Evaluation of Otta Seal Surfacing for Low-Volume Roads in Iowa

tech transfer summary

Otta seal is a thin bituminous surface treatment technology that can provide a flexible, durable, and impervious surface for low-volume roads using readily available equipment and local aggregates.

Problem Statement

Low-volume roads represent a significant proportion of transportation infrastructure, and the cost of maintaining low-volume roads is quite high for secondary road departments. The excellent performance of Otta seal as a bituminous surface treatment (BST) and dust mitigation technology offers a low-cost solution to county road engineers. However, because Otta seals have not been used in Iowa, there was a need for increased understanding and demonstration of this technology in practice.

Background

Otta seal technology has been used in northern Europe and Africa, among other locations, as an economic and practical alternative to traditional BSTs. It provides a flexible, durable, and impervious surface more tolerant of the higher anticipated pavement deflections on low-volume roads constructed using lower-quality materials.

Compared to traditional BSTs, which require high-quality materials and specialized expertise, Otta seals can often be constructed using more economical local aggregates and readily available equipment.

Objectives

- Evaluate the feasibility of Otta seals as an alternative surface treatment on low-volume roads using local aggregates, including lower quality aggregates, and demonstrate Otta seal technology in Iowa
- Evaluate the cost-effectiveness and performance of Otta seals compared to traditional bituminous seal coat surfaces and with respect to maintenance of granular surfaced roads

Research Description

Site Condition for Otta Seal Field Demonstration

The site selected for this Otta seal demonstration project, County Road (CR) L-40 in Cherokee County, Iowa, has a length of about 4.0 miles (6.43 km) and an average daily traffic volume of 190 vehicles, with up to 30% truck traffic. The existing hot-mix asphalt (HMA) surface had only been treated with crack seal.

June 2018

RESEARCH PROJECT TITLE
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SPONSORS
Iowa Highway Research Board
(IHRB Project TR-674)
Iowa Department of Transportation
(InTrans Project 14-497)

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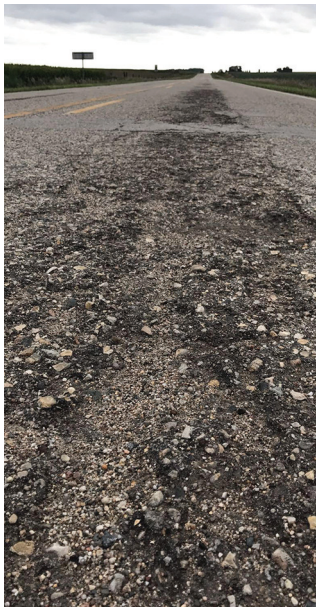

CR L-40 Otta seal project site prior to any surface treatment

Otta Seal Design

Based on the traffic volume and truck traffic on CR L-40, it was recommended that a dense aggregate gradation be applied, as specified in the Norwegian Road Research Laboratory (NRRL) design manual. The daily heavy agricultural truck traffic called for a double Otta seal design.

According to the NRRL design guide, gradation is the only material property that must be characterized for Otta seal design. Seven types of aggregates from five sources were assessed for this project.

After comparing the NRRL-recommended gradations and Minnesota Department of Transportation (MnDOT) Class 5 gradations, Source 4 aggregate was chosen for most road sections, and three other aggregate types with different gradations were used to construct three test sections.

Asphalt emulsion and cutback asphalt are the two binder types commonly used for Otta seals. HFMS-2s, characterized as an anionic high-float medium-setting emulsion with high viscosity, was selected for use in this project because both Minnesota and South Dakota have applied this binder type for Otta seal projects with satisfactory performance.

To examine the effect of aggregate type on Otta seal construction and performance, four test sections (TSs) were constructed using different types of aggregates. The first layer of TS 2 used filter sand, which is not recommended for Otta seals.

Otta Seal Construction

The following recommendations were provided by the research team regarding the use of aggregates, binder, and pneumatic tire rollers in Otta seal construction:

- The aggregate spreading rate should be 50 lbs/yd^2 (27.1 kg/m^2)
- The binder spraying rate should be 0.55 gal/yd^2 (2.5 L/m^2)
- Pneumatic tire rollers should be filled with aggregate to the required level to reach a sufficient weight
- Pneumatic tire rollers should be limited to 4 mile/h (6.4 km/h) for 30 passes on the day of construction to ensure proper compaction quality

Approximately one week before construction of the first layer, the deteriorated asphalt pavement surface was slurry sealed at both transverse and longitudinal cracking locations. Construction of the first Otta seal layer began on September 5, 2017, during which time the road was closed to traffic in both directions.

Construction took place in three steps: binder spraying, aggregate application, and rolling compaction.

Otta seal construction process: binder spraying, aggregate application, and rolling compaction

To ensure that most of the aggregate would be compacted and covered with the applied emulsion HFMS-2s, a 14-ton (12.7 metric tons) pneumatic roller was used after the first layer was completed. This action compensated for the extra aggregate applied and the lack of compaction effort during construction.

