# EVALUATION OF THIN OVERLAYS FOR BRIDGE DECKS

## Final Report

**SPR 304-431**

RESEARCH

Oregon Department of Transportation

# EVALUATION OF THIN OVERLAYS FOR BRIDGE DECKS

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**SPR 304-431**

by

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16. Abstract


Eight thin polymer overlay systems were evaluated in the laboratory and on two bridge decks exposed to trucks and passenger vehicles including those with studded tires. The products were Mark 154, Flex-O-Lith, Safetrack HW, Kwik Bond PPC MLS, Tyregrip, SafeLane HDX, Urefast PF60, and Unitex ProPoxyType III DOT. None of the overlay systems showed superior performance under moderate average daily traffic from the standpoint of maintaining good skid resistance and resisting wear through. Tyregrip and Safetrack HW started to wear through to the concrete after exposure of approximately 1.3 million vehicles, and Urefast PF60 wore through much sooner. For the five products that did not wear through, empirical equations predicted the friction number of the best of these five products would decrease to 40 (equivalent to the friction number of the concrete) within five months at a traffic level of 10,000 vehicles per lane per day. Delamination from the concrete was not a major problem with the products. Laboratory tests were not able to predict performance.


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# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 645.2 | millimeters squared | $mm^2$ |
| $ft^2$ | square feet | 0.093 | meters squared | $m^2$ |
| $yd^2$ | square yards | 0.836 | meters squared | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | kilometers squared | $km^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | ml |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | meters cubed | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | meters cubed | $m^3$ |
| NOTE: Volumes greater than 1000 L shall be shown in $m^3$. | | | | |
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams | Mg |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit | (F-32)/1.8 | Celsius | °C |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| $mm^2$ | millimeters squared | 0.0016 | square inches | $in^2$ |
| $m^2$ | meters squared | 10.764 | square feet | $ft^2$ |
| $m^2$ | meters squared | 1.196 | square yards | $yd^2$ |
| ha | hectares | 2.47 | acres | ac |
| $km^2$ | kilometers squared | 0.386 | square miles | $mi^2$ |
| | | **VOLUME** | | |
| ml | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | meters cubed | 35.315 | cubic feet | $ft^3$ |
| $m^3$ | meters cubed | 1.308 | cubic yards | $yd^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.205 | pounds | lb |
| Mg | megagrams | 1.102 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius | 1.8C+32 | Fahrenheit | °F |

*SI is the symbol for the International System of Measurement

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# 1.0 INTRODUCTION

Bridge decks, most of which are comprised primarily of concrete and reinforcing steel, are arguably the most important element in assuring safe passage of vehicles over a bridge. The surface of the deck must provide a balance between smooth ride and good skid resistance. The deck distributes and supports the weight of the traffic thereby contributing to the load capacity of the bridge. To some degree, the deck also protects the underlying bridge elements from environmental exposure. However, in performing its function, a bridge deck is exposed to load and thermally induced stresses, deicing chemicals, rain, and abrasion from traffic. These factors lead to cumulative damage and reduced performance including concrete cracks, missing concrete, delaminations, ruts, reduced skid resistance, and corrosion of the steel reinforcement. Often the interactions of the factors that decks are exposed to result in accelerated damage such as chloride from deicing chemicals infiltrating to the steel reinforcement through load induced cracks and causing accelerated corrosion of the steel.

All bridge decks require repairs and will eventually reach a damage state that requires an expensive deck replacement. Consequently, cost-effective procedures that can postpone deck replacement and maintain safe functionality are very appealing to bridge owners. Applying a thin polymer overlay is one such action that can prolong deck life by sealing cracks and restoring skid resistance. Thin polymer overlays consist of a polymer resin, generally epoxy, methyl methacrylate, or polyurethane, that is applied to the surface of the deck. Aggregate is embedded in the polymer. The polymer effectively seals cracks in the concrete, and the aggregate provides the wear and skid resistance. The overall thickness of thin polymer overlays is generally ¼ to ½ inch.

Oregon has had mixed results with thin polymer overlays. In some cases, the overlays have performed well; in other cases, the overlays have delaminated or have been worn to a point where the skid resistance was dangerously low. Compounding the problem of bridge deck preservation is the fact that Oregon allows studded tires, which undoubtedly reduce the life of the thin overlays. Nevertheless, the feeling among Oregon DOT personnel is that thin polymer overlays can provide substantial cost savings and reduce traffic congestion by delaying deck replacements if the products that perform well under Oregon conditions can be identified.

## 1.1 OBJECTIVE

The objectives of this investigation are to identify specific thin polymer overlay products that will provide good performance on Oregon bridges and to recommend a method for qualifying future products.

## 1.2 BACKGROUND

Only limited comparative field studies have been conducted to evaluate the performance of thin polymer overlays under operating conditions (*Guthrie et al. 2005; Wilson and Henley 1995; and*

*Sprinkel et al. 1993*). None of these comparisons were designed to make a direct comparison of the specific overlay products. Wilson and Henley summarized 10 years of experience with epoxy and methyl methacrylate (MMA) overlays in Washington State. According to the investigation, MMA overlays retain skid resistance better than epoxy overlays over time. However, the skid resistance of epoxy overlays starts higher than MMA. This general behavior is illustrated in Figures 1.1 and 1.2 for six different epoxy products and five different MMA products based on the Washington data.

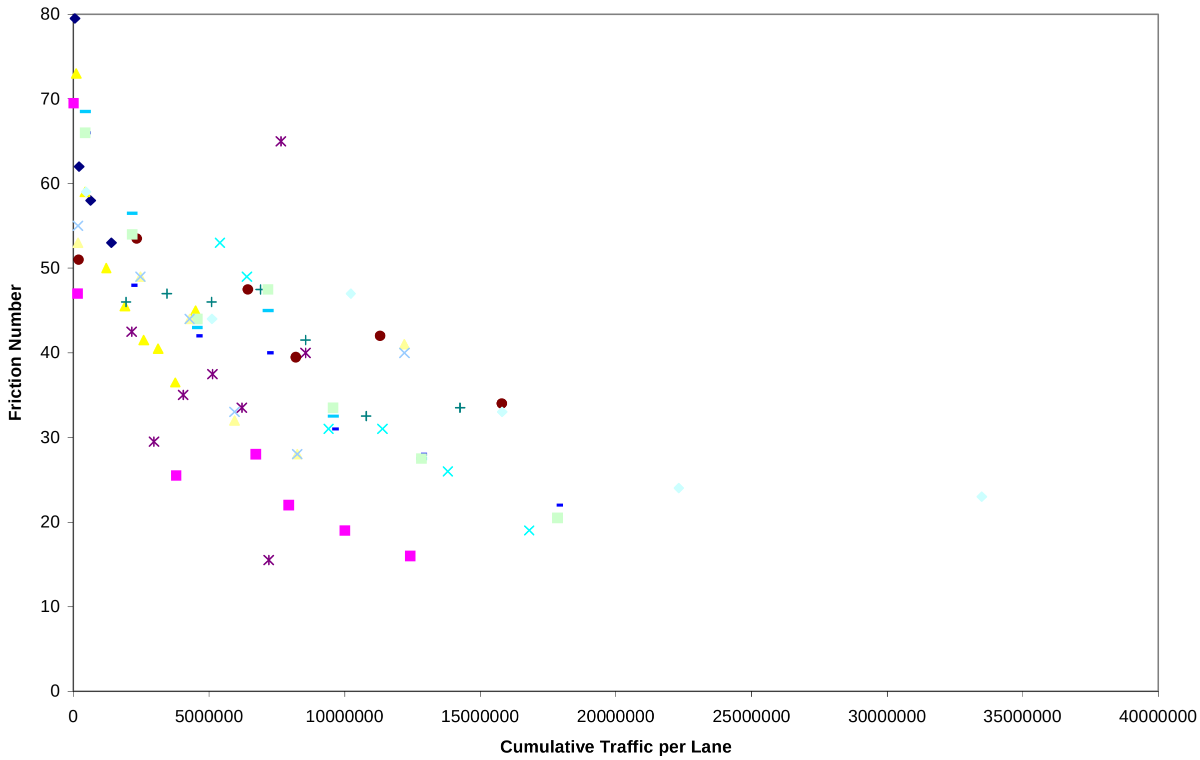



Figure 1.1: In-service skid resistance of thin epoxy overlays.

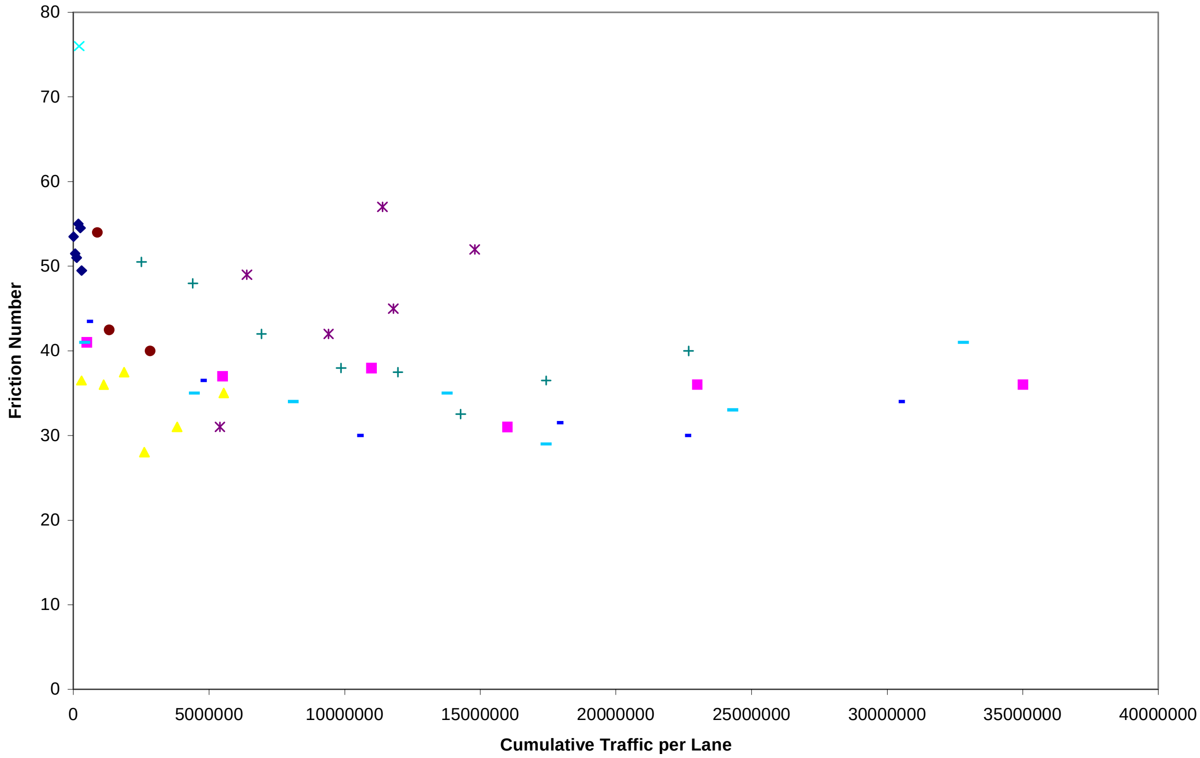



Figure 1.2: In-service skid resistance of thin MMA overlays.

# 2.0 APPROACH

Eight thin polymer overlay manufacturers agreed to provide and install two test sections of their respective products free-of-charge. The manufacturers were responsible for preparing the test sections and applying their respective overlays. Each section had to be a minimum of 120 feet long in order to conduct skid resistance testing with the ODOT skid trailer. Two bridges were selected, Willamette River Bridge at Newberg (08156) and the South Yamhill River Highway 39 McMinnville Spur Bridge (06758), that were long enough to accommodate four test sections in each travel direction. This arrangement allowed the following:

- a direct comparison of each product to five of its peers,
- a second application for each product in case defects in a test section were a result of the section location and not the overlay product, and
- a test of whether the performance of a product can be repeated.

Prior to installation, ODOT mapped the locations of joints, drains, major cracks, and delaminations for each section. Most sections showed substantial cracking, in which case, the cracks in an area extending across the width of the lane and 5-foot along the lane were highlighted and photographed in order to document the degree of cracking. The pre-installation section maps are shown in Appendix A. The section locations and the respective products are shown in Table 2.1. A photograph of the highlighted cracks from Section E is shown in Figure 2.1. Delaminated areas delineated with paint are also shown in the photograph.

**Table 2.1: Overlay product locations.**

| Section ID | Bridge | Start of Section* | Material |
|---|---|---|---|
| A | 08156 - Newberg | 167’ N | Mark 154 by Polycarb |
| B | 08156 - Newberg | 404’ N | Flex-O-Lith by Euclid/Tamms |
| C | 08156 - Newberg | 587’ N | Safetrack HW – 2 Coat System by Stirling Lloyd |
| D | 08156 - Newberg | 712’ N | Kwik Bond PPC MLS by Kwik Bond Polymers |
| E | 08156 - Newberg | 259’ S | Tyregrip by Ennis/Prismo |
| F | 08156 - Newberg | 384’ S | SafeLane HDX by Cargill |
| G | 08156 - Newberg | 566’ S | Urefast PF60 by LiquidConcrete |
| H | 08156 - Newberg | 804’ S | Unitex Pro-Poxy Type III DOT by Unitex |
| I | 06758 - McMinnville | 182’ S | Flex-O-Lith by Euclid/Tamms |
| J | 06758 - McMinnville | 313’ S | Mark 154 by Polycarb |
| K | 06758 - McMinnville | 603’ S | Unitex Pro-Poxy Type III DOT by Unitex |
| L | 06758 - McMinnville | 741’ S | Urefast PF60 by LiquidConcrete |
| M | 06758 - McMinnville | 132’ N | SafeLane HDX by Cargill |
| N | 06758 - McMinnville | 270’ N | Tyregrip by Ennis/Prismo |
| O | 06758 - McMinnville | 560’ N | Kwik Bond PPC MLS by Kwik Bond Polymers |
| P | 06758 - McMinnville | 691’ N | Safetrack HW – 2 Coat System by Stirling Lloyd |

*Distance is from start of bridge in the direction indicated. N – northbound lane, S – southbound lane.

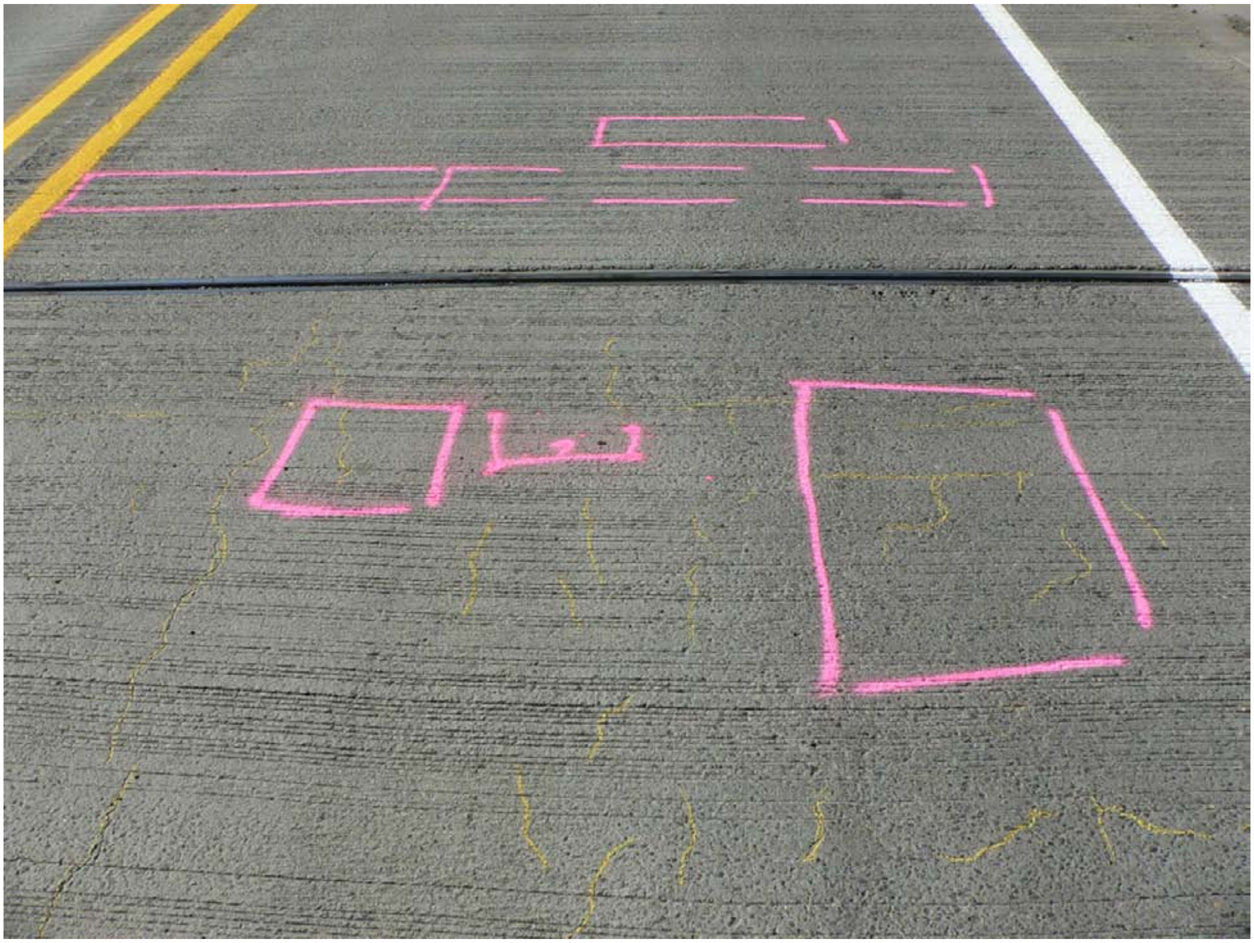


Figure 2.1:  Highlighted cracks and marked delaminations.

