Otta Seal Construction for Asphalt Pavement Resurfacing

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ABSTRACT

Otta Seal resurfacing methods have been widely demonstrated for unpaved roads and road rehabilitation in a few states in the U.S. as well as in Scandinavia and Africa. Application of Otta Seal over a deteriorated hot mix asphalt (HMA) surface has been considered as the feasible concept that has not been applied for real construction. In this study, a double-layer Otta Seal construction over HMA surface was monitored. The applied materials for the construction were introduced. The following performance of the constructed Otta Seal layers was evaluated by measuring the international roughness index (IRI) and dust. The road IRI did not significantly change, and the dustometer test results indicated satisfied dust control on Otta Seal layer. The findings from this study provide guidance on designing and implementing Otta Seal on asphalt concrete pavement as a resurfacing overlay.

INTRODUCTION

As the global economy and development slow down, for pavement engineering, engineers are seeking more durable and economical technologies for road preservations and rehabilitations. Accordingly, many efforts have been made to study the resurfacing strategies including all kinds of sealing (e.g. sand seal and chip seal). Among those sealing methods, Otta seal is one that has not been properly addressed.

The Otta Seal technique was implemented for the first time in Norway in 1963. The road authorities in Norway decided to treat 40,000 km of gravel roads, which was 50 % of public roads in Norway with such technique (Overby 1999). Theoretically, in comparison with chip seal, aggregates in Otta seal should be hold more tightly such that either passing traffic or snowplow blades have very slight impact on Otta seal surface. The key reason is that oil in chip seal always cannot fully coat aggregates, while Otta seal is capable to mostly coat aggregates due to the use of graded aggregates that can fill more voids and provide more interlock between aggregate particles. However, it has seen limited used in the U.S. because of the empirical design approach associated with this technique that requires evaluation of trial or demonstration sections before deployment. The state of South Dakota (SD) completed its first Otta seal project in Day County, SD in 2008 to provide a low-cost surface using in-house resources and equipment rather than constructing a standard asphalt pavement surface (Weiss 2010). Also, various agencies (city, county, and state department of transportation) in Minnesota (MN) have applied Otta seal for traffic volumes ranging from very low up to 2,000 average daily traffic since early 2000 (Johnson and Pantelis 2008; Johnson 2011). Most Otta seal surfaced road sections constructed in MN have performed well except when they experienced unexpected situations, such as unanticipated high traffic volumes or flood damage during the service lives (Johnson 2011). Otta seal construction was also reasonably affordable compared to hot mix asphalt (HMA) or Portland cement concrete (PCC) pavement systems for low volume roads. It was considered to be one of the most cost-effective and durable forms of dust control wherever gravel roads are present. In developing countries, the available evidence suggested that the most cost-effective and durable form of dust control in life-cycle terms is a bitumen-based seal such as surface dressing, cape Seal, or Otta Seal (Greening 2011).

In this study, the first demonstration site in state of Iowa was constructed with a double-layer Otta seal over a 6.4 km (4 mile) long asphalt pavement. The materials used for this construction and the construction process were illustrated in this paper for the purpose of basically introducing this technique. Further, the constructed Otta seal site was evaluated by conducting international roughness index (IRI) testing and measuring the dust induced by passing traffic. The principal objective of this study is to document the Otta seal construction process and evaluate the performance of Otta seal on top of asphalt pavement.

OTTA SEAL MATERIALS

Bituminous material. To achieve complete coating of aggregates and successful performance of Otta seals, the binder type and application rate must be tailored to the properties of the aggregate. Overby (1999) listed the following desirable characteristics for a binder used in Otta seal:

- It should be of sufficiently low viscosity to initially coat the fine aggregate;
- It should be soft enough to allow for rapid movement through the aggregate voids under the actions of rolling and traffic flow;
- It should be soft enough to allow for continued movement through the aggregate interstices over a period of 4 to 8 weeks after the surface is opened to traffic;
- It should allow for large-scale application in one spraying operation;
- It should be stored at a temperature of 50 to 140 ^{o}C;
- It should be sprayed at a temperature of 85 to 122 ^{o}C.

