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Abstract

All types of roads, including those with asphalt pavements, steadily deteriorate over time because of repeated mechanical (traffic) and climatic loadings. Pavement preservation consists of applying a suitable treatment on deteriorated roads to maintain good conditions and extend their service lives (1, 2). Fog seal is a low-cost application of liquid asphalt or emulsion derived from petroleum or coal tar to slow down microcracking propagation, prevent oxidation, and seal against water infiltration. The conventional fog sealants need heating before spraying on the pavement surface, and the recommended spray temperature should be between 52°C and 71°C (125°F and 160°F). Although such petroleum-based traditional fog sealers have been successfully used to maintain road surfaces for many years, they not only need a long curing time, which results in delayed traffic opening, but they can also cause health issues from chemical components such as polycyclic aromatic hydrocarbons (3, 4). Furthermore, the use of fossil fuel-based products increases the risks associated with an energy crisis and environmental contamination (5, 6).

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Comments

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INTRODUCTION

All types of roads, including those with asphalt pavements, steadily deteriorate over time because of repeated mechanical (traffic) and climatic loadings. Pavement preservation consists of applying a suitable treatment on deteriorated roads to maintain good conditions and extend their service lives (*1, 2*). Fog seal is a low-cost application of liquid asphalt or emulsion derived from petroleum or coal tar to slow down microcracking propagation, prevent oxidation, and seal against water infiltration. The conventional fog sealants need heating before spraying on the pavement surface, and the recommended spray temperature should be between 52°C and 71°C (125°F and 160°F). Although such petroleum-based traditional fog sealers have been successfully used to maintain road surfaces for many years, they not only need a long curing time, which results in delayed traffic opening, but they can also cause health issues from chemical components such as polycyclic aromatic hydrocarbons (*3, 4*). Furthermore, the use of fossil fuel-based products increases the risks associated with an energy crisis and environmental contamination (*5, 6*).

In recent years, a few bio-based fog sealers have been developed as sustainable alternatives to traditional petroleum-based sealers; soy-based fog sealant derived from agricultural oil is one such product. The manufacturers of the bio-sealant claim that it protects asphalt from oxidation, potholing, edge rutting, and cracking and can extend the life of paved asphalt surfaces when applied every 3–5 years (*7*); the other advantages and disadvantages are summarized in Table 1. States such as Missouri and Ohio have reported success in using bio-based products for county road preventive maintenance (*7, 8*). Even though the reported observations include quick shedding of water from roadways treated with bio-sealant while retaining the skid resistance of normal pavement, documentation of construction and performance experience is limited.

Based on the successful use of bio-sealant in other states, this study aimed at evaluating a bio-based product as a fog sealant for low-volume asphalt pavements in Iowa. With the intent of checking the effect of such bio-sealant on skid resistance, pavement-marking retroreflectivity, water absorption, and permeability, the construction process and consequent field and laboratory investigations based on varied sealant spray rates over a 2-year period were documented.

TABLE 1 Benefits and Limitations of Using Bio-Sealant for Fog Seal (*7, 8*)

Benefits of Using Bio-Sealant	Limitations of Using Bio-Sealant
• Resistance to deterioration – 3–5 additional years of service life. – Reduces oxidation. – Penetrates deep into asphalt. – Adding polymers to the asphalt cement. • Improvements to surface – Seals hairline cracks. – Helps maintain skid resistance. – Reduces moisture penetration. – Reduces potholing and edge rutting. • Financial considerations – Does not affect line stripping. – Is not removed by snowplowing. – No heating, carbon negative. – Reduces life-cycle costs.	• If a road is in good shape, bio-sealant should be applied every 4 to 5 years. If it is in fair shape, it should be applied every 2 to 3 years, as long as the road is not ravelling. If the road has alligator cracking, bio-sealant cannot repair the damage and should not be used. • Applying bio-sealant calls for dry conditions and a dry road with temperatures above 40ºF. Bio-sealant should never be applied in wet or freezing conditions.