# 3.0 RESULTS

## 3.1 OVERLAY INSTALLATIONS

Most of the eight products were applied to the two bridges in July and August. Two sections were overlayed in September. Approximately half of the sections were overlayed at night. Table 3.1 shows the installation dates, the resin type, and the general application steps for each of the eight products. The table also shows photographs of typical application procedures. After the installations, Kwik Bond informed ODOT that Kwik Bond had used different aggregate types for its two installations contrary to the instructions given to the suppliers. The aggregate used on the Newberg Bridge was a 4:1 ratio of Steilacoom Basalt to #6-10 Oregon Emery; the aggregate used on the McMinnville Bridge was 100% Steilacoom Basalt.

**Table 3.1: General application procedure for the overlay products.**

| Product | Installation Date | Installation Contractor | Deck Preparation |
|---|---|---|---|
| Mark 154 | 7/23/07 day - Newberg<br>8/20/07 night - McMinnville | Polycarb | Riding shot blaster |
| Flex-O-Lith | 7/24/07 day - Newberg<br>7/16/07 day - McMinnville | Tough Stuff | Walk behind shot blaster<br> |
| Safetrack HW | 7/23/07 day - Newberg<br>8/22,23/07 night - McMinnville | Pioneer Waterproofing | Walk behind shot blaster |
| Kwik Bond PPC MLS | 7/24/07 day – Newberg<br>9/24/07 night - McMinnville | Concrete Barrier | Riding shot blaster<br> |
| Tyregrip | 7/26/07 day - Newberg<br>8/22/07 night - McMinnville | Apply-A-Line | Walk behind shot blaster |
| SafeLane HDX | 7/25/07 day - Newberg<br>8/28/07 night - McMinnville | Pioneer Waterproofing | Walk behind shot blaster |
| Urefast PF60 | 7/26/07 day - Newberg<br>8/20/07 night - McMinnville | Sullivan | Walk behind shot blaster |
| Unitex Pro-Poxy Type III DOT | 7/26/07 day - Newberg<br>7/16/07 day - McMinnville | Pioneer Waterproofing | Walk behind shot blaster |

**Table 3.1 continued**

| Product | Resin Type | Primer Application | Number of Lifts | Resin Application |
|---|---|---|---|---|
| Mark 154 | Epoxy | None | 2 | Resin in bulk. Components mixed at nozzle of applicator.  |
| Flex-O-Lith | Epoxy | None | 2 | Resin in buckets. Full buckets combined and mixed with drill mixer. |
| Safetrack HW | MMA | PAR-1 resin only | 1 | Primer resin in drum; lift resin in buckets. Resins mixed with activator with drill mixer. Amount of activator depends on concrete temperature. Pre-measured thixotrope added to lift resin to increase viscosity. Inhibitor added to lift resin if concrete temperature too high. |
| Kwik Bond PPC MLS | Polyester | KBP103/204 polyacrylate resin only | 2 | Primer mixed in tank and sprayed onto deck from truck. Approximately 4 gallons of lift resin poured into 5 gallon buckets from bulk drum and mixed with 8 oz of activator using drill mixer. |
| Tyregrip | Epoxy | None | 1 | Resin in buckets. Full buckets combined and mixed with drill mixer. |
| SafeLane HDX | Epoxy | None | 2 | Resin in bulk drums. 4 gallons of resin and hardener were mixed in garbage can with drill mixer. |
| Urefast PF60 | Urethane | R-60 resin and aggregate | 2 | Resin in bulk. Components mixed at nozzle of applicator. |
| Unitex Pro-Poxy Type III DOT | Epoxy | None | 2 | Resin in bulk drums. Approximately 4 gallons of resin and hardener were combined in garbage can and mixed with drill mixer.  |

**Table 3.1 continued**

| Product | Aggregate Type | Aggregate Application | Cleanup |
|---|---|---|---|
| Mark 154 | Oklahoma Flint #8 | Machine broadcast<br> | Compressed air |
| Flex-O-Lith | 3M Indag Basalt #8 | Hand broadcast<br> | Brooms |
| Safetrack HW | Steilacoom basalt | Hand broadcast | Brooms |
| Kwik Bond PPC MLS | 4:1 ratio of Steilacoom Basalt + #6-10 Oregon Emery blend on Newberg Bridge; 100% Steilacoom Basalt on McMinnville Bridge | Hand broadcast | Sweeper<br> |
| Tyregrip | Calcined bauxite | Hand broadcast from back of truck<br> | Sweeper |
| SafeLane HDX | Dolomitic limestone | Hand broadcast | Brooms |
| Urefast PF60 | Steilacoom Basalt | Hand broadcast | Blowers and brooms |
| Unitex Pro-Poxy Type III DOT | #6-10 Oregon Emery | Hand broadcast | Compressed air and brooms<br> |

## 3.2 INSTALLATION OBSERVATIONS

All the installers shot blasted the bridge deck prior to applying resin. The degree of bridge deck preparation varied among the field sections. Some crews made sure all paint and residues were completely removed; other crews made only a cursory attempt at removing the paint lines. Very few crews abraded the deck to the curb. Only one crew was observed adjusting their magnetic sweeping to thoroughly remove shot from the tine grooves on the Newberg Bridge. However, most of the surface areas of the decks were abraded and free of foreign matter and laitance prior to resin application.

The degree of crew experience was obvious during the installations. Some crews did not place the resin and aggregate consistently, which resulted in thin spots in individual lifts and subtle waves in the overlay. The waves are unlikely to affect performance, but the thin areas could wear through prematurely. In some cases, the crews opened the bags of aggregate in such a way that paper and plastic fell into the aggregate and ended up in the overlay. In one case, several steel nuts were found in the overlay.

The installation of the Urefast PF60 overlay on the Newberg Bridge was compromised when the equipment that applies the resin malfunctioned and did not mix the resin components at the correct ratio. Unfortunately, the problem was not detected by the operator, and much of the section was laid down with a resin that did not set up. The crew scraped off the soft layers resulting in a section with many thin and bare areas. The other Urefast PF60 section on the McMinnville Bridge was installed correctly, but after two months, patches of the top lift in the wheel tracks were coming off. Test results for the Urefast PF60 are shown in this report, but the product is not included in the comparative performance analysis.

Kwik Bond informed ODOT that one batch of its resin on the McMinnville Bridge did not receive the correct amount of accelerator. Inspection of the section shortly after this notification showed a 2 ft x 10 ft area with patches of deformed or missing top lift.

## 3.3 SKID RESISTANCE

Skid testing was conducted according to ASTM E 274 for a locked wheel dragged over a wetted pavement surface. Testing was conducted on the overlay sections and bare concrete for each bridge. The data are shown in Table 3.2.

**Table 3.2: Skid testing results.**

| Product | Location | Date | Cumulative Traffic | Pass 1 | Pass 2 | Pass 3 | Pass 4 | Average |
|---|---|---|---|---|---|---|---|---|
| Concrete | Newberg | 9/5/2007 | Initial FN | 36 | 34 | 35 | | 35 |
| | | 2/4/2008 | 281,000 | 58 | 34 | 47 | 48 | 47 |
| | | 6/2/2008 | 501,000 | 37 | 38 | 36 | | 37 |
| | | 10/15/2008 | 751,000 | 32 | 38 | | | 35 |
| | | 6/30/2009 | 1,228,000 | 36 | 41 | 40 | 40 | 40 |
| | | 5/11/2010 | 1,811,000 | 39 | 42 | | | 41 |
| | | 9/20/2010 | 2,055,000 | 40 | 41 | | | 41 |
| | McMinnville | 9/5/2007 | Initial FN | 32 | 34 | 35 | 36 | 34 |
| | | 2/4/2008 | 1,160,000 | 47 | 45 | | | 46 |
| | | 10/15/2008 | 3,090,000 | 32 | 29 | | | 31 |
| | | 6/30/2009 | 5,046,000 | 26 | 29 | | | 28 |
| | | 5/11/2010 | 7,440,000 | 40 | 30 | | | 35 |
| | | 9/20/2010 | 8,444,000 | 38 | 32 | | | 35 |
| Mark 154 | Newberg | 9/5/2007 | 81,400 | 69 | 57 | 66 | 70 | 66 |
| | | 10/30/2007 | 183,000 | 61 | 64 | 77 | 67 | 67 |
| | | 2/4/2008 | 363,000 | 70 | 64 | 72 | 60 | 67 |
| | | 6/2/2008 | 583,000 | 43 | 44 | 45 | 43 | 44 |
| | | 10/15/2008 | 832,000 | 39 | 40 | 40 | 40 | 40 |
| | | 6/30/2009 | 1,310,000 | 32 | 32 | 34 | 36 | 33 |
| | | 5/11/2010 | 1,893,000 | 33 | 35 | 31 | | 33 |
| | | 9/20/2010 | 2,137,000 | 29 | 27 | 25 | | 27 |
| | McMinnville | 9/5/2007 | 114,000 | 70 | 67 | 69 | 67 | 68 |
| | | 10/30/2007 | 532,000 | 61 | 56 | 59 | 59 | 59 |
| | | 2/4/2008 | 1,270,000 | 54 | 59 | 54 | 59 | 56 |
| | | 6/2/2008 | 2,170,000 | 34 | 35 | 35 | 36 | 35 |
| | | 10/15/2008 | 3,200,000 | 32 | 33 | 33 | 32 | 33 |
| | | 6/30/2009 | 5,160,000 | 25 | 21 | 22 | 25 | 23 |
| | | 5/11/2010 | 7,554,000 | 29 | 27 | 25 | | 27 |
| | | 9/20/2010 | 8,558,000 | 26 | 25 | 25 | | 25 |
| Flex-O-Lith | Newberg | 9/5/2007 | 79,600 | 61 | 64 | 65 | 61 | 63 |
| | | 10/30/2007 | 181,000 | 61 | 56 | 59 | 59 | 59 |
| | | 2/4/2008 | 361,000 | 65 | 70 | 56 | 63 | 64 |
| | | 6/2/2008 | 581,000 | 41 | 41 | 40 | 37 | 40 |
| | | 10/15/2008 | 831,000 | 35 | 34 | 32 | 35 | 34 |
| | | 6/30/2009 | 1,308,000 | 27 | 28 | 30 | 33 | 30 |
| | | 5/11/2010 | 1,891,000 | 20 | 21 | 19 | | 20 |
| | | 9/20/2010 | 2,135,000 | 29 | 38 | 18 | | 28 |
| | McMinnville | 9/5/2007 | 388,000 | 63 | 64 | 64 | 64 | 64 |
| | | 10/30/2007 | 806,000 | 61 | 64 | 77 | 67 | 67 |
| | | 2/4/2008 | 1,540,000 | 44 | 55 | 57 | 54 | 52 |
| | | 6/2/2008 | 2,450,000 | 30 | 31 | 32 | 32 | 31 |
| | | 10/15/2008 | 3,470,000 | 30 | 30 | 31 | 30 | 30 |

**Table 3.2 continued**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6/30/2009 | 5,434,000 | 19 | 18 | 20 | 18 | 19 |
| | | 5/11/2010 | 7,828,000 | 22 | 17 | 16 | | 18 |
| | | 9/20/2010 | 8,831,000 | 18 | 19 | 21 | | 19 |
| Safetrack HW | Newberg | 9/5/2007 | 81,400 | 62 | 64 | 64 | 62 | 63 |
| | | 10/30/2007 | 183,000 | 57 | 59 | 63 | 60 | 60 |
| | | 2/4/2008 | 363,000 | 61 | 60 | 60 | 59 | 60 |
| | | 6/2/2008 | 583,000 | 41 | 41 | 40 | 47 | 42 |
| | | 10/15/2008 | 832,000 | 36 | 38 | 37 | 38 | 37 |
| | | 6/30/2009 | 1,310,000 | 32 | 32 | 28 | 33 | 31 |
| | | 5/11/2010 | 1,893,000 | 23 | 28 | 24 | | 25 |
| | | 9/20/2010 | 2,137,000 | 24 | 22 | 21 | | 22 |
| | McMinnville | 9/5/2007 | 106,000 | 67 | 67 | 66 | 66 | 67 |
| | | 10/30/2007 | 524,000 | 64 | 61 | 62 | 70 | 64 |
| | | 2/4/2008 | 1,260,000 | 68 | 58 | 57 | 57 | 60 |
| | | 6/2/2008 | 2,170,000 | 38 | 39 | 37 | 36 | 38 |
| | | 10/15/2008 | 3,190,000 | 34 | 35 | 35 | 33 | 34 |
| | | 6/30/2009 | 5,153,000 | 28 | 28 | 17 | 18 | 23 |
| | | 5/11/2009 | 7,547,000 | 23 | 24 | 21 | | 23 |
| | | 9/20/2010 | 8,550,000 | 35 | 28 | 27 | | 30 |
| Kwik Bond PPC MLS* | Newberg | 9/5/2007 | 79,600 | 62 | 63 | 64 | 58 | 62 |
| | | 10/30/2007 | 181,000 | 60 | 60 | 59 | 58 | 59 |
| | | 2/4/2008 | 361,000 | 62 | 64 | 62 | 62 | 63 |
| | | 6/2/2008 | 581,000 | 48 | 48 | 47 | 48 | 48 |
| | | 10/15/2008 | 831,000 | 42 | 41 | 41 | 38 | 41 |
| | | 6/30/2009 | 1,308,000 | 46 | 44 | 45 | 50 | 46 |
| | | 5/11/2010 | 1,891,000 | 23 | 37 | 36 | | 32 |
| | | 9/20/2010 | 2,135,000 | 35 | 33 | 32 | | 33 |
| | McMinnville | 10/10/2007 | 122,000 | 72 | 69 | 64 | 61 | 67 |
| | | 10/30/2007 | 274,000 | 38 | 47 | 51 | 51 | 46 |
| | | 2/4/2008 | 1,010,000 | 57 | 62 | 62 | 62 | 61 |
| | | 6/2/2008 | 1,920,000 | 37 | 38 | 40 | 41 | 39 |
| | | 10/15/2008 | 2,940,000 | 35 | 36 | 39 | 36 | 36 |
| | | 6/30/2009 | 4,902,000 | 27 | 31 | 31 | 28 | 29 |
| | | 5/11/2010 | 7,296,000 | 29 | 27 | 27 | | 28 |
| | | 9/20/2010 | 8,299,000 | 28 | 28 | 37 | | 31 |
| Tyregrip | Newberg | 9/5/2007 | 75,800 | 73 | 51 | 69 | 69 | 66 |
| | | 10/30/2007 | 178,000 | 72 | 74 | 78 | 76 | 75 |
| | | 2/4/2008 | 357,000 | 74 | 75 | 76 | 71 | 74 |
| | | 6/2/2008 | 577,000 | 60 | 61 | 63 | 59 | 61 |
| | | 10/15/2008 | 827,000 | 49 | 50 | 40 | 34 | 43 |
| | | 6/30/2009 | 1,304,000 | 53 | 60 | 60 | 53 | 56 |
| | | 5/11/2010 | 1,887,000 | 49 | 47 | 47 | | 47 |
| | | 9/20/2010 | 2,131,000 | 47 | 49 | 53 | | 50 |

**Table 3.2 continued**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | McMinnville | 9/5/2007 | 106,000 | 79 | 75 | 75 | 77 | 77 |
| | | 10/30/2007 | 524,000 | 47 | 54 | 50 | 62 | 53 |
| | | 2/4/2008 | 1,260,000 | 60 | 77 | 72 | 69 | 69 |
| | | 6/2/2008 | 2,170,000 | 40 | 38 | 42 | 44 | 41 |
| | | 10/15/2008 | 3,190,000 | 44 | 48 | 46 | 48 | 46 |
| | | 6/30/2009 | 5,153,000 | 41 | 45 | 42 | 44 | 43 |
| | | 5/11/2010 | 7,547,000 | 47 | 47 | 47 | | 47 |
| | | 9/20/2010 | 8,550,000 | 55 | 55 | 52 | | 54 |
| SafeLane HDX | Newberg | 9/5/2007 | 77,700 | 55 | 54 | 58 | 56 | 56 |
| | | 10/30/2007 | 179,000 | 47 | 54 | 46 | 62 | 52 |
| | | 2/4/2008 | 359,000 | 54 | 50 | 57 | 53 | 53 |
| | | 6/2/2008 | 579,000 | 36 | 37 | 35 | 38 | 37 |
| | | 10/15/2008 | 829,000 | 35 | 27 | 29 | 30 | 30 |
| | | 6/30/2009 | 1,306,000 | 27 | 29 | 25 | 30 | 28 |
| | | 5/11/2010 | 1,889,000 | 25 | 23 | 21 | | 23 |
| | | 9/20/2010 | 2,133,000 | 29 | 20 | 18 | | 22 |
| | McMinnville | 9/5/2007 | 60,800 | 70 | 69 | 66 | 67 | 68 |
| | | 10/30/2007 | 479,000 | 72 | 74 | 78 | 76 | 75 |
| | | 2/4/2008 | 1,220,000 | 52 | 53 | 51 | 50 | 51 |
| | | 6/2/2008 | 2,120,000 | 33 | 31 | 36 | 29 | 32 |
| | | 10/15/2008 | 3,150,000 | 23 | 26 | 26 | 25 | 25 |
| | | 6/30/2009 | 5,107,000 | 18 | 18 | 18 | 20 | 19 |
| | | 5/11/2010 | 7,501,000 | 18 | 18 | 23 | | 20 |
| | | 9/20/2010 | 8,504,000 | 20 | 23 | 22 | | 22 |
| Urefast PF60 | Newberg | 9/5/2007 | 75,800 | 54 | 55 | 51 | 48 | 52 |
| | | 10/30/2007 | 178,000 | 38 | 47 | 51 | 51 | 46 |
| | | 2/4/2008 | 357,000 | 48 | 46 | 43 | 43 | 45 |
| | | 6/2/2008 | 577,000 | 34 | 32 | 32 | 33 | 33 |
| | | 10/15/2008 | 827,000 | 29 | 31 | 26 | 29 | 29 |
| | | 6/30/2009 | 1,304,000 | 32 | 32 | 29 | 31 | 31 |
| | | 5/11/2010 | 1,887,000 | 27 | 24 | 26 | | 25 |
| | | 9/20/2010 | 2,131,000 | 25 | 23 | 23 | | 24 |
| | McMinnville | 9/5/2007 | 114,000 | 51 | 47 | 48 | 48 | 49 |
| | | 10/30/2007 | 532,000 | 60 | 60 | 59 | 58 | 59 |
| | | 2/4/2008 | 1,270,000 | 48 | 49 | 46 | 48 | 48 |
| | | 6/2/2008 | 2,170,000 | 32 | 30 | 32 | 42 | 34 |
| | | 10/15/2008 | 3,200,000 | 27 | 26 | 28 | 27 | 27 |
| | | 6/30/2009 | 5,160,000 | 32 | 26 | 26 | 27 | 28 |
| | | 5/11/2010 | 7,554,000 | 38 | 40 | 40 | | 39 |
| | | 9/20/2010 | 8,558,000 | 39 | 39 | 38 | | 39 |
| Unitex Pro-Poxy Type | Newberg | 9/5/2007 | 75,800 | 73 | 36 | 75 | 77 | 65 |
| | | 10/30/2007 | 178,000 | 64 | 61 | 63 | 70 | 64 |
| | | 2/4/2008 | 357,000 | 63 | 62 | 64 | 60 | 62 |

**Table 3.2 continued**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 6/2/2008 | 577,000 | 47 | 46 | 39 | 50 | 45 |
| | | 10/15/2008 | 827,000 | 40 | 42 | 41 | 41 | 41 |
| | | 6/30/2009 | 1,304,000 | 43 | 42 | 38 | 50 | 43 |
| | | 5/11/2010 | 1,887,000 | 32 | 32 | 31 | | 32 |
| | | 9/20/2010 | 2,131,000 | 33 | 31 | 36 | | 33 |
| | McMinnville | 9/5/2007 | 388,000 | 67 | 67 | 66 | 66 | 67 |
| | | 10/30/2007 | 806,000 | 64 | 61 | 62 | 70 | 64 |
| | | 2/4/2008 | 1,540,000 | 68 | 58 | 57 | 57 | 60 |
| | | 6/2/2008 | 2,450,000 | 38 | 39 | 37 | 36 | 38 |
| | | 10/15/2008 | 3,470,000 | 34 | 35 | 35 | 33 | 34 |
| | | 6/30/2009 | 5,434,000 | 28 | 30 | 37 | 31 | 32 |
| | | 5/11/2010 | 7,828,000 | 48 | 30 | 27 | | 35 |
| | | 9/20/2010 | 8,831,000 | 37 | 32 | 31 | | 33 |

*For Kwik Bond, Newberg aggregate was 4:1 Steilacoom Basalt to Oregon Emery; McMinnville aggregate was 100% Steilacoom Basalt.