In general, binder spray rates for Otta seal construction vary anywhere from 1.80 to 2.50 L/m^2 for various traffic levels and aggregate gradations. The actual spray rate for a given project can be determined through preliminary road data. An emulsified asphalt (HFMS-2s) was designed to be sprayed at the rate of 2.50 L/m^2 on the segment of this project. The bituminous material used in this study has the characteristics of high floating and medium setting, which meet the desired performance based on previous studies.

Aggregates. Local aggregates, typically of lower quality, were often used in Otta sealed roads. To meet the required aggregate gradation, graded aggregate for Otta seals can be produced from either crushed or uncrushed materials or a mixture of both (Overby and Pinard, 2013). Overby (1999) provided typical examples of aggregate types that have been successfully used in the construction of Otta seal. The aggregate utilized for this project was required to be within the maximum and minimum limits of the dense gradation by Overby (1999) design, and the engineers identified multiple locally available aggregates for use in the project. The recommended aggregate application rate was 27 kg/m^2 for both layer in terms of Overby (1999).

In Figure 1, the gradation of the selected aggregate is compared with different criteria. The gradation curve properly falls within the Overby (1999) dense gradation, and the percent of particles passing #200 sieve meets the minimum requirement of Overby (1999). As several Otta seal constructions have shown satisfied performance in the state of MN, it is interesting to compare the aggregate gradation of this study to the MN Department of Transportation (MnDOT) Class 5 aggregate gradation criteria, which was used as a provision for the previous and on-going Otta seal implementations in MN. Even though the coarse and fine parts of the gradation curve fall near the boundary of the MnDOT Class 5 criteria, the entire curve is still in the general required range (Figure 1).

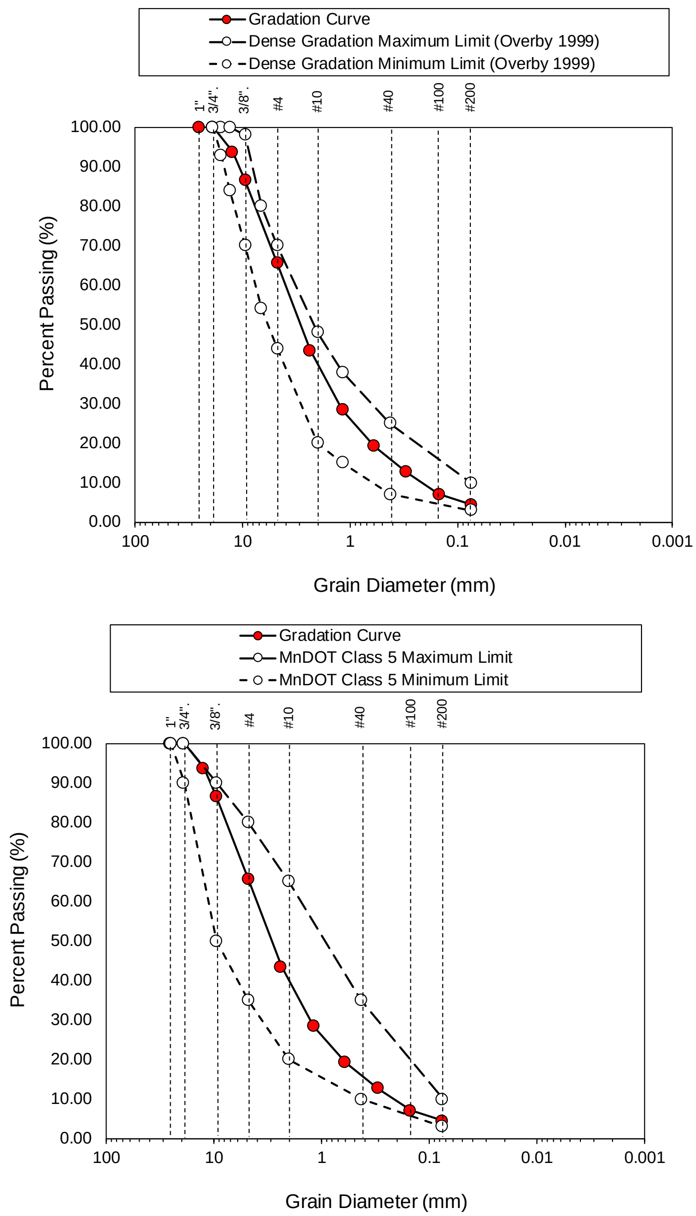

Figure 1. Utilized aggregate gradation in Otta seal in comparison with the Overby design (upper) and MnDOT Class 5 gradation (lower).

