MONTANA
Department of Transportation
Research

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Project Summary Report
FHWA/MT-23-006/9757-705

EVALUATION OF THIN POLYMER OVERLAYS FOR BRIDGE DECKS

https://www.mdt.mt.gov/research/projects/const/evaluation.aspx

Introduction

Polymer overlays are composite materials consisting of organic polymer resins and aggregates (Figure 1). They are often applied to bridge decks to protect the deck from deicer (chloride) intrusion and subsequent corrosion-induced damage. A high friction surface treatment (HFST) applied to a bridge deck often refers to a thin polymer overlay that only differs from a conventional thin polymer overlay (TPO) by the use of special aggregates intended to increase and maintain high friction.

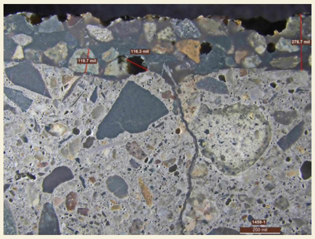

Figure 1: *Photograph of the HFST on top of a core collected in this study (Core 1459-1). A crack in the deck substrate is present and visibly filled with polymer for the depth shown in the photograph.*

The Montana Department of Transportation (MDT) installed HFSTs on four bridge decks in 2014 and 2015 in order to improve their skid resistance. Initial skid numbers were approximately 80 after HFST installation but after only 3 or 4 years, two of the HFSTs had average skid numbers between 50 and 55 while the other two HFSTs had average skid numbers of 36 and 17. A skid number of 30 to 35 is typically considered to be the minimum acceptable skid number for highway structures.

Because of the variable performance of the HFSTs and quick loss of skid resistance for two of the HFSTs, the suitability of HFSTs for Montana's diverse climates and traffic, which commonly uses studded tires and snow chains in the winter, were questioned. Subsequently, the objective of this research was to assess the factors that influence the long-term performance of polymer-based HFST systems in Montana, specifically with respect to friction resistance and durability, and to provide guidance and recommendations to MDT regarding the use of HFSTs across Montana's varying geographic regions.

What We Did

The research consisted of the following scope:

1. A literature review of the performance reported for HFSTs and TPOs used in the United States was performed. Construction challenges, potential performance issues, and best practices for mitigating the risks of poor quality installation and poor long-term performance were compiled.
2. A survey of select transportation agencies across the United States and Canada was conducted

Figure 2: *Locations of the HFSTs included in the field investigation of the study. A purple marker indicates the HFST is in the Billings District and a blue marker indicates the HFST is in the Missoula District. Each HFST is labelled with the state identification number of the bridge.*

to enhance the list of challenges and best practices collected in the literature review. The respondents described the history of use of polymer overlays, materials and specifications used, expected performance, lessons learned, and current best practices used by the surveyed agencies.

3. The conditions of fourteen HFSTs were monitored over a period of three years. Four HFSTs were subjected to detailed investigations including visual inspection and sounding surveys to identify overlay disbondment or corrosion-induced delaminations under the HFSTs in 2020 and again in 2022. The remaining ten HFSTs were visually inspected in 2020 and/or 2022 and sounding surveys were completed when traffic conditions permitted. Skid testing (ASTM E274) was performed on select HFSTs included in the field investigation in 2020 and 2023.
4. Cores were collected from the four HFSTs that underwent detailed field investigations for laboratory testing. Laboratory testing included petrographic examination (ASTM C856), rapid chloride penetration (ASTM C1202), rapid chloride migration testing (AASHTO T 357), bond strength testing (ASTM C1583), pavement macrotexture depth (ASTM E965, modified for testing of cores), and chemical methods to characterize the polymers used and their degradation.

What We Found

The HFSTs were found to be in overall satisfactory condition over the course of the study, and the laboratory testing indicated that the installations were of good quality and had not experienced excessive material degradation. The following conditions were observed in the field investigation:

- Aggregate pop-out and areas of surface polishing (Figure 3);
- Reflective cracking and spalling around some older partial-depth repairs;
- Few small pop-out spalls on the order of one or two inches in diameter (Figure 4);
- Local deterioration of the HFSTs at bridge ends;
- Occasional delaminations under sound HFST areas where no cracking was present; and
- Occasional delaminations adjacent to cracks in the HFST.

Wear, i.e., aggregate pop-out and surface polishing, typically did not appear to have progressed between inspections with the exception of very new HFSTs that had been placed in 2020. While one of the HFSTs experienced a large increase in the number of pop-out spalls over the course of the study, most of the HFSTs did not contain small pop-out spalls. Lastly, the amount of cracking appeared to increase between inspections for some of the HFSTs, in which case the cracks were typically either transverse cracks located over bents or regularly spaced transverse cracks that were usually reflective of cracks in the deck.

Based on the results of the laboratory testing, the HFSTs retained good bond to the deck substrates and demonstrated good resistance to chloride penetrability. Cracks in the deck substrates were commonly filled with polymer resin and often did not reflect in the HFSTs (Figure 1). Embrittlement observed in the polymer binder was judged to have occurred as part of the regular aging process. Wear of the HFST was found to be characterized by fracture of aggregates at the level of the resin and the dislodgment of aggregate agglomerations, indicating good bond between the aggregates and the polymer.