## 3.4 LABORATORY TESTS

Laboratory tests were conducted to characterize the resins, aggregates, and the overlay systems. The intent was to investigate whether a set of common tests could be used to predict field performance. Except for the ultraviolet light exposure, tests were selected that could be conducted easily in most transportation laboratories. The laboratory tests performed on the Kwik Bond PPC MLS system were done only for specimens containing the 4:1 Steilacoom Basalt to Oregon Emery.

The aggregate for each product was characterized. Because Safetrack HW, Urefast PF60, and Kwik Bond at McMinnville used the same aggregate, the same aggregate sample was used to represent these three systems. The results of the aggregate testing are shown in Table 3.3 with details in Appendix B-1.

**Table 3.3: Aggregate characteristics.**

| Product | Aggregate Type | Average Size* (in) | Bulk Specific Gravity | Absorption (%) | Soundness (Total % Loss) | Microdeval (% Loss) |
|---|---|---|---|---|---|---|
| Mark 154 | Oklahoma Flint #8 | 0.13 | 2.572 | 1.16 | 2.6 | 9.2 |
| Flex-O-Lith | 3M Indag Basalt #8 | 0.08 | 3.079 | 0.32 | 1.2 | 7.4 |
| Safetrack HW; Urefast PF60; Kwik Bond PPC (McMinnville) | Steilacoom Basalt | 0.10 | 2.670 | 1.07 | 1.4 | 8.1 |
| Kwik Bond PPC MLS (Newberg) | Steilacoom Basalt + #6-10 Oregon Emery | 0.10 | 2.690 | 0.87 | 1.2 | 8.0 |
| Tyregrip | Calcined bauxite | 0.10 | 3.176 | 1.60 | 0.2 | 5.1 |
| SafeLane HDX | Dolomitic limestone | 0.16 | 2.720 | 1.29 | 1.0 | 12.9 |
| Unitex Pro-Poxy Type III DOT | #6-10 Oregon Emery | 0.08 | 2.875 | 1.23 | 0.6 | 5.3 |

*Based on the weighted average of the sieve analysis.

Abrasion testing was conducted on panels made on-site when the overlay sections were installed. Two areas on the panels were tested. The abrasion test was based on the rotating cutter method described in ASTM C 944. The rotating cutter samples were conditioned prior to testing by dragging a crowbar across the surface for three minutes. This procedure knocked off the aggregate that were weakly bonded to the overlay. A force of 22 pounds was exerted on the cutter, and a rotation speed of 250 rpm was used. Each test location was abraded for five 2-minute intervals, and the weight loss was measured after each interval. By the last interval, the rate of weight loss had leveled off. Table 3.4 reports the average weight loss for the last interval for each of the overlay systems with details provided in Appendix B-2.

**Table 3.4: Abrasion test results.**

| Product | Aggregate Type | Sample 1 | Sample 2 | Average |
|---|---|---|---|---|
| Mark 154 | Oklahoma Flint #8 | 0.7 | 0.8 | 0.8 |
| Flex-O-Lith | 3M Indag Basalt #8 | 0.7 | 0.5 | 0.6 |
| Safetrack HW | Steilacoom Basalt | 0.4 | 0.5 | 0.4 |
| Kwik Bond PPC MLS (Newberg) | Steilacoom Basalt + #6-10 Oregon Emery | 0.8 | 0.6 | 0.7 |
| Tyregrip | Calcined bauxite | 0.5 | 0.6 | 0.5 |
| SafeLane HDX | Dolomitic limestone | 1.3 | 1.1 | 1.2 |
| Urefast PF60 | Steilacoom Basalt | 0.2 | 0.5 | 0.3 |
| Unitex Pro-Poxy Type III DOT | #6-10 Oregon Emery | 0.4 | 0.4 | 0.4 |

Note: Values are the weight loss in grams during the last two minutes of ten minutes of grinding.

Water absorption tests were conducted on the resins according to ASTM D-570. The tests were run for five weeks at which time the specimens showed little or no additional water absorption. Table 3.5 shows the percent increase in weight due to water absorption after the five weeks.

**Table 3.5: Water absorption results of the resins.**

| Product | Sample 1 | Sample 2 | Sample 3 | Average |
|---|---|---|---|---|
| Mark 154 | 5.8 | 2.9 | 4.8 | 4.5 |
| Flex-O-Lith | 2.3 | 2.3 | 2.1 | 2.3 |
| Safetrack HW | 2.0 | 1.4 | 1.3 | 1.6 |
| Kwik Bond PPC MLS | 1.9 | 1.7 | 2.0 | 1.9 |
| Tyregrip | 0.9 | 1.1 | 1.0 | 1.0 |
| SafeLane HDX | 1.4 | 1.5 | 1.3 | 1.4 |
| Urefast PF60 | 5.0 | 5.1 | 5.0 | 5.0 |
| Unitex Pro-Poxy Type III DOT | 1.3 | 1.3 | 1.4 | 1.3 |

Note: Values are the percentage increase in weight.

Tensile strength tests were conducted on the resins according to ASTM D 638. Specimens were tested at 0, 70, and 140$^{o}$F in order to cover the range of expected operating temperatures. In addition, sets of tensile specimens were exposed to ultraviolet light based on ASTM G 155 in a Weatherometer to simulate sunshine prior to testing at 70$^{o}$F. The results are shown in Tables 3.6, 3.7, and 3.8.

**Table 3.6: Tensile strength results of the resins at various temperatures.**

| Temperature | Product | Sample 1 (psi) | Sample 2 (psi) | Sample 3 (psi) | Sample 4 (psi) | Average (psi) |
|---|---|---|---|---|---|---|
| 0°F | Mark 154 | 4596 | 2147 | 5330 | 5555 | 4407 |
| | Flex-O-Lith | 4958 | 5952* | 6458 | 5147 | >5629 |
| | Safetrack HW | 2667 | 2484 | 1916 | 1489 | 2139 |
| | Kwik Bond PPC MLS | 12500* | 6396 | 8333* | 13158* | >10097 |
| | Tyregrip | 6662 | 8621* | 5762 | 2996 | >6010 |
| | SafeLane HDX | 8200 | 3598 | 5281 | 7576* | >6164 |
| | Urefast PF60 | 6461 | 6890 | 5547 | 7152 | 6513 |
| | Unitex Pro-Poxy Type III DOT | 8265 | 7353* | 7671 | 9615* | >8226 |
| 70°F | Mark 154 | 3620 | 2730 | 2643 | 2896 | 2972 |
| | Flex-O-Lith | 1938 | 2314 | 2580 | 1825 | 2164 |
| | | | | | | |
| | Safetrack HW | 3272 | 2523 | 2178 | 2936 | 2727 |
| | Kwik Bond PPC MLS | 3020 | 1626 | 2178 | 2936 | 2440 |
| | Tyregrip | 5330 | 5366 | 4848 | 5036 | 5138 |
| | SafeLane HDX | 2659 | 2447 | 2636 | 2516 | 2565 |
| | Urefast PF60 | 3368 | 2304 | 1924 | 2590 | 2547 |
| | Unitex Pro-Poxy Type III DOT | 4366 | 5251 | 2708 | 3802 | 4032 |
| 140°F | Mark 154 | 243 | 328 | 340 | 296 | 302 |
| | Flex-O-Lith | 201 | 250 | 219 | 283 | 238 |
| | Safetrack HW | 975 | 1457 | 1295 | 1247 | 1244 |
| | Kwik Bond PPC MLS | 1154 | 880 | 740 | 449 | 806 |
| | Tyregrip | 518 | 486 | 1480 | 181 | 666 |
| | SafeLane HDX | 144 | 215 | 123 | 221 | 176 |
| | Urefast PF60 | 873 | 599 | 378 | 608 | 615 |
| | Unitex Pro-Poxy Type III DOT | 268 | 281 | 405 | 430 | 346 |

*Exceeded load cell range of 250 pounds, so specimen strength was greater than reported value.

**Table 3.7: Tensile elongation results of the resins at various temperatures.**

| Temperature | Product | Sample 1 (%) | Sample 2 (%) | Sample 3 (%) | Sample 4 (%) | Average (%) |
|---|---|---|---|---|---|---|
| 0°F | Mark 154 | 25 | 20 | 30 | 30 | 26 |
| | Flex-O-Lith | 35 | 25 | 25 | 20 | 26 |
| | Safetrack HW | 20 | 15 | 20 | 10 | 16 |
| | Kwik Bond PPC MLS | 35 | 30 | 30 | 30 | 31 |
| | Tyregrip | 30 | 30 | 35 | 20 | 29 |
| | SafeLane HDX | 30 | 15 | 20 | 30 | 24 |
| | Urefast PF60 | 30 | 50 | 40 | 40 | 40 |
| | Unitex Pro-Poxy Type III DOT | 50 | 20 | 35 | 35 | 35 |
| 70°F | Mark 154 | 60 | 70 | 80 | 90 | 75 |
| | Flex-O-Lith | 70 | 80 | 90 | 65 | 76 |
| | Safetrack HW | 20 | 20 | 15 | 30 | 21 |
| | Kwik Bond PPC MLS | 40 | 40 | 45 | 30 | 39 |
| | Tyregrip | 30 | 30 | 30 | 40 | 33 |
| | SafeLane HDX | 65 | 80 | 50 | 65 | 65 |

**Table 3.7 continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| | Urefast PF60 | 115 | 105 | 105 | 130 | 114 |
| | Unitex Pro-Poxy Type III DOT | 35 | 55 | 40 | 45 | 44 |
| | Mark 154 | 110 | 115 | 120 | 145 | 123 |
| 140°F | Flex-O-Lith | 80 | 80 | 55 | 70 | 71 |
| | Safetrack HW | 15 | 35 | 65 | 20 | 34 |
| | Kwik Bond PPC MLS | 70 | 60 | 65 | 55 | 63 |
| | Tyregrip | 55 | 45 | 40 | 30 | 43 |
| | SafeLane HDX | 60 | 70 | 45 | 60 | 59 |
| | Urefast PF60 | 140 | 145 | 90 | 120 | 124 |
| | Unitex Pro-Poxy Type III DOT | 80 | 85 | 90 | 70 | 81 |
| | | | | | | |

**Table 3.8: 70°F tensile results of the resins after exposure to simulated terrestrial sunlight.**

| Exposure (hours) | Product | Strength | | | Elongation | | |
|---|---|---|---|---|---|---|---|
| | | Sample 1 (psi) | Sample 2 (psi) | Average (psi) | Sample 1 (%) | Sample 2 (%) | Average (%) |
| 500 | Mark 154 | 599 | 1426 | 1013 | 25 | 19 | 22 |
| | Flex-O-Lith | 1029 | 959 | 994 | 22 | 19 | 21 |
| | Safetrack HW | 1933 | 2140 | 2037 | 22 | 25 | 24 |
| | Kwik Bond PPC MLS | 4911 | 2588 | 3750 | 47 | 25 | 36 |
| | Tyregrip | 1950 | 2888 | 2419 | 22 | 28 | 25 |
| | SafeLane HDX | 1185 | 1133 | 1159 | 9 | 19 | 14 |
| | Urefast PF60 | 2242 | 2505 | 2374 | 88 | 94 | 91 |
| | Unitex Pro-Poxy Type III DOT | 1891 | 2451 | 2171 | 28 | 19 | 24 |
| 1000 | Mark 154 | 1481 | 2025 | 1753 | 25 | 19 | 22 |
| | Flex-O-Lith | 1245 | 1217 | 1231 | 19 | - | 19 |
| | Safetrack HW | 579 | 2056 | 1318 | 6 | 19 | 13 |
| | Kwik Bond PPC MLS | 3714 | 4051 | 3883 | 31 | 38 | 35 |
| | Tyregrip | 2914 | 1133 | 2024 | 19 | 19 | 19 |
| | SafeLane HDX | 1930 | 1667 | 1799 | 13 | 19 | 16 |
| | Urefast PF60 | 2000 | 2050 | 2025 | 113 | 94 | 104 |
| | Unitex Pro-Poxy Type III DOT | 1694 | 1000 | 1347 | 19 | 19 | 19 |
| 1500 | Mark 154 | 1395 | 1295 | 1345 | 13 | 13 | 13 |
| | Flex-O-Lith | - | 1105 | 1105 | 19 | 16 | 18 |
| | Safetrack HW | 1829 | 1250 | 1540 | 19 | 13 | 16 |
| | Kwik Bond PPC MLS | 2444 | 4618 | 3531 | 19 | 22 | 21 |
| | Tyregrip | 391 | 645 | 518 | 9 | - | 9 |
| | SafeLane HDX | 1417 | 1143 | 1280 | 16 | - | 16 |
| | Urefast PF60 | 2125 | 2081 | 2103 | 103 | 78 | 91 |
| | Unitex Pro-Poxy Type III DOT | 1588 | 1568 | 1578 | 16 | 16 | 16 |

Flexural strength and compressive strength tests were conducted on the overlay systems according to ASTM C 580 and ASTM C 579 respectively. Specimens were tested at 0, 70, and 140°F in order to cover the range of expected operating temperatures. The results are shown in Tables 3.9 and 3.10.

**Table 3.9: Flexural strength results of the overlay systems at various temperatures.**

| Temperature | Product | Sample 1 (psi) | Sample 2 (psi) | Sample 3 (psi) | Sample 4 (psi) | Average (psi) |
|---|---|---|---|---|---|---|
| 0°F | Mark 154 | 2564 | 3839 | 4154 | 4048 | 3651 |
| | Flex-O-Lith | 3494 | 3902 | 4169 | 3468 | 3758 |
| | Safetrack HW | 3520 | 3730 | 3791 | 3616 | 3664 |
| | Kwik Bond PPC MLS | 3978 | 4162 | 3696 | 3806 | 3911 |
| | Tyregrip | 4444 | 4679 | 4391 | 4966 | 4620 |
| | SafeLane HDX | 3337 | 3100 | 3043 | 2937 | 3104 |
| | Urefast PF60 | 2737 | 2776 | 2752 | 2689 | 2739 |
| | Unitex Pro-Poxy Type III DOT | 4908 | 5114 | 5109 | 5304 | 5109 |
| 70°F | Mark 154 | 1611 | 2436 | 1937 | 1159 | 1786 |
| | Flex-O-Lith | 2346 | 2237 | 2362 | 2243 | 2297 |
| | Safetrack HW | 3031 | 3082 | 3184 | 2275 | 2893 |
| | Kwik Bond PPC MLS | 2223 | 2055 | 2217 | 2150 | 2161 |
| | Tyregrip | 2770 | 2933 | 2762 | 2745 | 2803 |
| | SafeLane HDX | 1676 | 1783 | 1725 | 2260 | 1861 |
| | Urefast PF60 | 1100 | 1725 | 1038 | 1320 | 1296 |
| | Unitex Pro-Poxy Type III DOT | 4100 | 4442 | 4480 | 4091 | 4278 |
| 140°F | Mark 154 | 259 | 332 | 211 | 245 | 262 |
| | Flex-O-Lith | 384 | 297 | 242 | 225 | 287 |
| | Safetrack HW | 1402 | 1444 | 1418 | 1079 | 1336 |
| | Kwik Bond PPC MLS | 585 | 449 | 404 | 392 | 458 |
| | Tyregrip | 344 | 264 | 351 | 428 | 347 |
| | SafeLane HDX | 282 | 288 | 305 | 281 | 289 |
| | Urefast PF60 | 458 | 194 | 332 | 273 | 314 |
| | Unitex Pro-Poxy Type III DOT | 314 | 339 | 325 | 365 | 336 |

**Table 3.10: Compressive strength results of the overlay systems at various temperatures**

| Temperature | Product | Sample 1 (psi) | Sample 2 (psi) | Sample 3 (psi) | Sample 4 (psi) | Average (psi) |
|---|---|---|---|---|---|---|
| 0°F | Mark 154 | 10648 | 9825 | 11901 | 11500 | 10968 |
| | Flex-O-Lith | 10865 | 9697 | 10586 | 11902 | 10762 |
| | Safetrack HW | 7118 | 9049 | 8498 | 9520 | 8546 |
| | Kwik Bond PPC MLS | 11703 | 12660 | 12263 | 11014 | 11910 |
| | Tyregrip | 12486 | 10806 | 10418 | 13143 | 11713 |
| | SafeLane HDX | 12952 | 9357 | 11547 | 7704 | 10390 |
| | Urefast PF60 | 4047 | 4342 | 3964 | 3549 | 3976 |
| | Unitex Pro-Poxy Type III DOT | 14619 | 13646 | 11973 | 13707 | 13486 |
| 70°F | Mark 154 | 4429 | 4779 | 4452 | 3976 | 4409 |
| | Flex-O-Lith | 4515 | 4706 | 6171 | 4808 | 5050 |
| | Safetrack HW | 6359 | 8155 | 4666 | 5866 | 6262 |
| | Kwik Bond PPC MLS | 5150 | 5230 | 5256 | 5294 | 5233 |
| | Tyregrip | 7927 | 7722 | 7352 | - | 7667 |
| | SafeLane HDX | 5076 | 4129 | 4073 | 3696 | 4243 |
| | Urefast PF60 | 3371 | 2108 | 2251 | 2484 | 2554 |
| | Unitex Pro-Poxy Type III DOT | 5905 | 7726 | 7917 | 6949 | 7124 |

**Table 3.10 continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| 140°F | Mark 154 | 482 | 329 | 304 | 464 | 395 |
| | Flex-O-Lith | 550 | 543 | 734 | 669 | 624 |
| | Safetrack HW | 2299 | 1929 | 2146 | 1922 | 2074 |
| | Kwik Bond PPC MLS | 989 | 1216 | 1084 | 1273 | 1140 |
| | Tyregrip | 1035 | 1225 | 1190 | 1147 | 1149 |
| | SafeLane HDX | 449 | 629 | 545 | 576 | 550 |
| | Urefast PF60 | 468 | 394 | 467 | 569 | 474 |
| | Unitex Pro-Poxy Type III DOT | 710 | 730 | 558 | 708 | 676 |

## 3.5 INSPECTION

Visual and delamination inspections were conducted in June of 2009 and 2010. By June 2010 the overlays were in service for 33 to 35 months, depending on the installation date for a particular section. The mapped delaminations are included on the surveys in Appendix A and summarized in Table 3.10. Close-up photographs of the overlays are shown in Figure 3.1.