OTTA SEAL CONSTRUCTION

Although the construction operations for an Otta seal are similar to those for traditional bituminous surface treatments (BSTs), Otta seals differ in multiple aspects from a traditional BST implementation such as chip seal. Binder distributors, self-propelled chip-spreaders, tandem axle end dump trucks, pneumatic rollers, front-end loaders, and mechanical brooms are typically required in the construction of Otta seal (Johnson and Pantelis 2008; Johnson 2011). In essence, the following steps are involved in the construction of Otta seal:

- Producing the aggregate for Otta seal;

- Preparing the road base (brooming) prior to Sealing;
- Preparing the required binder;
- Spraying the binder;
- Applying the aggregate;
- Rolling and compacting the surface;
- Mechanically brooming the surface.

Otta Seal construction always requires less than one day to construct a single layer depending on the road length. However, if a double-layer Otta seal is designed, the first layer is constructed followed by the application of the second layer 2 to 4 weeks later.

Construction monitoring. Before the construction, the deteriorated asphalt pavement surface was slurry sealed at the cracking locations. The purpose of this operation was to prevent any moisture infiltration through the Otta seal layer into the asphalt layer, which may cause severe distresses. The road was closed to traffic in both directions while placing the first layer of Otta seal. The asphalt distributor began spraying the bituminous material, HFMS-2s at a rate of 2.5 L/m^2 on the existing asphalt surface, and then followed with aggregate application. Immediately after placing the binder and the aggregate, compacting and rolling efforts started with a minimum of 30 passes on the first day and a minimum of 15 passes on the second day. The entire Otta seal construction process is shown in Figure 2. The contractor was able to finish a length of 2.9 km of the first layer during the first day and continued with the remaining 3.2 km on the second day.

Two weeks post the first layer construction, the road was paved with second layer. The same technique and procedure was followed, but there were additional quality control (QC) and quality assurance (QA) operations to monitor the aggregate application rate. The recommended aggregate application rate in the design for L-40 in Cherokee, IA was 27 kg/m^2 for the first and second layers. The aggregate spreader was applying more than the recommended rate by 8 kg/m^2 on the first layer and 3 kg/m^2 on the second layer. From the construction perspective, aggregate distribution uniformity and aggregate moisture content are two important factors influencing the actual aggregate spread amount, even though the spread rate on the aggregate spreader is set at any specific value. Table 1 shows the recommended value versus the actual aggregate application rate and the billable unit quantity to the owner. The asphalt spreader was set up to spray at the rate of 2.50 L/m^2, but the billable quantity to the owner was 2.08 L/m^2.

Figure 2. Otta seal construction process of (a) binder spraying, (b) aggregate application, (c) rolling compaction, and (d) the complete process.

Table 1. Recommended Aggregate Application Rate versus Actual and Billable.

Comparison of Aggregate Application Rates	
Recommended aggregate application rate for construction	27 kg/m^2
Actual aggregate application rate used for first layer construction	35 kg/m^2
Actual aggregate application rate used for second layer construction	30 kg/m^2
Billable quantity to the owner	33 kg/m^2

PERFORMANCE EVALUATION

Post construction, the initial appearance of the Otta seal was noticed by the change in surface color. Within a few weeks of traffic flow, the binder was squeezed upward through the matrix of aggregate voids, which resulted in a similar color of conventional asphalt pavement surface. Figure 3 shows surface colors both for the initial appearance of Otta seal and for that after one month in service. Despite the two major variations between recommended and actual application rates, a satisfied performance of Otta seal was observed at two weeks and one month post construction. However, further in situ testing is still needed to evaluate the scientific performance of the Otta seal site. The following sections describe the IRI and dust measurement results.

Figure 3. Appearance of Otta seal at immediately after the construction (left) and one month post construction (right).

