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RESEARCH PROJECT TITLE

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

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Evaluation of Otta Seal Surfacing for Low-Volume Roads in Iowa, Phase II Study: Comprehensive Laboratory Evaluation and Characterization and Full-Scale Field Implementation

tech transfer summary

Evaluating laboratory and field performance of Otta seal specimens and sites in Iowa and establishing recommended specifications for Otta seal implementation.

Objective

This study aimed to evaluate the performance of Otta seal in Iowa through laboratory and field investigations and to establish recommended specifications for Otta seal implementation.

Background

Otta seal is a low-cost bituminous surface treatment (BST) for low-volume roads that involves placing a graded aggregate layer on top of a bitumen emulsion layer and then rolling the aggregate into the emulsion to form a seal. In contrast to traditional BSTs such as chip seal, Otta seal supports the use of locally available and marginal aggregates, thereby lowering construction costs.

Iowa has over 70,000 miles of secondary roads that carry very low daily traffic volumes but frequently support heavy vehicles (e.g., farm equipment). The potential life-cycle cost benefits of Otta seal and its excellent performance internationally and in Minnesota and South Dakota gained the interest of Iowa county engineers responsible for these roads.

In the Phase I study, the first Otta seal site in Iowa was successfully constructed in Cherokee County in 2017. Since then, more than 50 Otta seal sites have been constructed in the state.



Otta seal construction

Problem Statement

Existing empirical guidelines for Otta seal construction are primarily based on the performance of Otta seal sites in Norway. Given variations in local aggregates and climatic conditions, these guidelines may not be entirely applicable to other countries. A more scientifically grounded approach is needed that considers local factors in determining Otta seal design parameters.

Research Description

This Phase II study assessed Otta seal performance and developed recommended Otta seal specifications for Iowa through a field survey of existing Otta seal sites, laboratory investigation of Otta seal specimens, field implementation of Otta seal design approaches, and a life-cycle cost analysis (LCCA).

Field Survey

Among the Iowa Otta seal sites constructed since 2018, 12 sites using various aggregate types and gradations, asphalt binders, and application rates were selected for an assessment of field performance. Performance data, including composite stiffness, dust generation, roughness, and surface friction, were gathered over five years, and the sites were visually inspected.

Laboratory Investigation

A laboratory assessment was conducted to investigate aggregate loss from Otta seal specimens prepared using different aggregate and binder materials and design methods. MC 3000 and HFMS-2s were used as binders, and aggregates included limestone, recycled concrete aggregate (RCA), steel slag, and river aggregate in open, medium, and dense gradations.

Aggregate and binder application rates were determined using three design methods: the Overby method for Otta seal, the McLeod method for chip seal, and a modified



Otta seal specimen showing aggregate rolled into asphalt binder

version of the McLeod method to accommodate the types of aggregate used in Otta seal. These methods recommend different aggregate and binder application rates and various binder-to-aggregate (BR/AR) ratios.

Aggregate loss was quantified using a version of the sweep test (ASTM D7000) modified to suit the specific characteristics of Otta seal specimens.

Field Implementation

Three full-scale Otta seal test sections were constructed on County Road J55 in Page County, Iowa, to investigate the performance of Otta seal designed using the modified McLeod method.

Test section TS-1 was built using the Overby design method, while test section TS-2 was constructed using the modified McLeod method. Prior to Otta seal construction, the base layers of both test sections were stabilized with cement. An additional control test section, TS-3, was built on a nonstabilized base layer using the Overby design method.



Buchanan County Otta seal site built in July 2018 (photo taken April 2023)



Otta seal on test site TS-2 one month after construction

The test sections' performance was evaluated using a high-speed profilometer to measure International Roughness Index (IRI) values, the British pendulum test to measure skid resistance, a dustometer to measure dust generation, and a vacuum device to measure loose aggregate.

Life-Cycle Cost Analysis

An economic analysis was performed to determine the costs and benefits of implementing Otta seal in Page County, Iowa, using the modified McLeod design method. The equivalent uniform annual cost (EUAC) was used to compare the life-cycle benefits of different Otta seal design and construction approaches. Four scenarios with various maintenance frequencies were evaluated.

Key Findings

- Since 2017, Iowa has successfully constructed over 50 Otta seal sites. After several years of service, most of the Otta seal sites in Iowa exhibit excellent performance.
 - The Otta seal sites constructed in Iowa demonstrate that local aggregates (e.g., limestone and river gravel) and recycled materials (e.g., RCA and steel slag) can be utilized in Otta seal.
 - The most prominent challenges for Otta seal in Iowa include bleeding and loss of aggregate cover. The use of appropriate BR/AR ratios combined with adequate compaction could effectively reduce such problems.
 - Otta seal has proved to be a cost-effective surfacing technique and has allowed the construction of roads under unfavorable circumstances where conventional bituminous surfacing would have been too expensive or impossible.
 - The laboratory investigation revealed that aggregate gradation plays a crucial role in aggregate loss. The use of open gradations resulted in reduced aggregate loss compared to denser gradations. Open-graded aggregates, characterized by their lower fines content, enable the binder to better coat the larger aggregates, leading to decreased aggregate loss.
 - Otta seal specimens prepared using the modified McLeod method exhibited superior performance in terms of aggregate loss during the laboratory investigation.
- The field study found that the Otta seal test section constructed using the modified McLeod method (TS-2) consistently exhibited the lowest IRI values and the lowest amounts of loose aggregate and dust one week, one month, one year, and two years after construction.
 - The Otta seal test section built without base stabilization (TS-3) consistently exhibited the highest IRI values because of its nonuniform base layer, which confirms the importance of constructing a well-prepared base aggregate layer before applying Otta seal.
 - The economic analysis showed that the Otta seal test section constructed using the modified McLeod method (TS-2) consistently demonstrated the lowest EUACs across maintenance scenarios. The lower costs can be attributed to the method's reduced aggregate and asphalt binder usage, which resulted in cost savings throughout the test section's life cycle.

Implementation Readiness and Benefits

This study developed a rational design method for Otta seal that considers the properties of locally available aggregates and binder. This method can help county engineers determine optimal binder and aggregate application rates for local materials and better understand how various parameters—such as aggregate gradation, aggregate and binder type, and aggregate and binder application rate—can affect the performance of Otta seal surfacing.

Comprehensive draft specifications for Otta seal design and construction in Iowa were developed and are presented in the project report. Such specifications can help the Iowa Department of Transportation (DOT) and county engineers implement Otta seal for low-volume roads in a way that ensures optimal performance.

Based on the positive results obtained with recycled materials, including steel slag and RCA, additional research is recommended to investigate the suitability of other locally available recycled aggregates for Otta seal construction. Use of recycled aggregates could reduce the environmental impact of road construction as well as construction and maintenance costs.