Most indications of delaminations were associated with known delaminations in the underlying concrete and were not included in Table 3.11. However, the delaminations that were reported in the Table may still be due to the concrete substrate if new concrete delaminations developed between the time of the pre-installation and overlay surveys - a period of three to four years. This could be the case especially for the McMinnville bridge, which was showing signs of deck deterioration. Most of the delaminations recorded in Table 3.10 were for the bridge at McMinnville. Due to the possibility of detecting concrete delamination instead of actual overlay delamination, a delamination survey was not conducted at the McMinnville Bridge for June 2010.

Safetrack HW and Tyregrip showed evidence of wearing through to the concrete. Flex-O-Lith also showed wear-through in one part of one section, but this was attributed to insufficient overlay thickness due to the contractor running out of resin during installation. Subsequent comparisons in this report do not show Flex-O-Lith exhibiting wear-through.

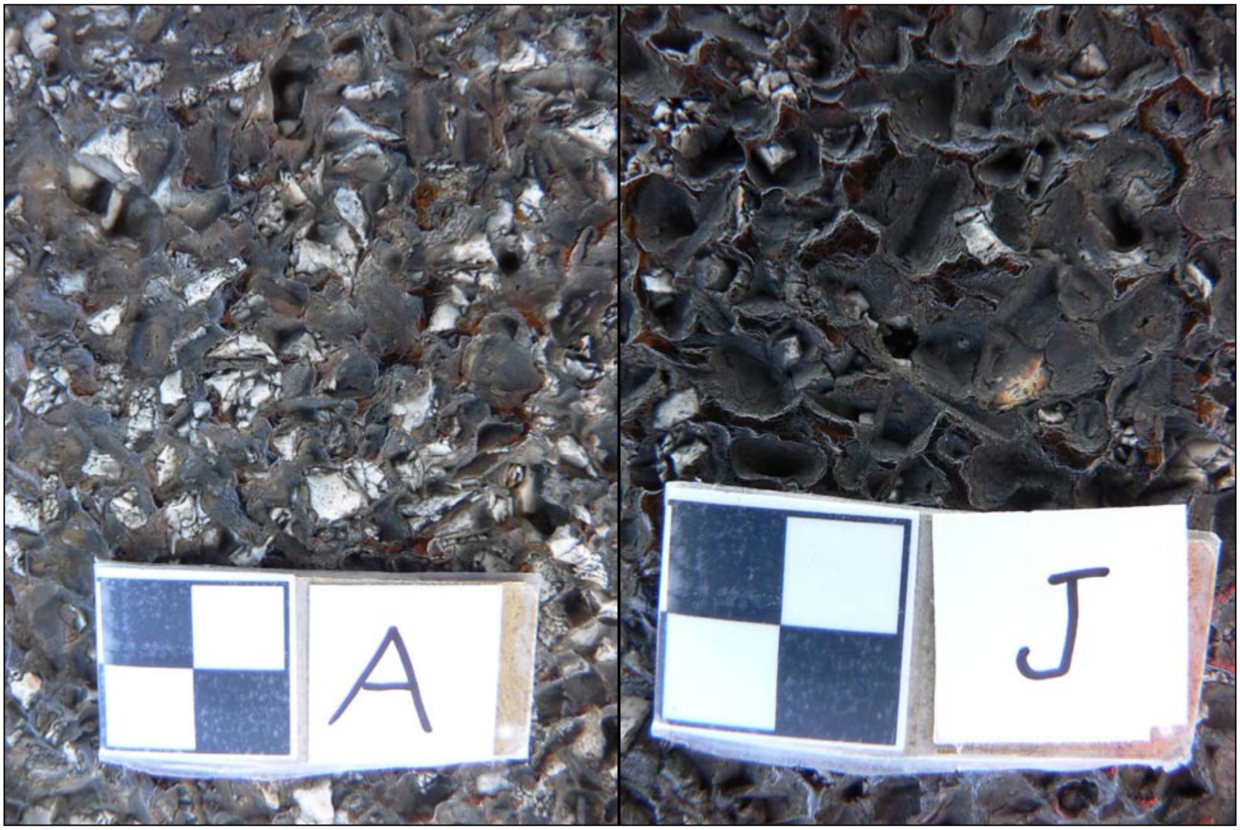
A common feature shown in the photographs of Figure 3.1 was voids in the overlays presumably from missing aggregate. No attempt was made to investigate the mechanism for the void formation (e.g., aggregate pull-out, aggregate crushing); however, some photographs showed aggregate that appeared highly fractured. The presence of fractured aggregate indicates that aggregate crushing may be one cause of the voids.

**Table 3.11: Inspection results.**

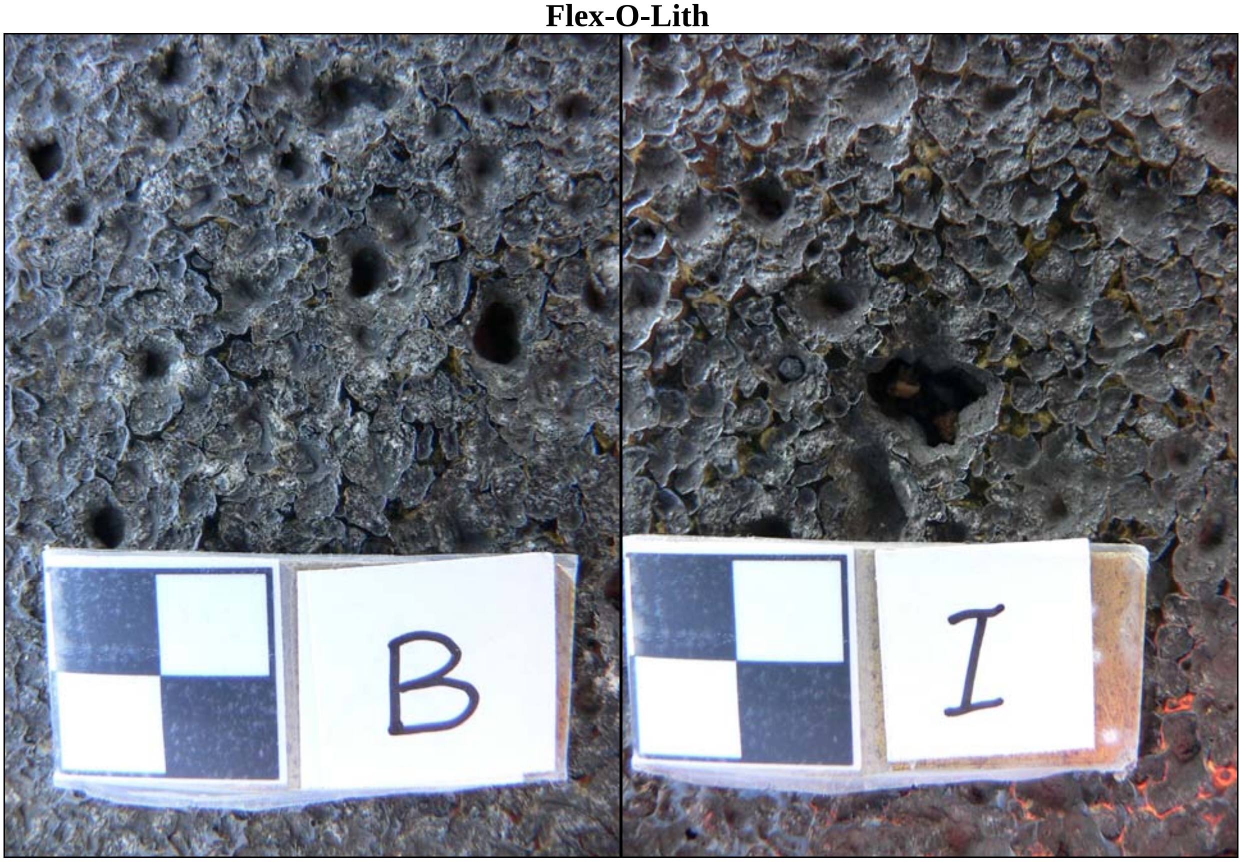
| Product | Installation Date | Traffic Exposure | Truck Exposure | Number of Delaminations * | Comments |
|---|---|---|---|---|---|
| Mark 154 | 7/23/07 Newberg | 1,300,000 | 112,000 | 0 | |
| | 8/20/07 McMinnville | 5,110,000 | 240,000 | 1 | |
| Flex-O-Lith | 7/24/07 Newberg | 1,300,000 | 112,000 | 1 | During installation, the contractor ran out of resin before completing the last 25' of the section. The overlay was wearing through to the concrete in this part of the section in June 2009 |
| | 7/16/07 McMinnville | 5,390,000 | 253,000 | 0 | |
| Safetrack HW | 7/23/07 Newberg | 1,300,000 | 112,000 | 7 | Started to wear through to concrete by June 2009. ~10% of wheel paths had worn through by June 2010 |
| | 8/22/07 McMinnville | 5,110,000 | 240,000 | 4 | ~10% of wheel paths had worn through to concrete by June 2009. ~15% of wheel paths had worn through by June 2010 |
| Kwik Bond PPC MLS** | 7/24/07 Newberg | 1,300,000 | 112,000 | 2 | |
| | 9/24/07 McMinnville | 4,860,000 | 228,000 | 3 | |
| Tyregrip | 7/26/07 Newberg | 1,290,000 | 111,000 | 0 | Beginning to wear through to concrete by June 2009. ~5% of wheel paths had worn through by June 2010. |
| | 8/22/07 McMinnville | 5,110,000 | 240,000 | 10 | Beginning to wear through to concrete. |
| SafeLane HDX | 7/25/07 Newberg | 1,290,000 | 111,000 | 2 | |
| | 8/28/07 McMinnville | 5,060,000 | 238,000 | 2 | |
| Urefast PF60 | 7/26/07 Newberg | 1,290,000 | 111,000 | Not surveyed | |
| | 8/20/07 McMinnville | 5,110,000 | 240,000 | Not surveyed | |
| Unitex Pro-Poxy Type III DOT | 7/26/07 Newberg | 1,290,000 | 111,000 | 4 | |
| | 7/16/07 McMinnville | 5,390,000 | 253,000 | 11 | |

*Delamination indications that coincided with pre-installation indications are not included in the counts shown. Newberg values are from the June 2010 survey and the McMinnville values are from the June 2009 survey.
**For Kwik Bond, Newberg aggregate was 4:1 Steilacoom Basalt to Oregon Emery; McMinnville aggregate was 100% Steilacoom Basalt.