The skid testing results were analyzed to determine if the data showed any correlations between wear and traffic volumes or HFST age. While there was a clear correlation between wear and traffic when the data from the shoulder, the passing lane, and the driving lane was compared for each individual bridge, no correlations between traffic or age and skid resistance were definitively identified between different bridges or geographical areas.

What The Researchers Recommend

Based on the findings of the study, the researchers recommend the following.

1. The conclusions and recommendations of this study only apply to the polymer HFST or overlay formulations investigated in this study. Other polymer formulations are likely to perform differently and should be evaluated separately. Trial installations and evaluation are recommended unless standard materials having proven performance are being used and the contractor is well experienced.

2. Use only cementitious repair materials for deck patching that are compatible with the polymer topping or other rapid setting materials shown to be compatible and having acceptable performance when used prior to placing polymer HFSTs. Avoid patch materials that are thermally incompatible or have high shrinkage. The polymer topping adhesion to any new patch material should be tested prior to use. Have contractors map locations and specifics of deck repairs prior to placing toppings and keep in project files for future reference.

3. Address issues with incomplete consolidation and entrapped air voids within the HFSTs by requiring that the contractor demonstrate that the resin content is appropriate in a trial demonstration, or through evaluation of the in-place overlay. Back rolling the first layer or an optimization study may be valuable.

4. Improve detailing at the bridge approach joint. Control and match elevations across the joint. Extend the thin HFST some distance, e.g., approximately 10 feet, beyond the bridge ends if the approaches are portland cement concrete to minimize vertical offsets and reduce snow plow damage and edge wear of the overlay on the bridge deck. Consider grinding out the existing deck along the approach joints to increase thickness of polymer topping along this edge.

Figure 3: *Close-up photographs of (a) the wheel path and (b) the shoulder of the HFST on Bridge 1367 in the Missoula District in 2022.*

5. Continue to monitor skid resistance of the HFSTs. Data pertaining to driving lanes and passing lanes should be kept in separate datasets instead of averaged. Additionally, the data should be categorized by aggregate source (type) in order to develop appropriate expectations for the performance of the various aggregate types and HFST systems and their appropriateness across different exposures.

6. Armorstone (basalt) appears to maintain skid resistance longer than naturally occurring calcined bauxite aggregate; however, differences in deck exposures of the study bridges may affect performance. A Mohs hardness of at least 7 is preferred and some states prohibit the use of flint rock in HFSTs due to their tendency to polish and have poor long-term skid performance.

7. HFSTs in this study lost surface friction before wearing through. Ideal HFSTs would maintain surface friction throughout their life. Surface friction and wear rely on the aggregate properties, resin to aggregate content, as well as the polymer resin modulus and toughness. New resin formulations that do not polish and maintain skid resistance as they wear could be a focus for future research.

8. Evaluate and test if an additional layer of HFST may be applied on top of the existing overlay. Consider reapplication of HFST to driving lanes after five years to restore skid resistance and to cost effectively extend overall deck protection.

Figure 4: *Close-up photograph of a small pop-out spall in the HFST on Bridge 1367 in 2020.*

9. Favor new bridge decks and decks without signs of corrosion initiation as candidates for thin polymer overlays and HFSTs. However, bridge decks in need of local full- or partial-depth patches do not need to be precluded from consideration, but overlay service life is likely to be reduced. Corrosion testing, half-cell potential surveys, and determination of chloride contents in the deck can aid in optimizing deck selection. Avoid use on decks with widespread damage due to reinforcing corrosion (decks near the end of their service life).

10. Transverse deck cracks tend to reflect with time. Primer was noted to penetrate deck cracks and may help reduce reflective cracking.

11. While current practice appears adequate, achieving good bond is critical to polymer overlay performance. Implement quality assurance/quality control testing to ensure adequate surface preparation and to monitor polymer batching, mixing, placement, and curing. Depending on the deck surface condition, micromilling may be advantageous to remove surface contamination and chloride-contaminated concrete. Specify a) concrete surface profile (CSP) of at least 5, b) Maximum concrete deck moisture of 5% per moisture meter (see NYSDOT), c) minimum direct tensile bond strength (ASTM C1583) of 250 psi, and d) specify primer to fill and seal cracks when available.

12. Developing in-house expertise related to the use and installation of polymer overlays and HFSTs may be valuable to help ensure quality and successful projects.

13. Consider a 5-year warranty clause for overlay performance as specified by some other states.

More Info:

The research is documented in Report FHWA/MT-23-006/9757-705

Principal Investigator:

Paul D. Krauss, pkrauss@wje.com, 847.272.7400

MDT Technical Contact:

Shane Pegram, spegram@mt.gov, 406.444.6289

MDT Research Project Manager:

Vaneza Callejas, vcallejas@mt.gov, 406.444.6338

To obtain copies of the final report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.