Two weeks after the first layer was constructed, the construction crew placed the second layer of Otta seal. The same technologies and procedures were used, but additional quality control and quality assurance operations were conducted to monitor the aggregate and binder application rates.

The recommended design aggregate application rate was 50 lbs/yd^2 (27.1 kg/m^2) for both the first and second layers. However, the actual application rates varied due to issues with the aggregate spreader related to distribution uniformity and aggregate moisture contents.

Otta Seal Performance

Otta seal surface appearance: (a) one day and (b) six months after construction

To evaluate Otta seal performance, the international roughness index (IRI) was measured using Roadroid, a mobile device-based app. IRI measurements were taken on the existing HMA pavement surface before construction and at different periods after Otta seal construction.

To perform a loose aggregate test, two wooden sticks were placed to establish a single 4 in. wide lane. A vacuum device was then used to collect any loose aggregate between the area of the two wooden sticks, with a bucket used to store the collected aggregate.

A dustometer was used to evaluate the effectiveness of the Otta seal in controlling dust. A car installed with a dustometer was driven at a speed of 25 mile/h (40.2 km/h) over the desired length, after which dust-vacuumed filter papers were weighed to determine the accumulated dust per segment.

Economic Analysis of Otta Seal

Using Minnesota and Iowa as case study locations, a life-cycle cost analysis (LCCA) was performed to compare the cost-effectiveness of Otta seal versus chip seal. The analysis included both deterministic and stochastic life-cycle cost analyses.

Key Findings

- Gradation is the most critical property for aggregate selection, and because the allowed aggregate gradation limits vary over a wide range, the selected Otta seal type should fall within specific limits. Extra-fine aggregate content is of concern because it may lead to unmanageable dust control resulting from the Otta seal surface.
- The binder spray rate recommended in the NRRL manual for cutback asphalt should be modified based on the asphalt content in emulsion. The amount of residual asphalt content in emulsion should be equal to the amount in cutback asphalt, as recommended by the NRRL manual.
- It is important for engineers to keep the aggregate in a dry condition for at least one day before construction to avoid the chance for moist aggregate to block at least a portion of the spreader head.
- The actual aggregate spread rates, which should be monitored carefully during construction, are always higher than the design rates. Improper operation may result in insufficient binder coating on the aggregate particles.
- The surface of the Otta seal had a relatively light color immediately after construction and became darker as time elapsed, indicating that the binder squeezed up through the aggregate layer to coat the aggregates.
- The IRI values slightly changed after Otta seal construction. The IRI values before and after construction ranged from 15.8 to 26.4 ft/mile (3 to 5 m/km) and showed that Otta seal can provide a surface satisfying the same smoothness requirements as an HMA pavement.
- The results of the loose aggregate test indicated that the test section using crushed limestone provided the lowest amount of loose material.
- The results of the dust control testing indicated that Otta seal is capable of controlling dust so that is under 0.09 oz/mile (1.58 g/km).
- The economic analyses using Minnesota and Iowa as case study locations indicate that Otta seal could be more cost-effective than chip seal.

Implementation Readiness and Benefits

The first Otta seal field demonstration project in Iowa was constructed using the design and construction guidelines and recommendations generated from the first part of this study. These research findings can be directly used by Iowa city, county, and department of transportation engineers to make decisions regarding the use of Otta seal surfacing for Iowa's low-volume roadways.

This project represents the first well-documented Otta seal project in North America and the world's first Otta seal field application for resurfacing and rehabilitation of a deteriorated HMA pavement. Iowa county engineers have expressed strong interest in seeing this technology implemented in their counties, and Cherokee and Buchanan Counties have plans for several Otta seal construction projects in 2018.

Click links below to see project-related videos and web pages:

- Otta seal construction
- Otta seal Facebook homepage
- Measuring loose aggregate materials on Otta seal surface
- Dustometer test on top of Otta seal

Future Research

To establish recommended specifications for Iowa Otta seal construction, including quality control/quality assurance procedures, the project technical advisory committee (TAC) recommends the following research directions:

- Evaluate Iowa's local aggregate types for their suitability for Otta seal construction
- Develop a rational or engineered approach for determining the optimum application rates for asphalt binder and aggregate in Otta seal applications
- Identify test and control procedures for checking and calibrating actual field application rates of asphalt binder and aggregate
- Identify road surface/base preparation requirements for Otta seal application
- Develop minimum requirements for aggregate layer thickness with California bearing ratio (CBR) ranges for subgrade strength to establish Otta seal selection criteria for unpaved roads
- Develop minimum requirements to identify candidates for Otta seal placement on existing HMA pavements
- Evaluate the rolling operations (e.g., number of passes) required to achieve appropriate field compaction
- Identify test procedures for determining curing times for Otta seal and recommend the optimum curing time between the first and second layer for double Otta seal construction
- Evaluate the feasibility of using recycled asphalt pavement (RAP) as an alternative to virgin aggregate in Otta seals
- Evaluate whether an Otta seal layer can be used as a holding strategy option for Iowa county roads