CONSTRUCTION AND EXPERIMENTAL APPROACHES

Bio-Based Fog Sealant

The soy-based bio-sealant used in this study is a black liquid with a nondescript slightly citrus odor. This product has a viscosity of 5 to 20 s at room temperature, similar to the flowability of water, and no heating needed before application. It is 88% bio-based, with 40% obtained from soybean oil. By making use of agricultural and recycled materials, this bio-sealant is a nontoxic and environmentally friendly alternative to petroleum-based sealing agents with competitive price. It contains some polymers and common admixtures in traditional asphalt emulsion used to improve pavement flexibility under colder conditions.

The typical spray rate of bio-sealant can vary from 0.045 to 0.091 l/m^2 (0.01 to 0.02 gal/yd^2), which is lower than for the rate of traditional fog sealant [0.45 to 0.82 l/m^2 (0.1 to 0.18 gal/yd^2)] (*9–14*). The relatively low rate of bio-sealant is due to its good followability. Bio-sealant can reduce not only the need to use petroleum-based products in pavement maintenance, but also the need for using bitumen in the manufacturing of new asphalt by causing the road surface to last longer.

Site Installation

The sites selected for bio-sealant installation were located near Toronto in Clinton County, IA, and included a 4,506-m (2.8-mi) section of asphalt-surfaced road in E63/Y32 and an 805-m- (0.5-mi-) long asphalt-surfaced section through the City of Toronto. These sections were part of a two-lane low-volume road. Each lane was 3.05 m (10 ft) wide with a 0.91-m- (3-ft-) wide sand-paved shoulder on each side. The test sections at the installation site were divided into five subsections and are shown in Table 2. These three spray rates, which are different from the typical rates, were selected to investigate the effects of high rate on the pavement surface.

TABLE 2 Construction Information About Bio-Sealant Installation

Section	Length, m (ft)	Spray rate, l/m^2 (gal/yd^2)
Control section (CS)	30.5 (100)	0 (0)
Treated section No. 1 (TS 1)	305 (1,000)	0.136 (0.03)
Treated section No. 2 (TS 2)	305 (1,000)	0.113 (0.025)
Treated section No. 3 (TS 3)	305 (1,000)	0.091 (0.02)
Remaining section (RS)	4,366 (14,324)	0.091 (0.02)

The application of bio-sealant in Clinton County, IA, began on June 29, 2016, during dry and clear weather. Before application, all road surfaces were swept and cleaned, and the boundary marking lines for each section were painted. A vehicle equipped with an automatic spray machine was used to spray the bio-sealant. During application, the vehicle speed typically ranged from 8 to 16 km/h (5 to 10 mph).

After the application, the bio-sealant-treated lane exhibited a darker color than the untreated lane; this difference in appearance disappeared after a few days. During construction, the pavement marking was applied along with the bio-sealant materials, but no obvious reduction in visibility of the marking was observed. Additionally, the bio-sealant-treated section did not exhibit free liquid standing on its surfaces, indicating that the bio-sealant could be quickly absorbed by the pavement surface because of its natural properties. Based on this characteristic, a bio-sealant-treated road can be opened to traffic within 30 min after application, somewhat more rapidly than when applying traditional fog sealers (*3*). In summary, the documented construction process showed that the application of bio-sealant is easy to perform and does not require extra energy for heating of the sealant, and the treated road section can be opened to traffic quickly. From these perspectives, it is a cost-effective technology.

EXPERIMENTAL PLAN

Field Investigations

To document the performance of bio-sealant-treated roads, several field visits were conducted to measure retroreflectivity of pavement marking and surface friction of pavement, including skid number (SN) and British pendulum number (BPN) for the bio-sealant installation site within the first 2 years after application. These parameters play important roles in safe driving (*15*). In this study, a retroreflectometer, a locked wheel skid tester, and a BP tester were used to measure the retroreflectivity, SN, and BPN, respectively, by following related specifications (*16–18*).

Laboratory Testing

To perform the laboratory testing for hot-mix asphalt (HMA) specimens, four cores with a 10.16-cm (4-in.) diameter were taken from the CS, TS 1, TS 2, and TS 3 in the site in 2017, and the same number of cores were taken in 2018. All HMA specimens were brought to the laboratory and sawed into 5.08 cm (2 in.) thickness, and then were oven-dried at 52°C (125°F) to obtain the constant mass for water absorption and air permeability measurements. ASTM D2726 was

followed to measure water absorption, and an air chamber device was used to measure air permeability (*19*).