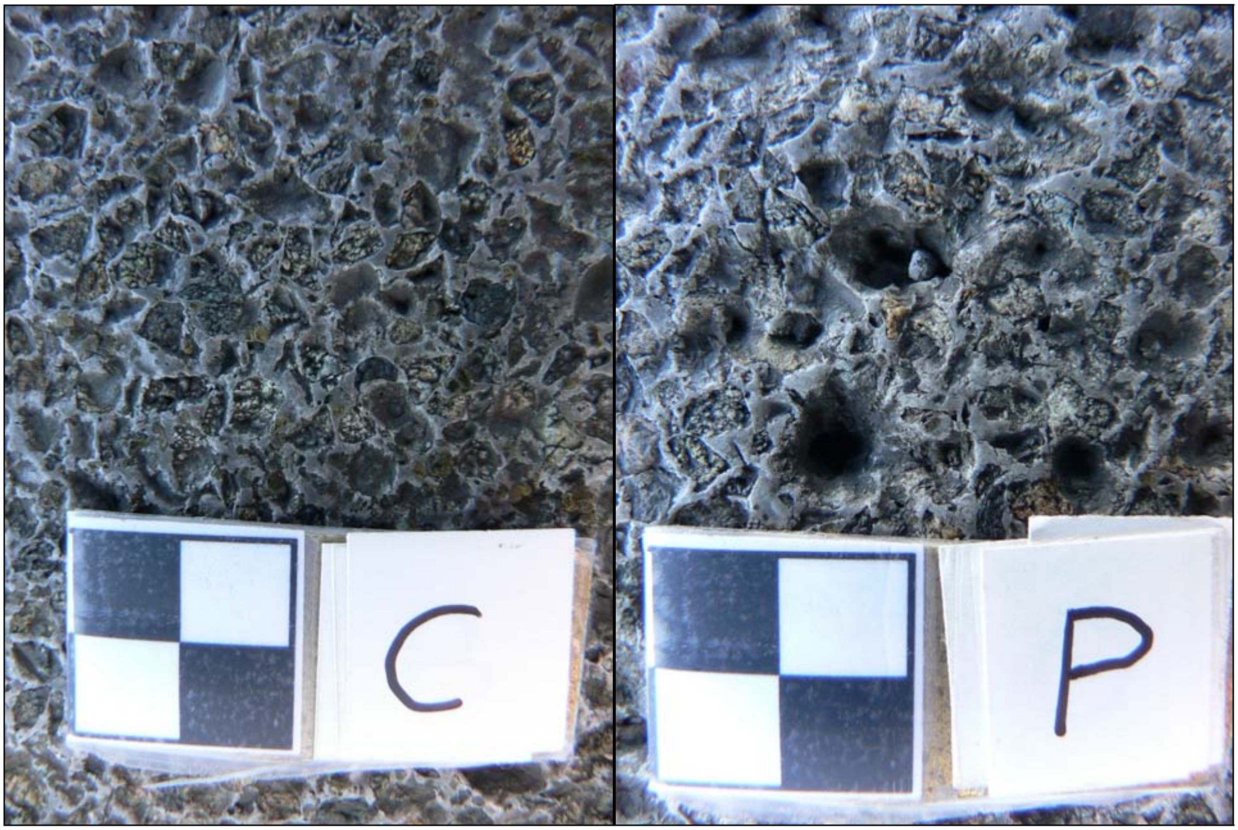
**Mark 154**




**Flex-O-Lith**

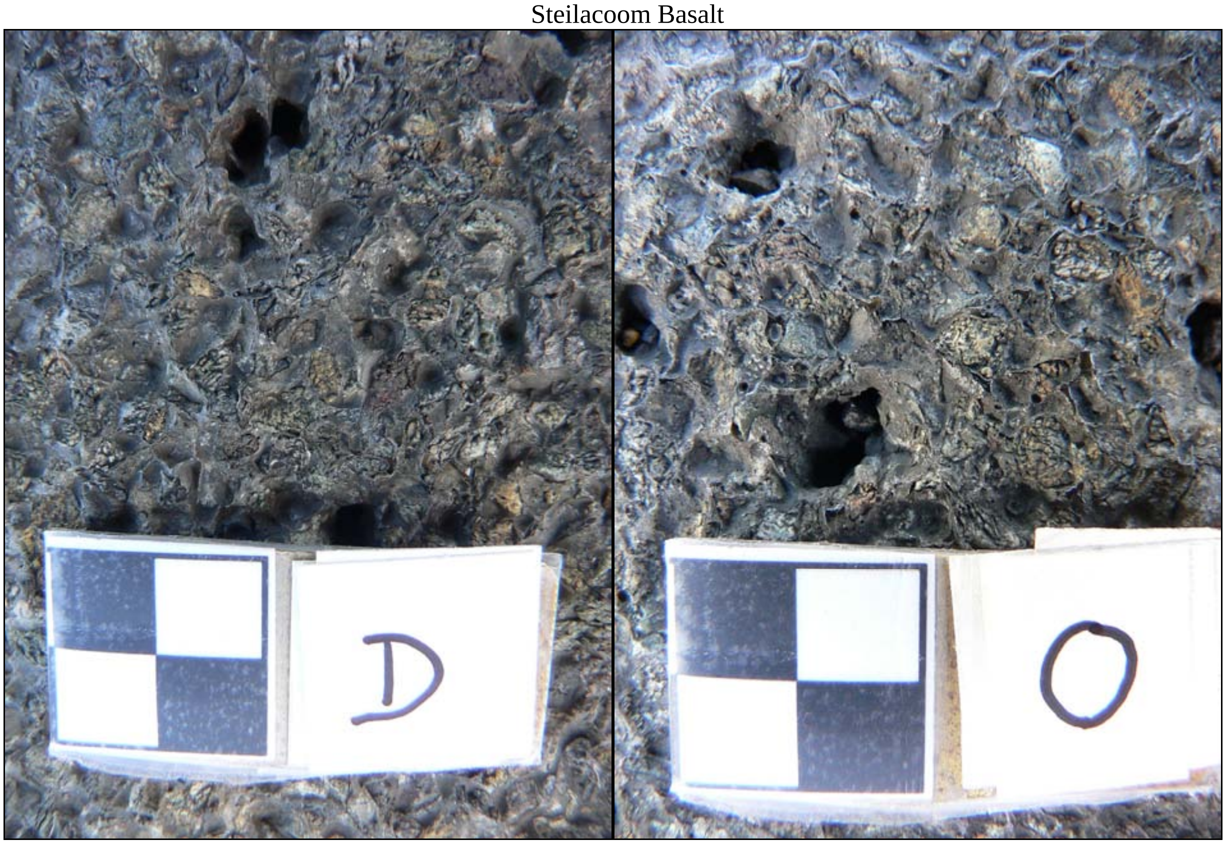


**Safetrack HW**

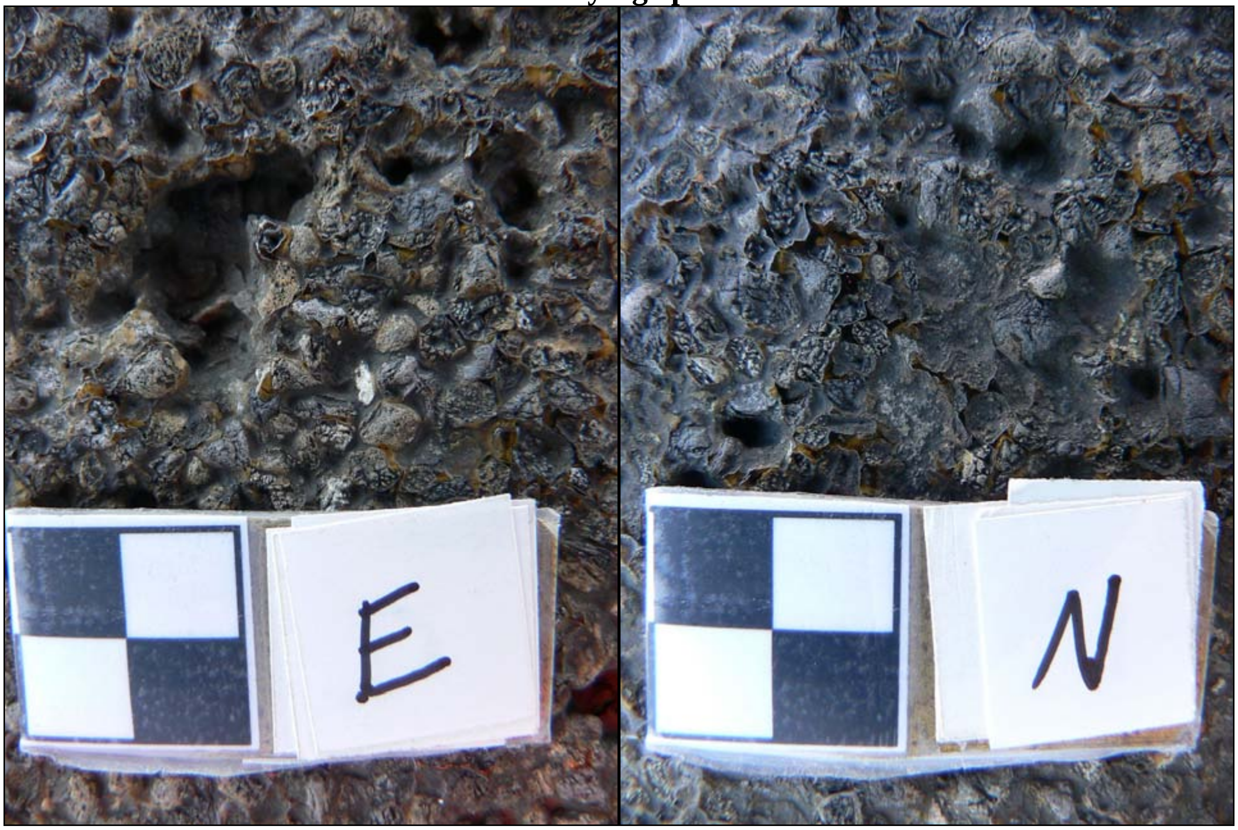



**Kwik Bond PPC MLS**

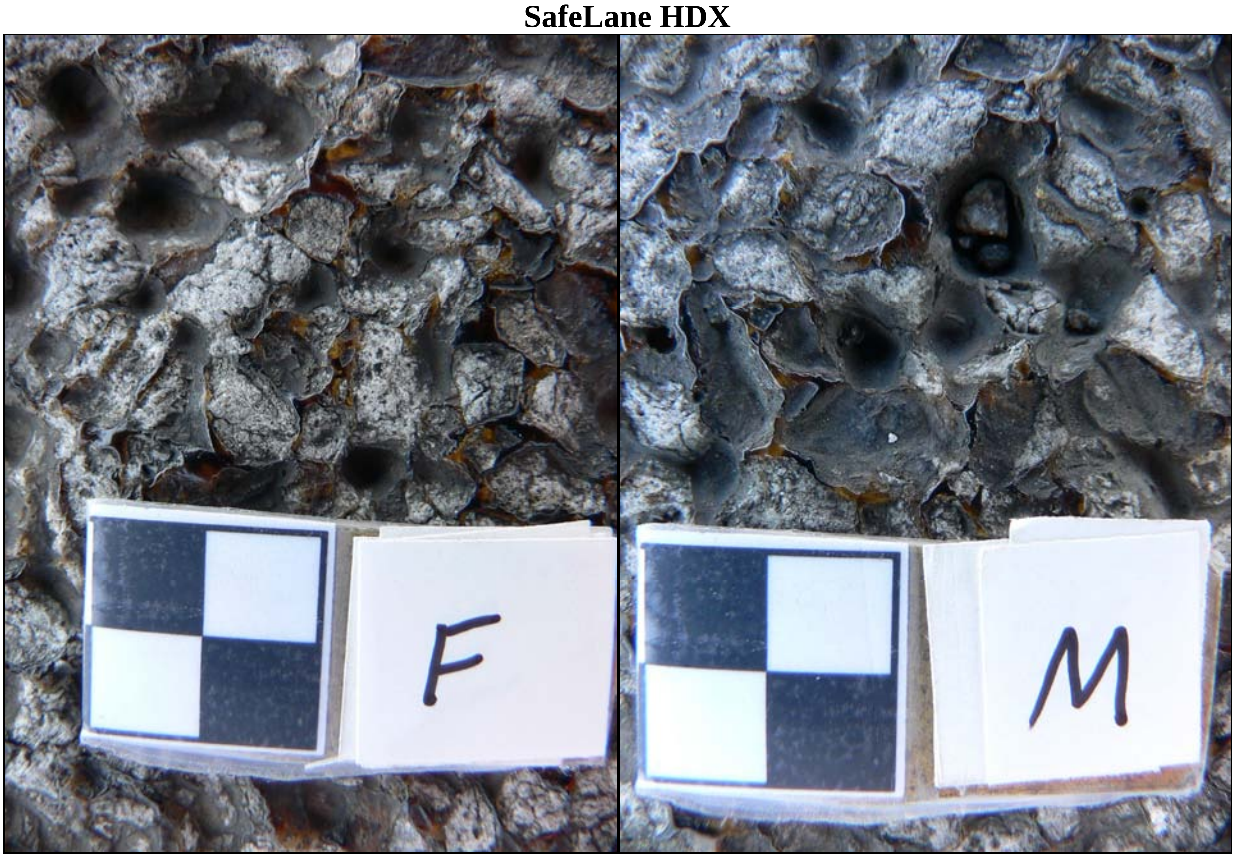
Newberg (left) aggregate was 4:1 Steilacoom Basalt to Oregon Emery; McMinnville (right) aggregate was 100% Steilacoom Basalt



**Tyregrip**




**SafeLane HDX**



**Unitex ProPoxy Type III DOT**

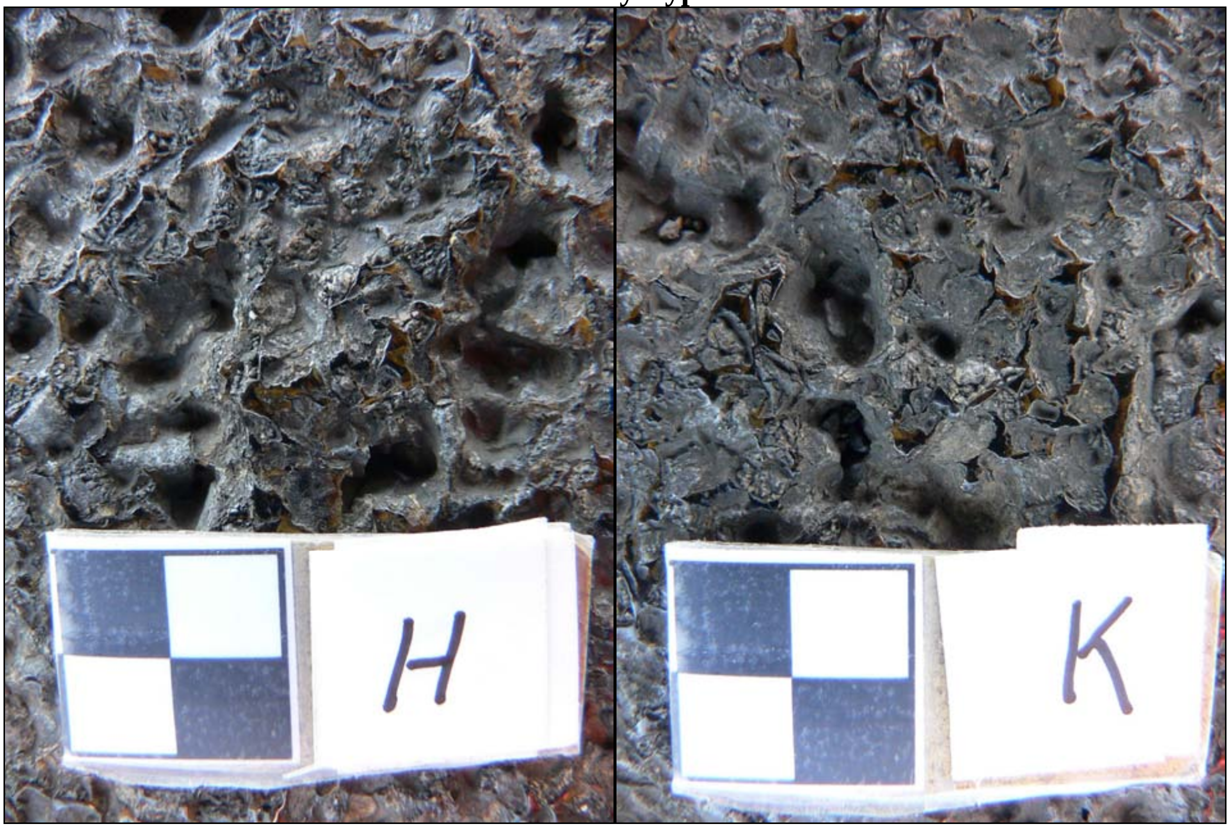



Figure 3.1: Surface condition of overlays at interim inspection. The small squares in the scale are 0.25 in. The left photos are from the bridge at Newberg and the right photos are from the bridge at McMinnville.

# 4.0 DISCUSSION

## 4.1 SKID TESTING

The overlays at Newberg were prone to more rapid decrease in friction number than those at McMinnville as shown in Figure 4.1. However, trucks made up a higher fraction of the traffic at Newberg (0.086) than at McMinnville (0.047). Also, the posted speed at Newberg was 55 mph compared to 35 mph at McMinnville. The effects of speed and fraction of trucks on friction number could not be extracted from the data.

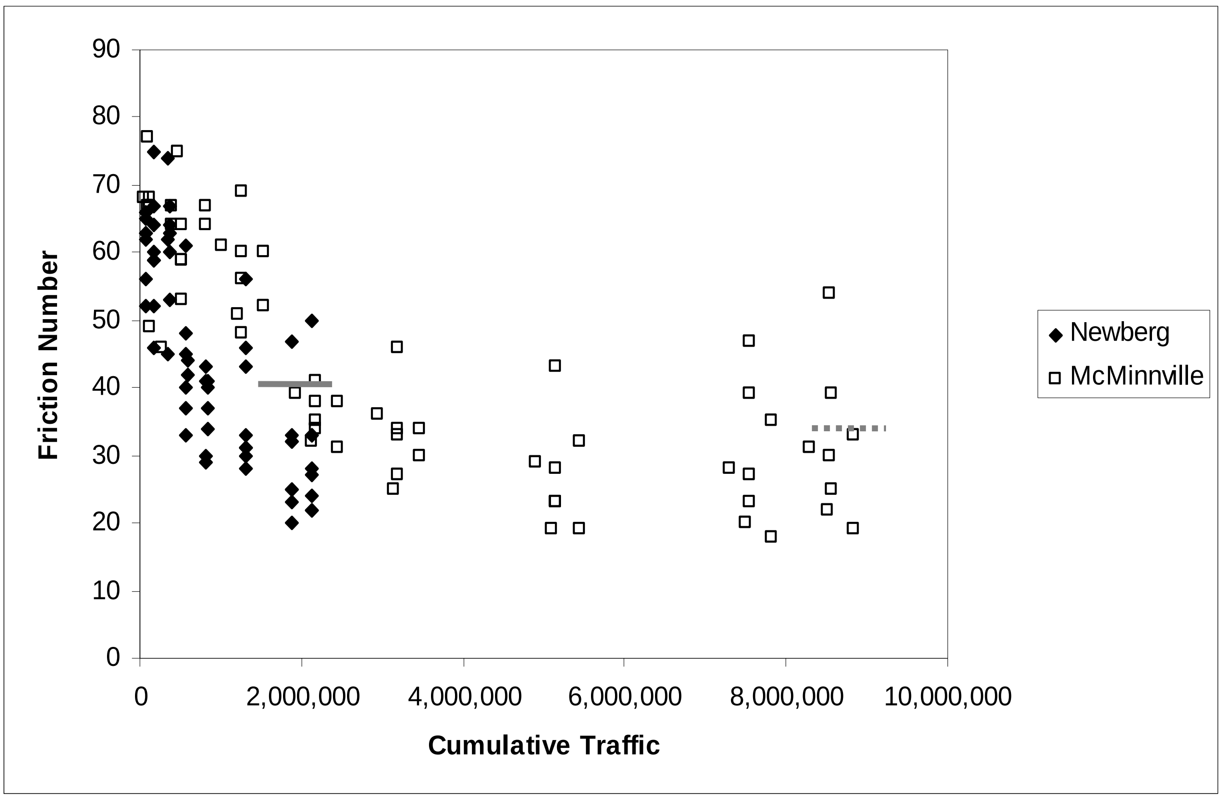



Figure 4.1: Combined skid testing results for all overlay systems. The solid and dashed horizontal lines show the friction number of the concrete for the last set of measurements at Newberg and McMinnville, respectively.

The friction number data for each product were used to develop predictive equations relating cumulative traffic exposure to friction number. Generally, a power curve provided the best fit to the data as shown in Appendix C. The equations and corresponding $R^2$ values for the conservative exposure conditions of the Newberg Bridge (highway speeds and larger fraction of truck traffic) are given in Table 4.1 along with calculated traffic exposure for corresponding friction numbers of 40 and 30. Due to the low $R^2$ value for Tyregrip, the equation for this product should not be used for predicting performance.

No product type showed a definitive advantage over other product types. Tyregrip maintained higher friction numbers over time compared to the other products, but Tyregrip also started to wear through to the concrete within two years. Except for Tyregrip, the skid resistance results for the products would be on the low side of the ranges reported in Section 1.2. Neglecting the two products that wore through, no product would be expected to last more than approximately four to five months under moderate average daily traffic per lane of 10,000 vehicles before reaching a friction number of 40. For comparison, the average friction number for the concrete on the Newberg Bridge over the time period of the study was 39 based on the values reported in Table 3.2.

**Table 4.1: Calculated traffic exposure to reduce friction number based on results from the Newberg Bridge.**

| Product | Product Type | Equation* | $R^2$ | Calculated Cumulative Traffic at FN=40 | Calculated Cumulative Traffic at FN=30 | Comments |
|---|---|---|---|---|---|---|
| Mark 154 | Epoxy | $y=2031x^{-.2878}$ | 0.82 | 840,000 | 2,200,000 | |
| Flex-O-Lith | Epoxy | $y=3283x^{-.3341}$ | 0.76 | 540,000 | 1,300,000 | |
| Tyregrip** | Epoxy | $y=308x^{-.1263}$ | 0.42 | 10,000,000 | 100,000,000 | Wearing through at 1,300,000 |
| Safelane HDX | Epoxy | $y=1989x^{-.3036}$ | 0.82 | 390,000 | 1,000,000 | |
| Unitex Pro-Poxy Type III DOT | Epoxy | $y=808x^{-.2153}$ | 0.66 | 1,200,000 | 4,400,000 | |
| Safetrack HW | MMA | $y=2955x^{-.3241}$ | 0.86 | 580,000 | 1,400,000 | Wearing through at 1,300,000 |
| Kwik Bond PPC MLS | Polyester | $y=651x^{-.1986}$ | 0.69 | 1,300,000 | 5,400,000 | |

*y is friction number; x is cumulative traffic. **Tyregrip is shown for completeness, but the equation should not be used for prediction due to the low $R^2$.

The aggregate properties measured in the laboratory did not provide good predictors of field performance. The most likely aggregate property to correlate with skid resistance, aggregate abrasion resistance measured with Microdeval, had little influence as shown in Figure 4.2. Similarly, system (resin + aggregate) abrasion resistance had little correlation with skid resistance as shown in Figure 4.3. The figures also show that only one overlay system, Tyregrip, had friction numbers greater than that of the concrete on the respective bridges.

