, September 2009.

Kim, Y. R. and J. Lee. *Quantifying the Benefits of Improved Rolling of Chip Seals*. Final report, FHWA/NC/2006-63, North Carolina DOT, Raleigh, June 2008.

EDITOR'S NOTE: Appreciation is expressed to Amir Hanna and G. P. Jayaprakash, Transportation Research Board, for their efforts in developing this article.

Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).

NCHRP Develops Manual on Chip Seals

NCHRP Synthesis of Highway Practice 342, *Chip Seal Best Practices*, focuses on the preservation treatment for flexible pavements in the United States and Canada, with some design and application procedures from Australia, New Zealand, South Africa, and the United Kingdom.[a] Design methods, the selection of materials, the equipment, the construction procedures, performance measures, and contract administration are described, supplemented with case studies of successful applications of the technology.

In the United States, a lack of nationally accepted guidance for the design and construction of chip seals, along with a lack of specifications and testing procedures for evaluating constituent materials, has hampered use. To address these needs, NCHRP initiated Project 14-17 to develop a manual that would identify the factors influencing chip seal design, construction, and performance and provide guidelines for practitioners considering chip seal as a preservation treatment. The resulting NCHRP Report 680, *Manual for Emulsion-Based Chip Seals for Pavement Preservation*, is available online.[b]

In addition to providing a rational approach to the design of chip seals for pavement preservation, the research identified several test methods for controlling construction. A laboratory test, for example, can be used to predict the time required before rotary brooms or uncontrolled traffic can be allowed on the surface of the chip seal. A simple-to-operate, portable test that measures the viscosity of emulsions was adapted from tests that measure the consistency of paints. Other tests were identified for determining the embedment depth for chip seal aggregates and for estimating chip seal loss.

The Highway Subcommittee on Materials of the American Association of State Highway and Transportation Officials (AASHTO) is considering the incorporation of these test methods into the AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing.

For more information, visit the NCHRP website, www.TRB.org/NCHRP/.

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[a]http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_342.pdf.
[b]http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_680.pdf.