RESULTS AND DISCUSSION

The results of retroreflectivity and friction are shown in Figure 1. For measurements of retroreflectivity, the results indicated that the application of bio-sealant did not cause a significant reduction of retroreflectivity at the early stage after application (Figures 1*a* and 1*b*).

For measurements of SNs, the eastbound lane (Figure 1*c*) and the westbound lane (Figure 1*d*) exhibited significant decreases in skid resistance within the first week after application. After several months (between July 2016 and May 2017), the skid resistance was restored to its original condition. The measured BPN values from May 2017 to March 2018 indicate that surface friction was in a stable stage. Decreased surface friction is because of the filling in of the pavement surface texture by fog sealant (*20, 21*). With continuous tire wear, the fog sealants were worn away from the surface, resulting in restoration in friction (*22*). In consideration of the average SN drop from 63 to 49, the minimum SN value before application of bio–fog seal must

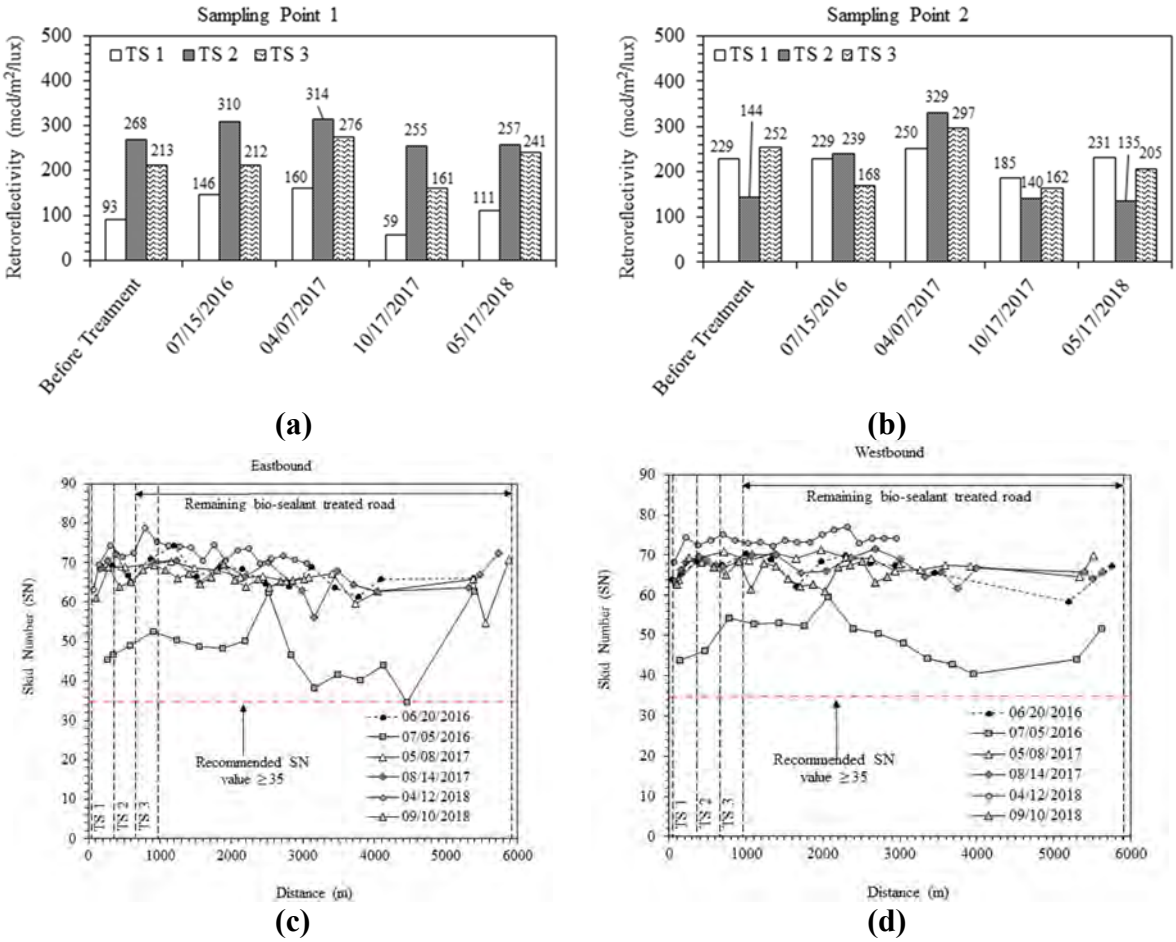


FIGURE 1 Results of (*a*) retroreflectivity of point 1; (*b*) retroreflectivity of point 2; (*c*) SN of eastbound; and (*d*) SN of westbound.