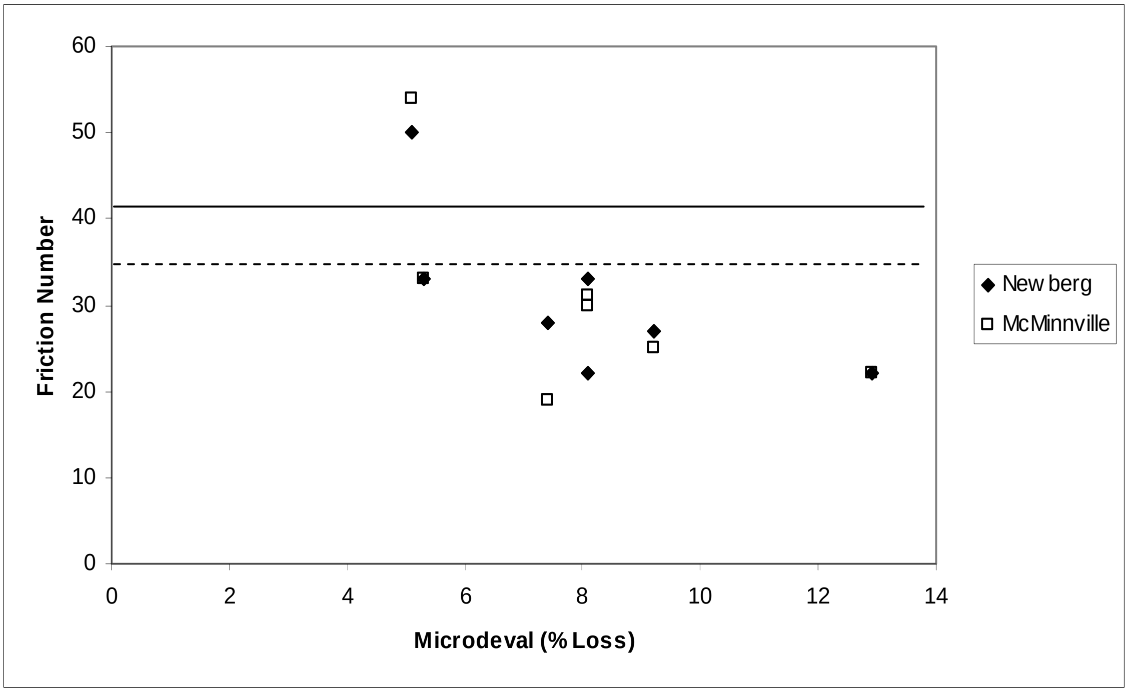



Figure 4.2: Comparison of skid resistance and aggregate abrasion resistance test results. The friction numbers are from the last set of skid tests where Newberg cumulative traffic ranged from 2,131,000 to 2,137,000 and McMinnville cumulative traffic ranged from 8,299,000 to 8,831,000. The solid and dashed horizontal lines show the concrete friction numbers at Newberg and McMinnville, respectively.

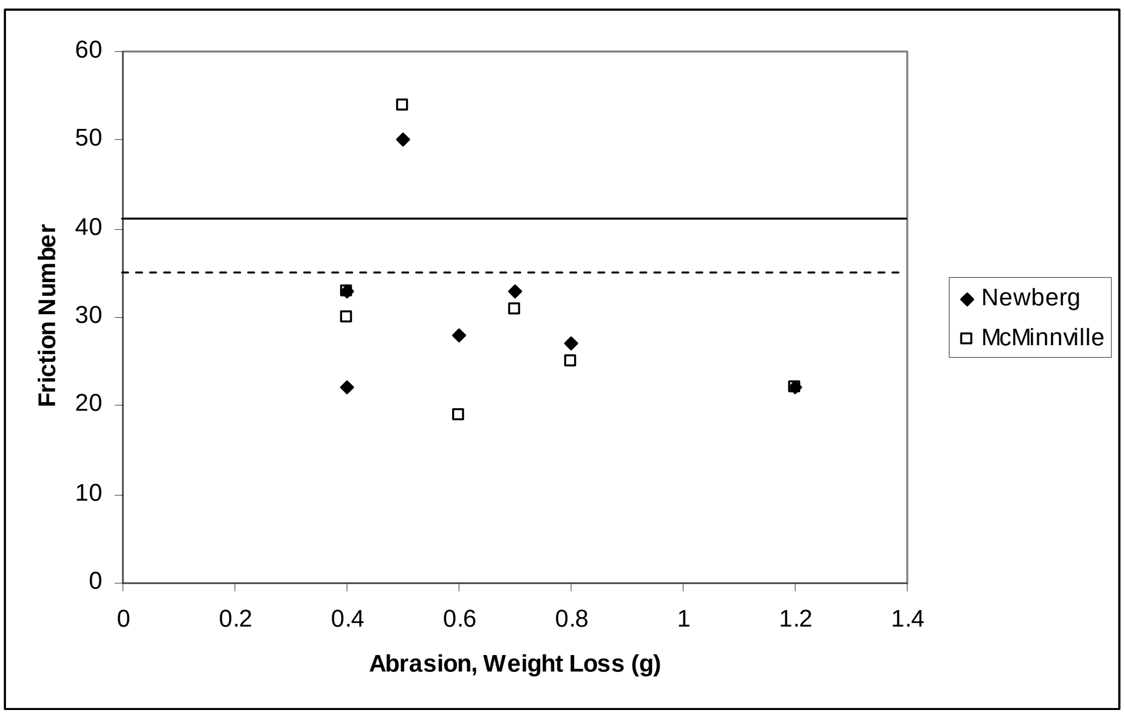



Figure 4.3: Comparison of skid resistance and system abrasion resistance test results. The friction numbers are from the last set of skid tests where Newberg cumulative traffic ranged from 2,131,000 to 2,137,000 and McMinnville cumulative traffic ranged from 8,299,000 to 8,831,000. The solid and dashed horizontal lines show the concrete friction numbers at Newberg and McMinnville, respectively.

## 4.2 MECHANICAL TESTING

The mechanical testing of the resins and overlay systems did not provide any obvious predictors of in-service performance. Figures 4.4 – 4.9 compare the testing results in conjunction with performance problems of the overlays. General observations are discussed below.

The resin tensile testing was conducted over the temperature range expected on the surface of bridge decks in the winter and summer. All resins showed appreciable reduction in tensile strength at 140$^{o}$F as shown in Figure 4.4. Based on the comparison of tensile elongations in Figure 4.5, none of the resins showed brittle behavior at 0$^{o}$F.

Most resins showed some reduction in tensile strength due to simulated sunlight exposure as shown in Figure 4.6. However, only Tyregrip showed continued reduction in tensile strength with increased exposure time. Four of the resins showed relatively large reductions of elongation after exposure, but, with the exception of Tyregrip and Kwik Bond, the elongation did not decrease appreciably with continued exposure (Figure 4.7). The general trend of degradation occurring mostly after initial exposure may be due to the fact that the surface deteriorates but protects the interior of the specimen. In service, however, a deteriorated surface could be worn away exposing a fresh surface for further deterioration. This would occur around an aggregate particle until there was not enough resin to keep the particle in place.

The flexural and compressive strength of the overlay systems in the temperature range of 0$^{o}$F to 140$^{o}$F followed the expected trend of decreased strength as the temperature increases (Figures 4.8 and 4.9). Though the strengths are substantially lower at 140$^{o}$F, none of the systems on the bridges showed evidence of shoving that would indicate hot weather deformation.

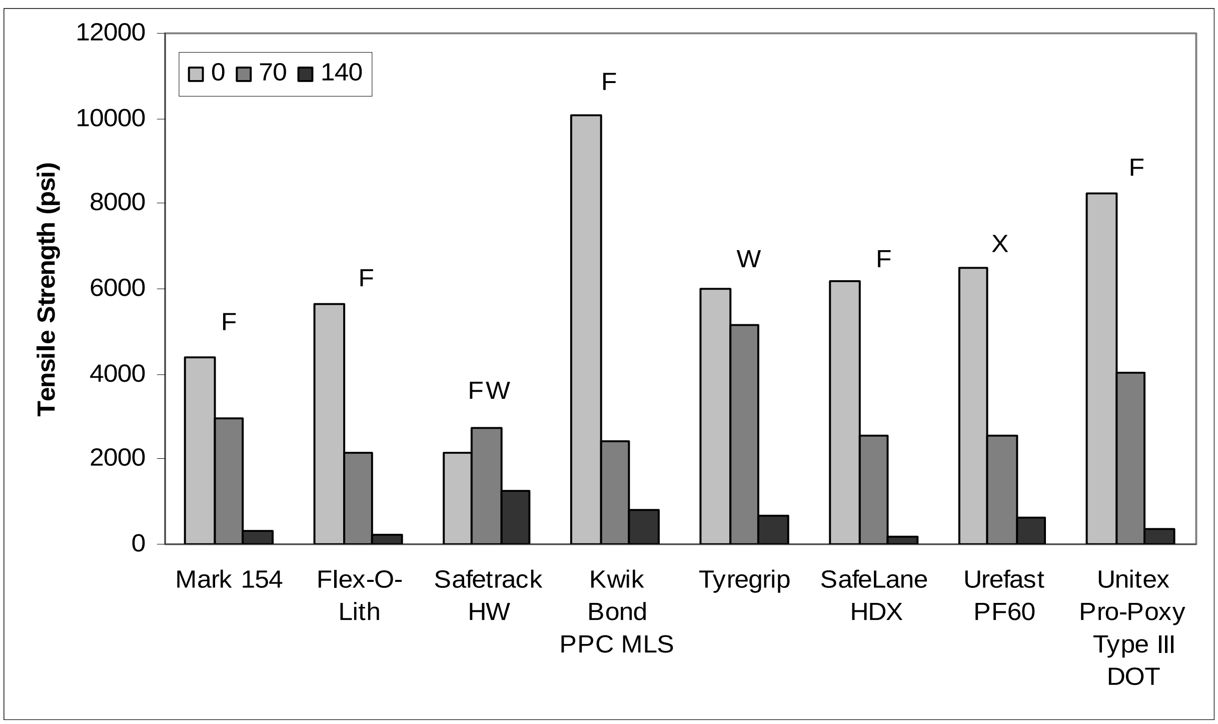



Figure 4.4: Comparison of the tensile strengths of the resins at 0, 70, and 140$^{o}$F. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

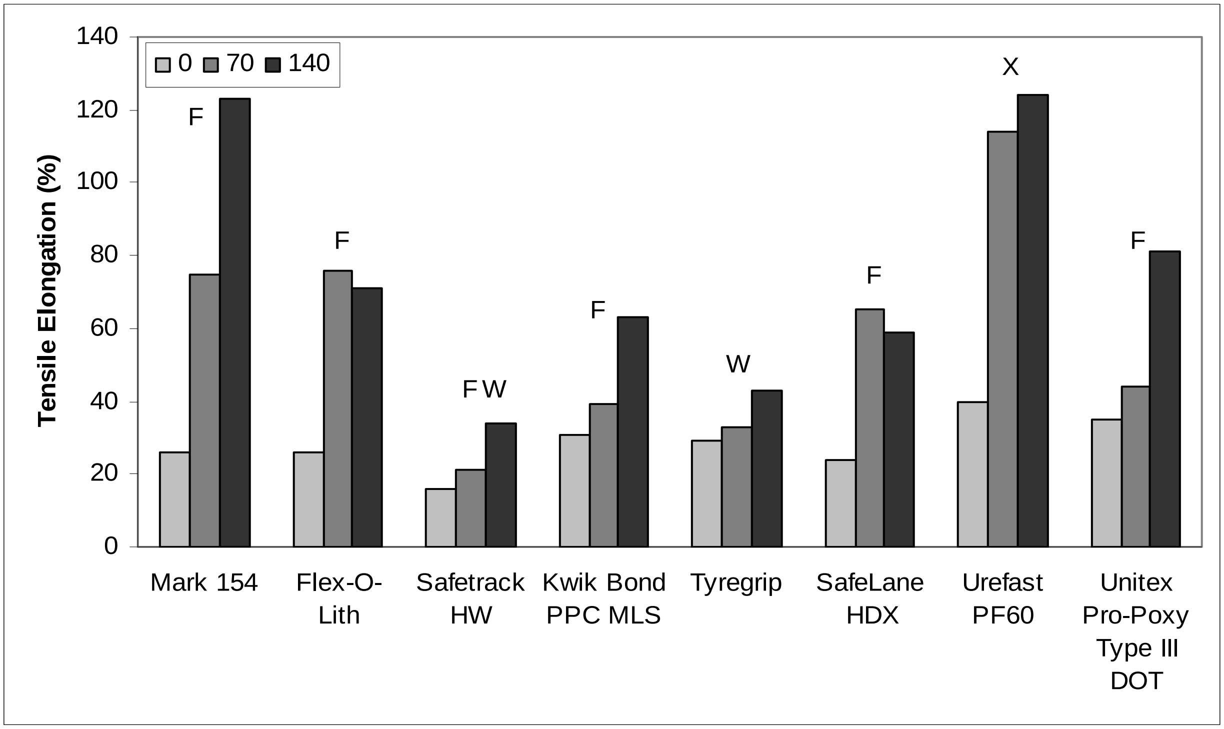



Figure 4.5: Comparison of the tensile elongations of the resins at 0, 70, and 140 °F. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

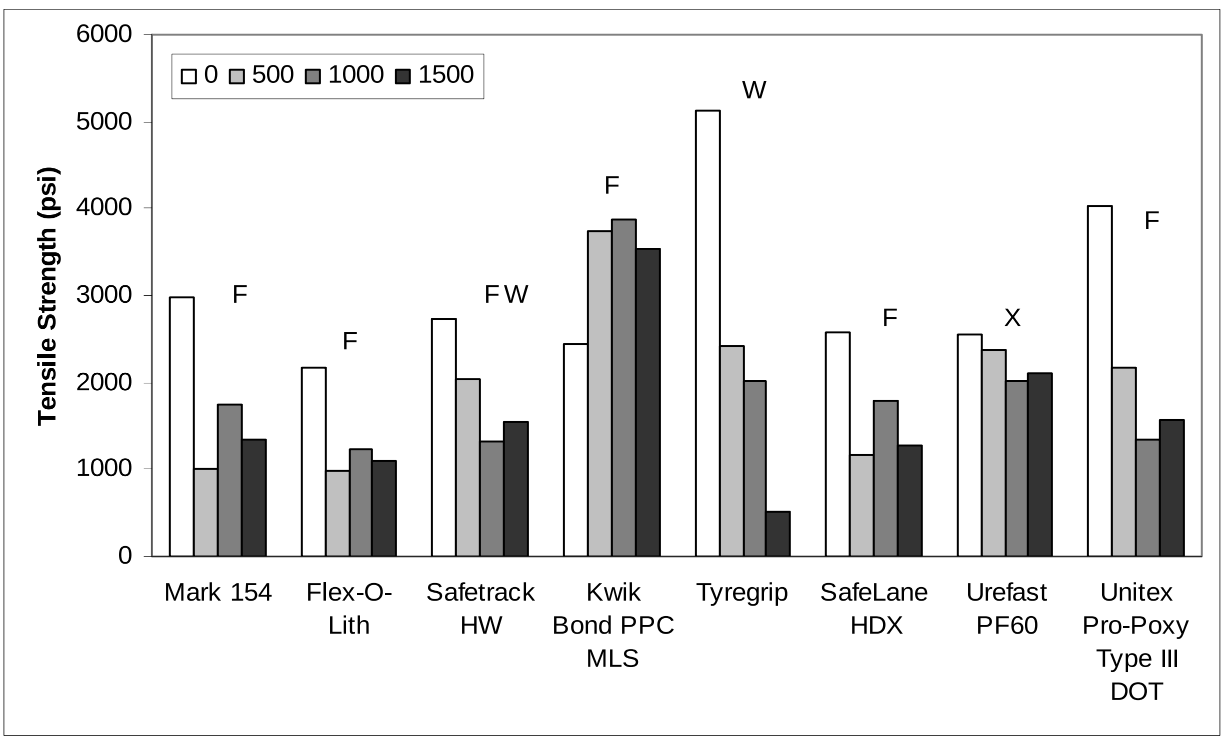



Figure 4.6: Comparison of the tensile strengths of the overlay resins after simulated sunlight exposure of 0, 500, 1000, and 1500 hours. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

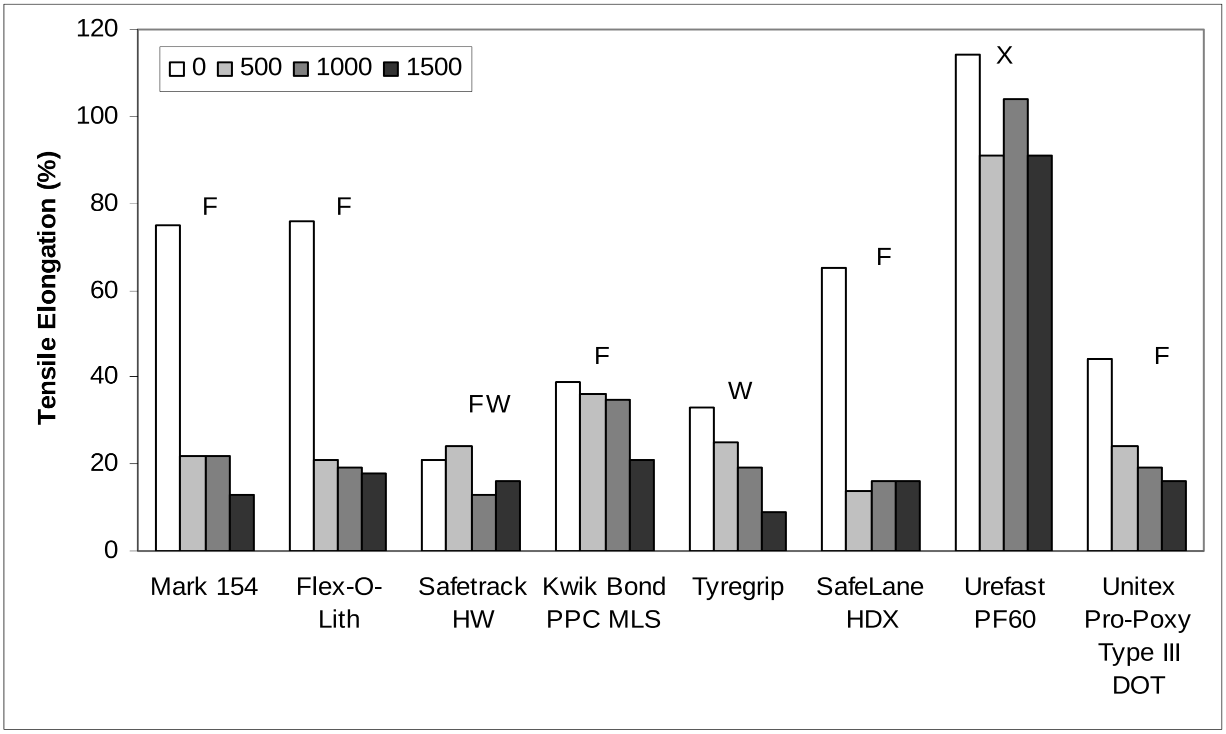



Figure 4.7: Comparison of the tensile elongations of the overlay resins after simulated sunlight exposure of 0, 500, 1000, and 1500 hours. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