Dustometer test results. The dust measurements described in this study followed the same technique developed in previous investigations (Sanders, et al. 1997). A dustometer device was used to measure the dust content at this project post construction of the Otta seal to evaluate the dust control ability of the constructed surface (Figure 4). A pump was carried on the same vehicle with dustometer and connected to the dustometer to vacuum the fly dust. Pieces of particular types of filter papers were installed in the dustometer to collect the dust induced by the passing traffic. Table 2 represents the data taken at two weeks after construction of the first and second layers. The results indicate a great reduction in the quantity of dust collected per kilometer two weeks after construction of the second layer.

Figure 4. Installing the (a) dustometer device and (b) vacuum pump.

Table 2. Dustometer Results.

Road Section	Collected Dust (g/km)
First layer	1.03
Second layer	0.08

International Roughness Index. The IRI is an important factor to evaluate road ride quality. For this project, a smart phone equipped with a newly developed software, called "Roadroid", was used to collect IRI data for the entire Otta sealed road (Roadroid 2017). The data was collected every 5 m and mathematically analyzed before Otta Seal application and two weeks after the second layers were implemented. There are two different output IRI values from this software, the calculated IRI (cIRI) and estimated IRI (eIRI), which were correlated and calculated based on different models (Roadroid 2017). As shown in Figure 5, the IRI values showed slight changes in both north and south lanes comparing before and after construction. Generally, both the cIRI and eIRI values decreased 1 to 2 m/km. This result indicates ride quality improvements after Otta seal application. Owners and users mentioned satisfaction on the road performance.

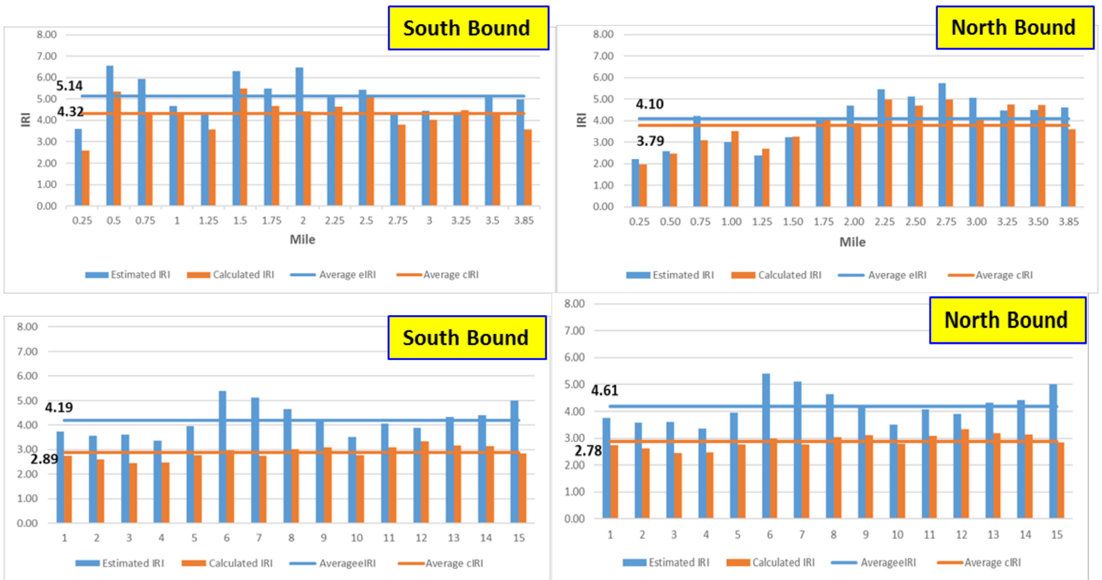

Figure 5. IRI results of pre-construction (upper) and post-construction (lower) (IRI in the unit of m/km).

SUMMARY AND CONCLUSIONS

The goal of this study was to document the first demonstration construction of Otta seal in the state of Iowa and to preliminarily evaluate the performance of Otta Seal in terms of the ride quality and dust control ability. The application rate of aggregate and spread rate of the bituminous material were two difficult parameters monitored during construction, but the actual values of these two parameters during construction influenced the final performance of Otta Seal. As well, the construction crew, the equipment, and the weather are crucial elements for achieving a successful Otta Seal. The results obtained in the form of IRI and dust collected per kilometer measurements indicate the road quality of using Otta Seal instead of asphalt pavement as resurfacing option was improved and satisfied.

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