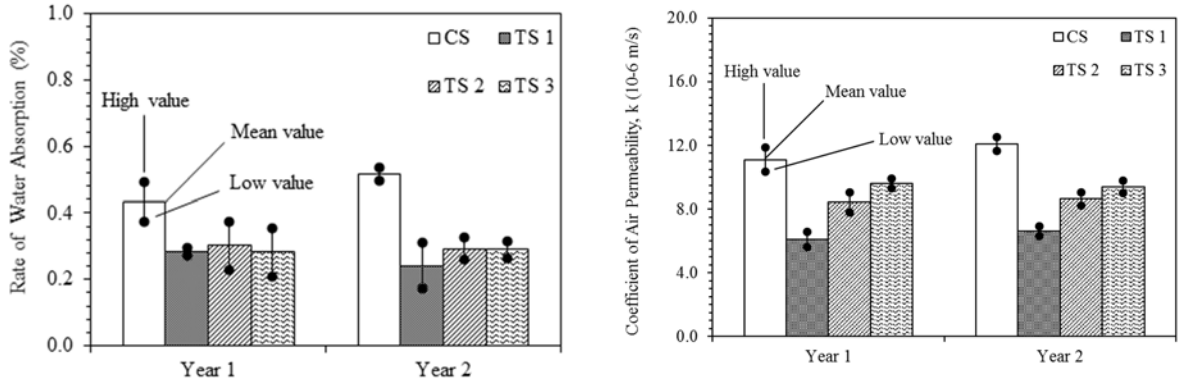
be 50 to avoid the SN dropping below the minimum requirement of 35 (*23*). The friction results indicated that the application of bio-sealant could lead to a reduction in surface friction at an early stage, although after several months the friction could be restored.

The results from water absorption and air permeability tests shown in Figure 2*a* and Figure 2*b*, respectively, reflect the lower rate of water absorption and air permeability in TS 1 and TS 2 compared to that in specimens from the control section. The thickest/highest rate of application resulted in the lowest rate of water absorption and air permeability for specimens taken from the first year (2017) and the second year (2018), reflecting the greater void-filling in bio-sealant-treated specimens. From the perspective of pavement preservation, lower water absorption and permeability are desirable since they can prevent water infiltration into pavement structures and thereby minimize damage caused by seasonal variations such as freeze–thaw cycles.

CONCLUSIONS

Traditional petroleum-based fog sealers have been successfully used for many years, while alternative nontraditional fog sealers derived from agricultural matter, which have more cost-effective and environmentally friendly potentials, have not yet been properly investigated. In this study, current practice in the use of fog seal was reviewed and summarized. Additionally, a bio-based fog sealer was applied to a selected asphalt pavement section at various spray rates over a 2-year evaluation interval. The detailed construction procedures were documented, and the key findings from field investigations and laboratory tests can be summarized as follows:

- Retroreflectivity of pavement marking decreased immediately after fog seal application using bio-sealant, but was restored to its preapplication level in 2 weeks.
- While a short-term decrease in friction was observed after bio-sealant application, friction requirements were met throughout and returned to their original levels within 11 months.
- The minimum SN value of a road before application of bio–fog seal must be 50.



(a) **(b)**

FIGURE 2 Test results of (*a*) water absorption and (*b*) air permeability (1 m/s = 3.28 ft/s).

- Laboratory results indicate that specimens treated with a higher bio-sealant spray rate are associated with lower water absorption and permeability.
- If the permeability is a critical issue in some roads, the highest bio-sealant spray rate of 0.136 l/m^2 (0.030 gal/yd^2) is practically applicable based on field and laboratory performance test results. The middle level of 0.113 l/m^2 (0.025 gal/yd^2) is also acceptable based on financial consideration.
- The construction of bio-sealant without heating process is rapid and cost-effective and needs only 30 min to open traffic. However, the dropped surface friction could be a concern to roads that have a low SN before application.
- Although the 2-year evaluation indicated that bio-sealant could seal voids in the pavement and resulting negative impact on retroreflectivity and friction could be restored, their function on friction maintenance should be evaluated in the following years.