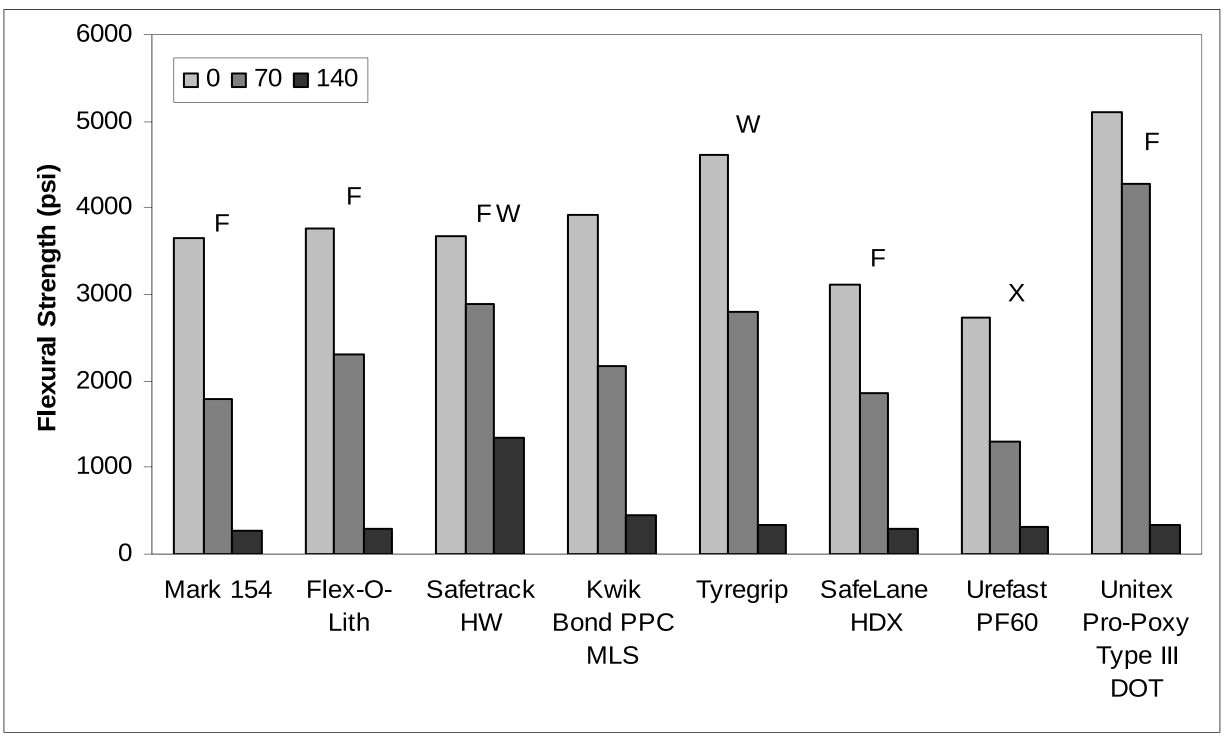



Figure 4.8: Comparison of the flexural strengths of the overlay systems at 0, 70, and 140 $^{o}$F. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

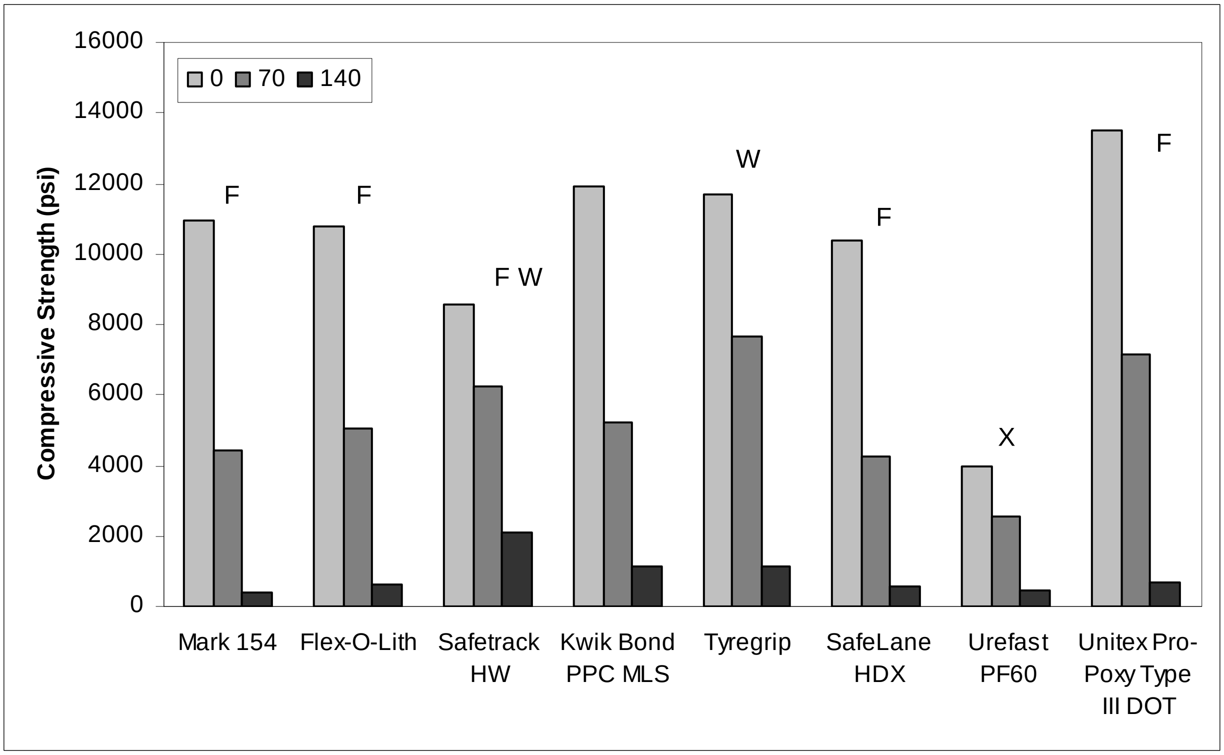



Figure 4.9: Comparison of the compressive strengths of the overlay systems at 0, 70, and 140 °F. "F" indicates systems that had friction numbers less than the concrete. "W" indicates systems that have worn through to the concrete. "X" indicates a system that failed early in the evaluation.

# 5.0 CONCLUSIONS

Eight thin polymer overlay systems were evaluated in the laboratory and on two bridge decks exposed to a mix of vehicles including those with studded tires. The products were Mark 154, Flex-O-Lith, Safetrack HW, Kwik Bond PPC MLS, Tyregrip, SafeLane HDX, Urefast PF60, and Unitex ProPoxyType III DOT. The results of the investigation supported the following conclusions:

Tyregrip and Safetrack HW started to wear through to the concrete after exposure of approximately 1.3 million vehicles. Urefast PF60 wore through much sooner.

For six of the eight products (Tyregrip and Urefast PF60 excluded), empirical equations were developed that could be used to predict friction number as a function of traffic exposure.

For the five products that did not wear through, none of them performed well under moderate average daily traffic. At a traffic level of 10,000 vehicles per lane per day, the friction number of the best of these five products was predicted to decrease to 40 within five months.

Tyregrip was the only system that maintained friction numbers (50 and 54) greater than that of the concrete at the end of the field evaluation.

Delamination from the concrete was not a major problem with the products.

Laboratory tests were not able to predict performance.

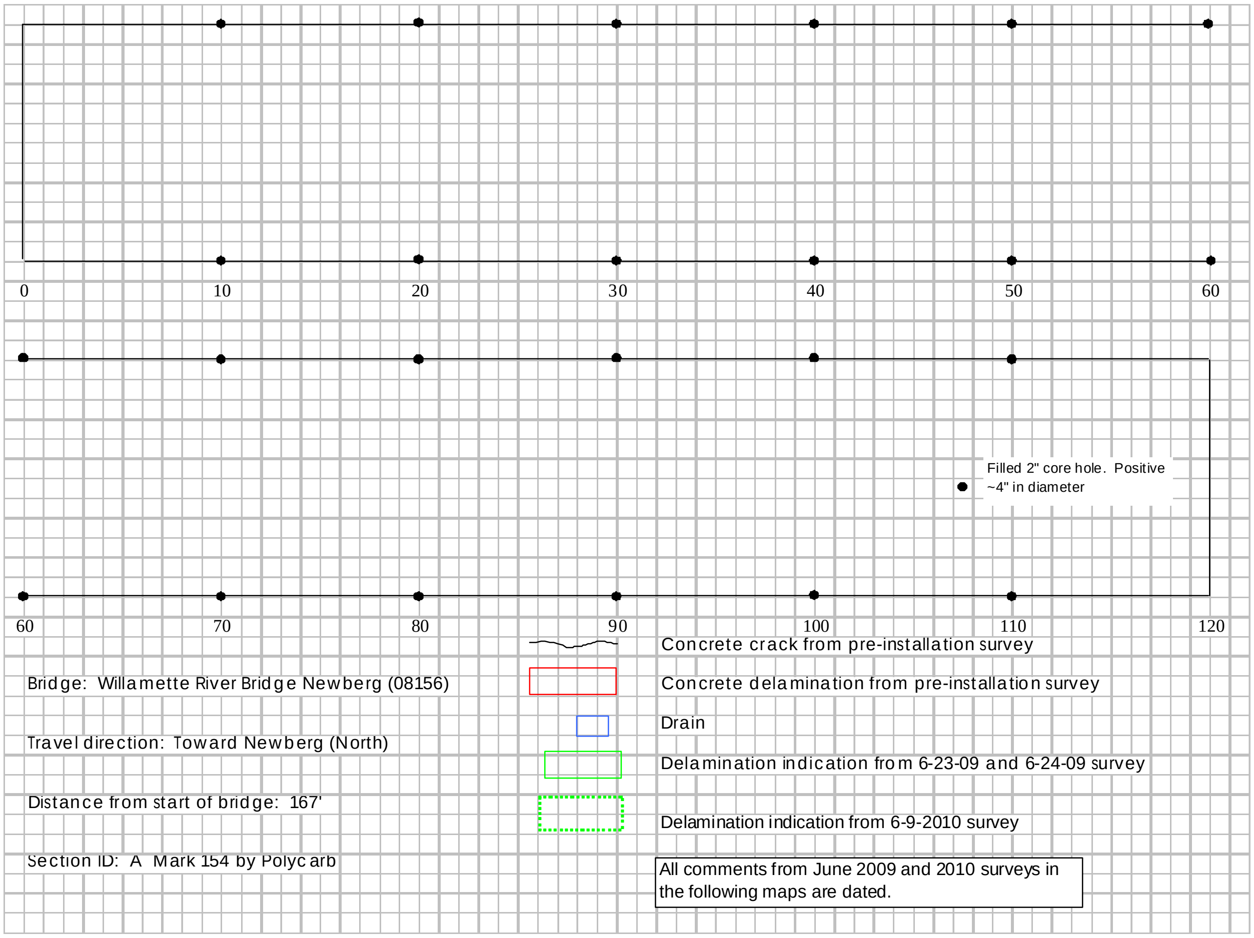
# 6.0 REFERENCES

Guthrie, W. S. et al. *Performance of Concrete Bridge Deck Surface Treatments*. Publication No. UT-05.05. Utah Department of Transportation Research and Development Division, May 2005.

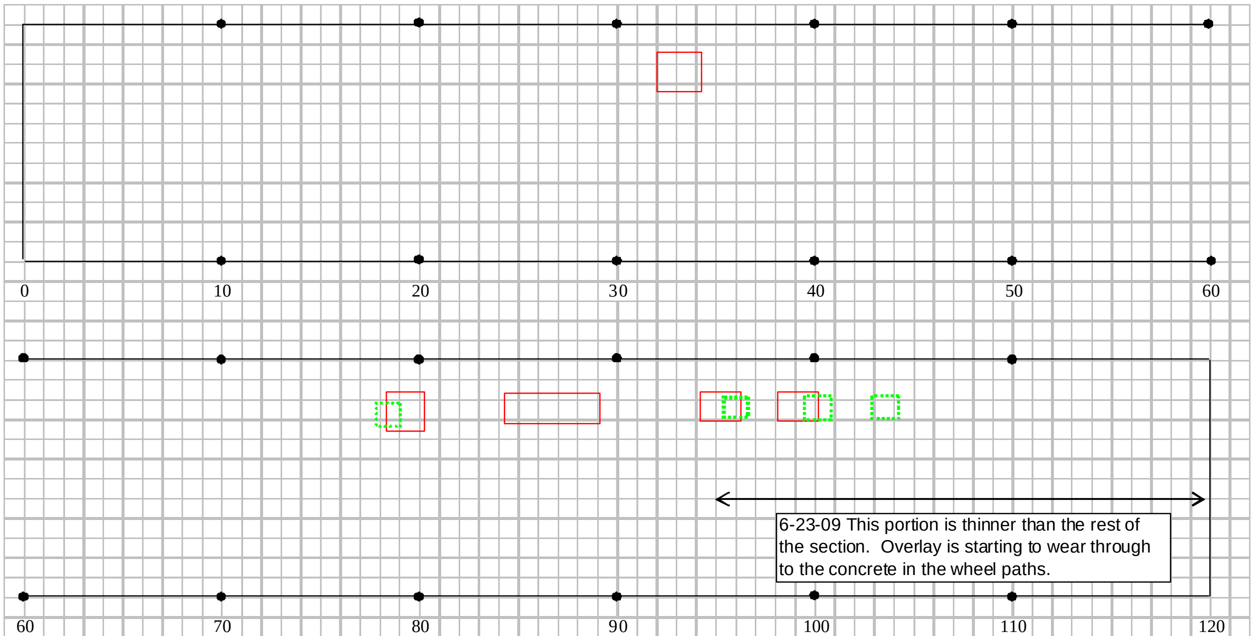
Sprinkel, M. M. et al. *Rapid Concrete Bridge Deck Protection, Repair and Rehabilitation*. Publication No. SHRP-S-344. Strategic Highway Research Program, National Research Council, 1993.

Wilson, D. L. and Henley, E. H. *Thin Polymer Bridge Deck Overlays*. Publication No. WA-RD 374.1. Washington Department of Transportation, February 19

# APPENDIX A:
# DECK SURVEYS



0
10
20
30
40
50
60
Filled 2" core hole. Positive
~4" in diameter
60
70
80
90
100
110
120
Concrete crack from pre-installation survey
Bridge: Willamette River Bridge Newberg (08156)
Concrete delamination from pre-installation survey
Drain
Travel direction: Toward Newberg (North)
Delamination indication from 6-23-09 and 6-24-09 survey
Distance from start of bridge: 167'
Delamination indication from 6-9-2010 survey
Section ID: A Mark 154 by Polycarb
All comments from June 2009 and 2010 surveys in the following maps are dated.