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REFERENCES

1. Johnson, A. M. *Best Practices Handbook on Asphalt Pavement Maintenance*. Report No. MN/RC-2000-04. University of Minnesota Center for Transportation Studies, 2000. Retrieved from https://ntl.bts.gov/lib/11000/11500/11596/2000-04.pdf.
2. Mamlouk, M. S., and J. P. Zaniewski. Pavement Preventive Maintenance: Description, Effectiveness, and Treatments. *Flexible Pavement Rehabilitation and Maintenance*, 1998. Retrieved from https://compass-astm-org.proxy.lib.iastate.edu/download/STP12856S.4799.pdf.
3. Kim, Y. R., and J. H. Im. *Fog Seal Effectiveness for Bituminous Surface Treatments*. Report No. HWY-2010-02. North Carolina Department of Transportation, 2012.
4. Ghosh, D., M. Turos, and M. Marasteanu. *Evaluation of Bio-Fog Sealants for Pavement Preservation*. Report No. MN/RC 2016-20. University of Minnesota.
5. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 1995: The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, Vol. 2. Cambridge University Press, New York, 1996.
6. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2014: Mitigation of Climate Change*, Vol. 3. Cambridge University Press, New York, 2015.
7. Shatnawi, S. *RePlay Agricultural Oil Seal and Preservation Agent: A Sustainable and Environmentally Safe Product for Effective Rejuvenation and Sealing of Asphalt Concrete Surfaced Pavements*, 2017.
8. BioSpan Technologies, Inc. *RePLAY Frequently Asked Questions*. May 24, 2010. Retrieved from https://biospantech.com/products/replay/replay-faq/.
9. Iowa Department of Transportation. *Standard Specifications for Highway and Bridge Construction*, 2012.
10. California Department of Transportation. *MTAG*: *Vol. 1. Flexible Pavement Preservation*, (2nd ed.), 2010.
11. Missouri Department of Transportation. *Standard Specifications for Highway Construction*, 2018.
12. Oregon Department of Transportation. *Oregon Standard Specification for Construction*, 2018.

13. Texas Department of Transportation. *Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges*, 2014.
14. Washington Department of Transportation. *Standard Specifications for Road, Bridge, and Municipal Construction*, 2018.
15. Austin, R. L., and R. J. Schultz. *Guide to Retroreflection Safety Principles and Retroreflective Measurement*, 2009.
16. *Materials I.M. 386: Determining Retroreflectivity of Durable Pavement Marking*. Iowa Department of Transportation, 2004.
17. ASTM E274-15: Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire, 2015.
18. ASTM E303-93: Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester, 2013.
19. ASTM D2726-14: Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures, 2014.
20. Abaza, O. A., T. D. Chowdhury, and M. Arafat. Comparative Analysis of Skid Resistance for Different Roadway Surface Treatments. *American Journal of Engineering and Applied Sciences*, Vol. 10, No. 4, 2017, pp. 890–899. https://thescipub.com/abstract/10.3844/ajeassp.2017.890.899. https://doi.org/10.3844/ajeassp.2017.890.899.
21. Lu, Q., and B. Steven. *Friction Testing of Pavement Preservation Treatments: Literature Review*. Technical Memorandum No. UCPRC-TM-2006-10. University of California Pavement Research Center, 2006.
22. Prapaitrakul, N., T. Freeman, and C. J. Glover. Analyze Existing Fog Seal Asphalts and Additives: Literature Review. Report No. FHWA/TX-06/0-5091-1. The Texas A&M University, 2005. https://doi.org/10.1080/10916460903330007.
23. Wambold, J. C. Road Characteristics and Skid Resistance. *Transportation Research Record: Journal of the Transportation Research Board*, *No. 1196*, 1988, pp. 294–299. http://onlinepubs.trb.org/Onlinepubs/trr/1988/1196/1196-029.pdf.