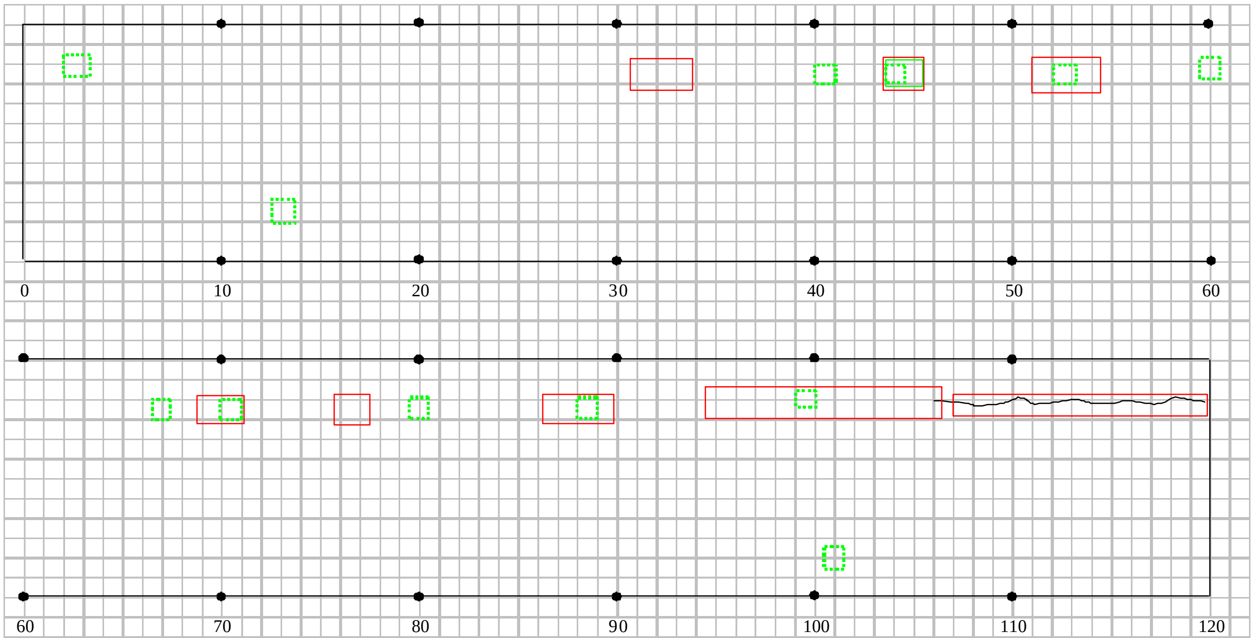



Bridge: Willamette River Bridge Newberg (08156)

Travel direction: Toward Newberg (North)

Distance from start of bridge: 404'

Section ID: B Flex-O-Lith by Euclid/Tamms




Bridge: Willamette River Bridge Newberg (08156)

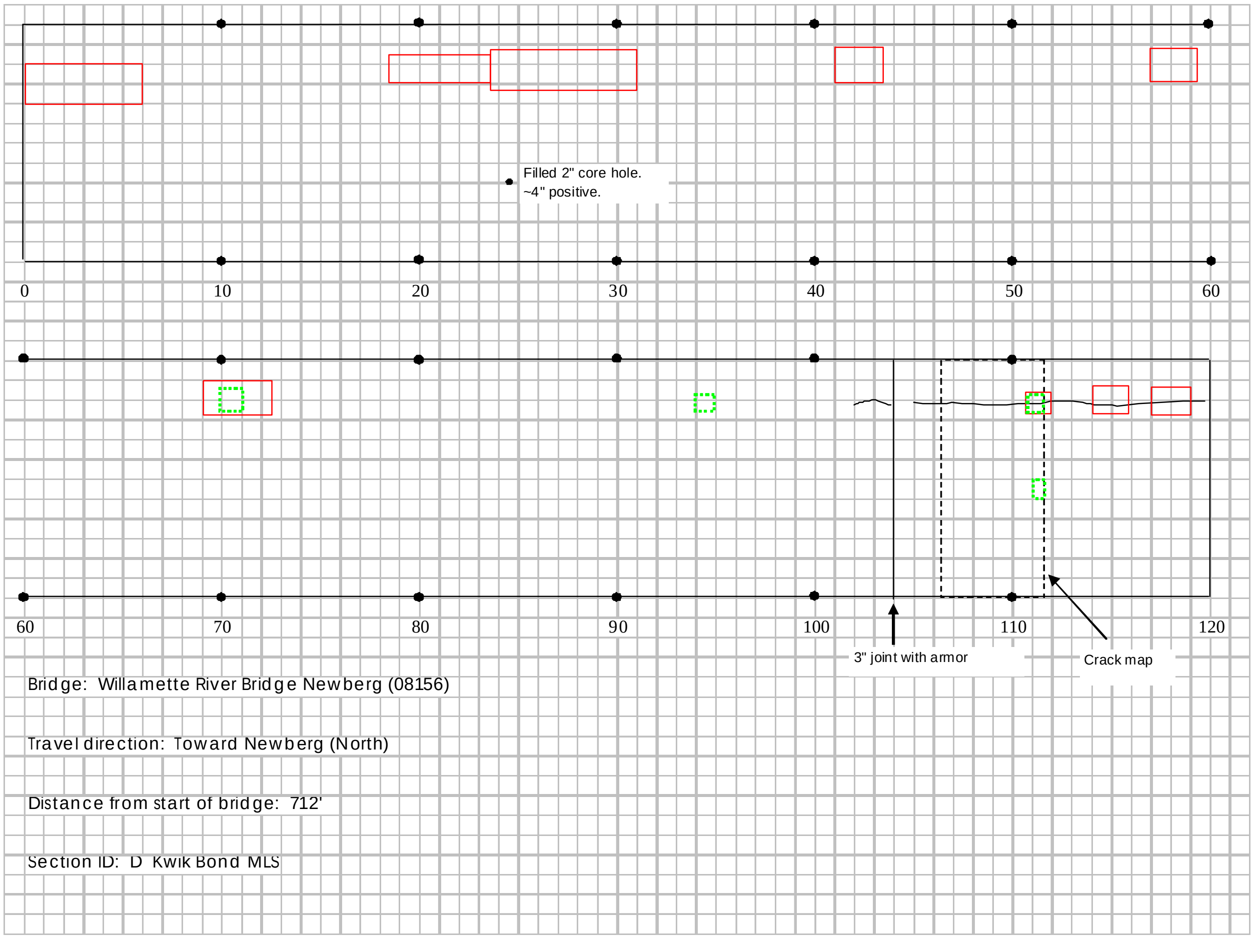
Travel direction: Toward Newberg (North)

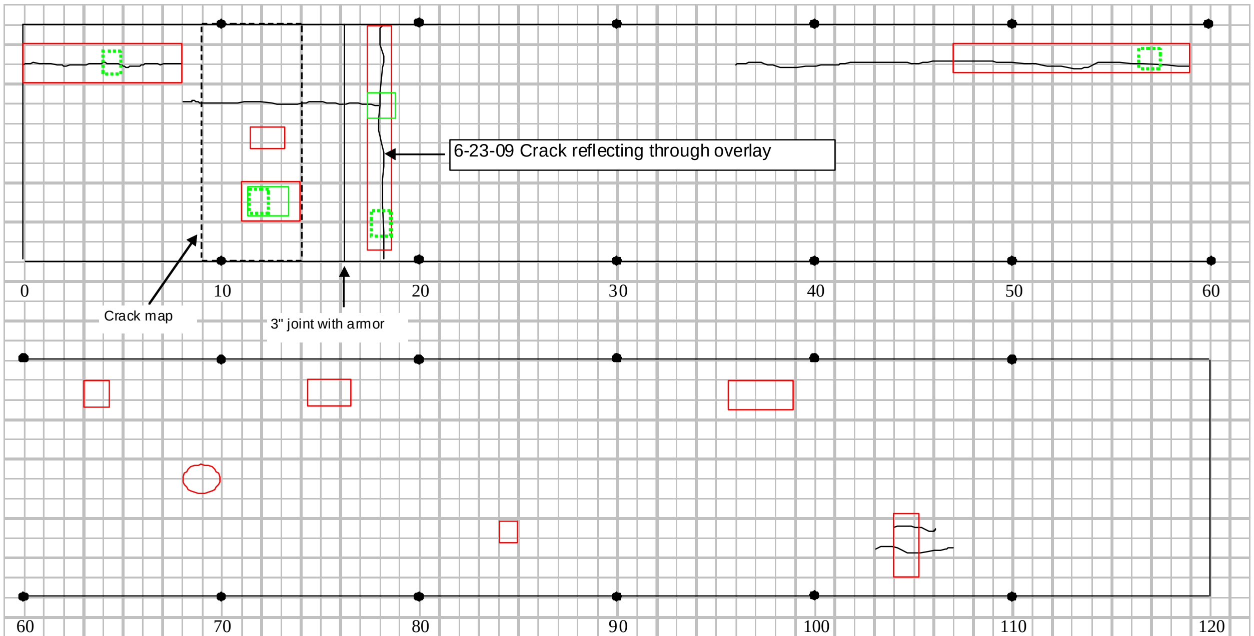
Distance from start of bridge: 587'

Section ID: C Safetrack HW - 2 Coat System by Stirling Lloyd

6-23-09 Overlay is starting to wear through to concrete in wheel paths.

6-9-2010 ~10% of the wheel path surface has worn through to the concrete.


Filled 2" core hole.
~4" positive.
0
10
20
30
40
50
60
70
80
90
100
110
120
3" joint with armor
Crack map
Bridge: Willamette River Bridge Newberg (08156)
Travel direction: Toward Newberg (North)
Distance from start of bridge: 712'
Section ID: D Kwik Bond MLS




Bridge: Willamette River Bridge Newberg (08156)

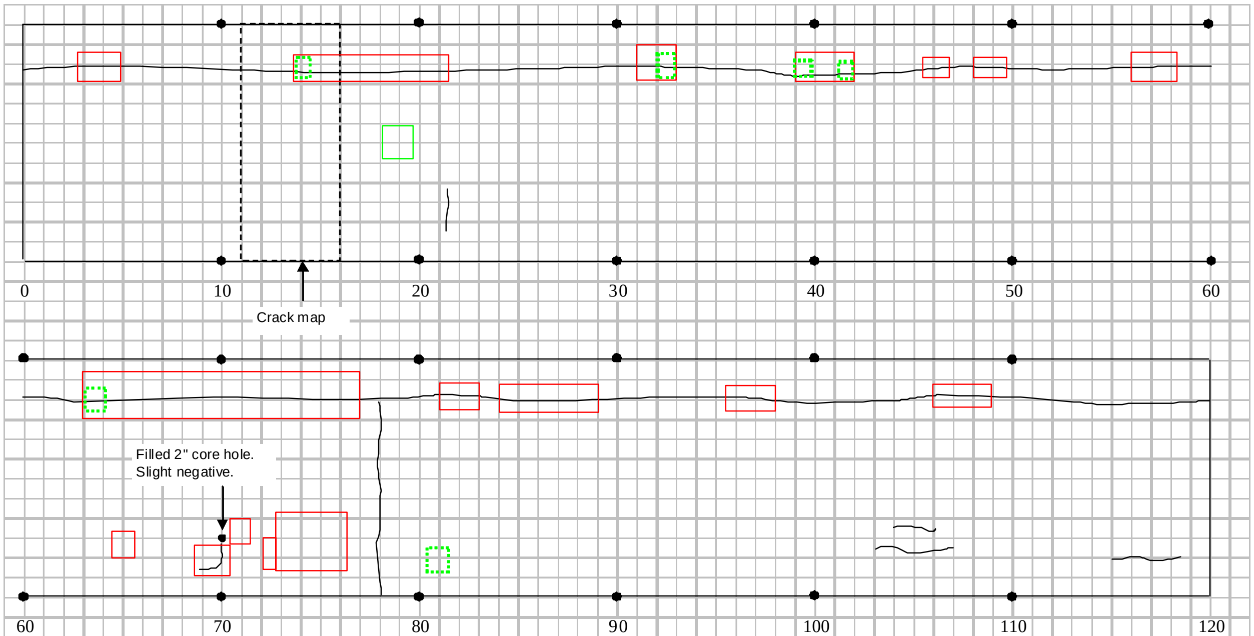
Travel direction: Away from Newberg (South)

Distance from start of bridge: 258.8'

Section ID: E Tyregrip by Ennis Paint Company

6-23-09 Overlay starting to wear through to concrete in wheel paths.

6-9-2010 ~5% of wheel path surface has worn through to concrete.



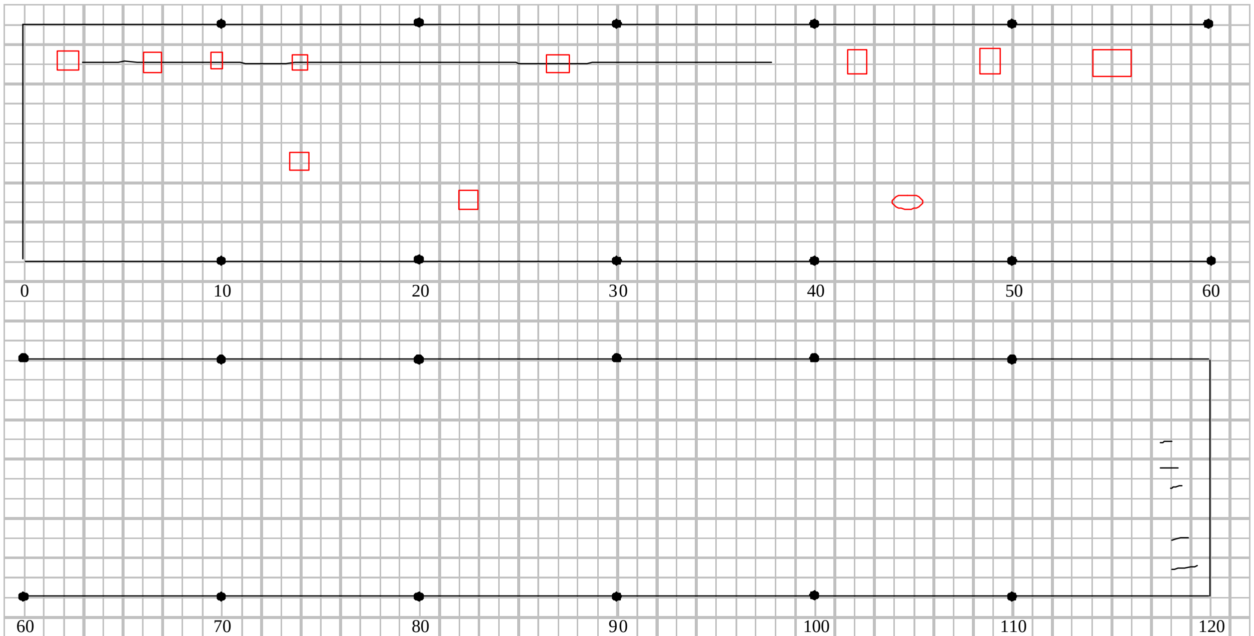

Bridge: Willamette River Bridge Newberg (08156)

Travel direction: Away from Newberg (South)

Distance from start of bridge: 383.6'

Section ID: F SafeLane HDX by Cargill

Comments: This section generally had more cracks than most other sections on the bridge, though the cracks were too small to map. There were several longitudinal cracks between 110 and 120'.

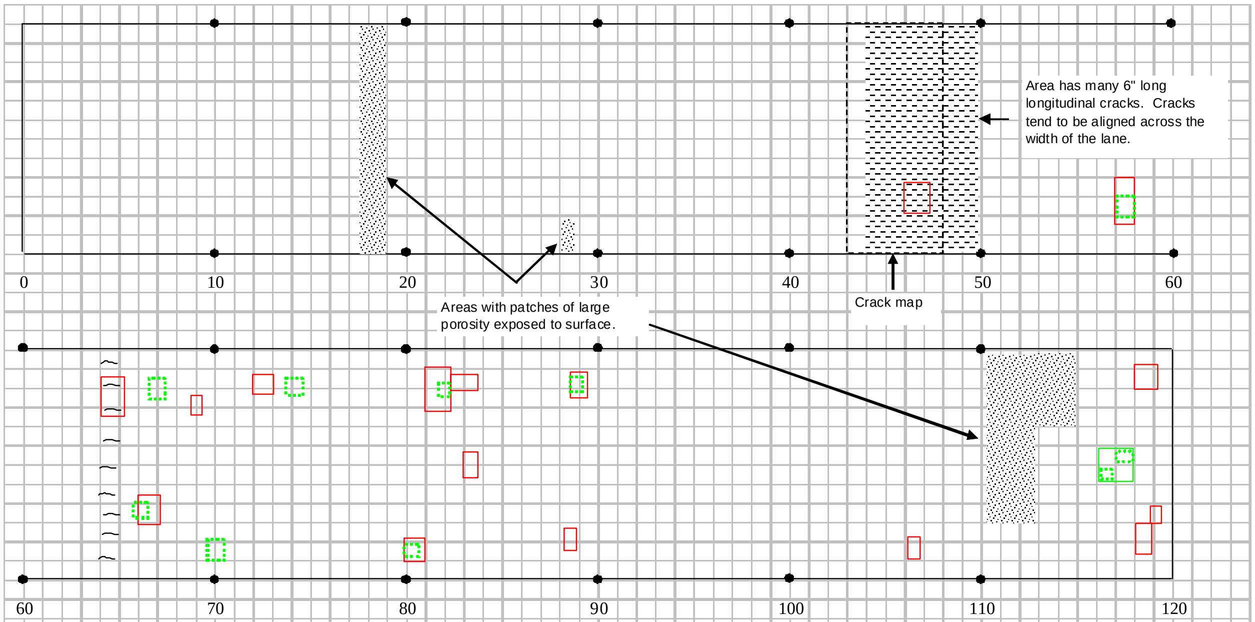



Bridge: Willamette River Bridge Newberg (08156)

Travel direction: Away from Newberg (South)

Distance from start of bridge: 565.9'

Section ID: G Urefast PF60 by Liquid Concrete

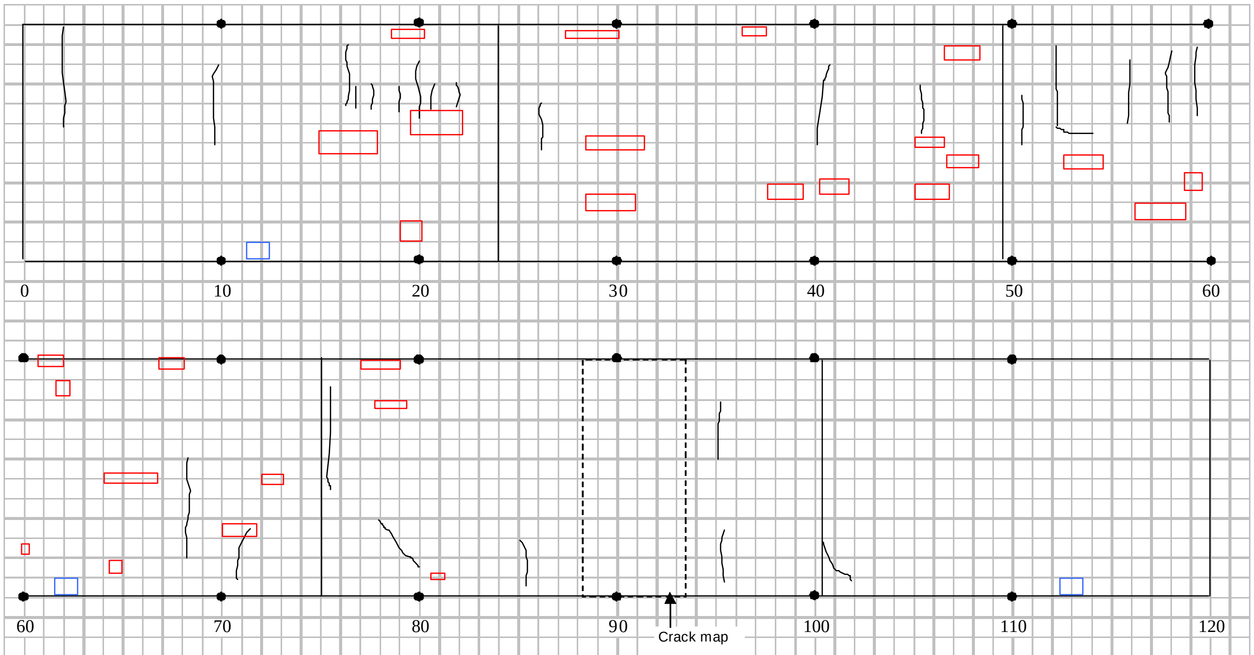



Bridge: Willamette River Bridge Newberg (08156)

Travel direction: Away from Newberg (South)

Distance from start of bridge: 803.5'

Section ID: H Unitex Type III DOT by Unitex



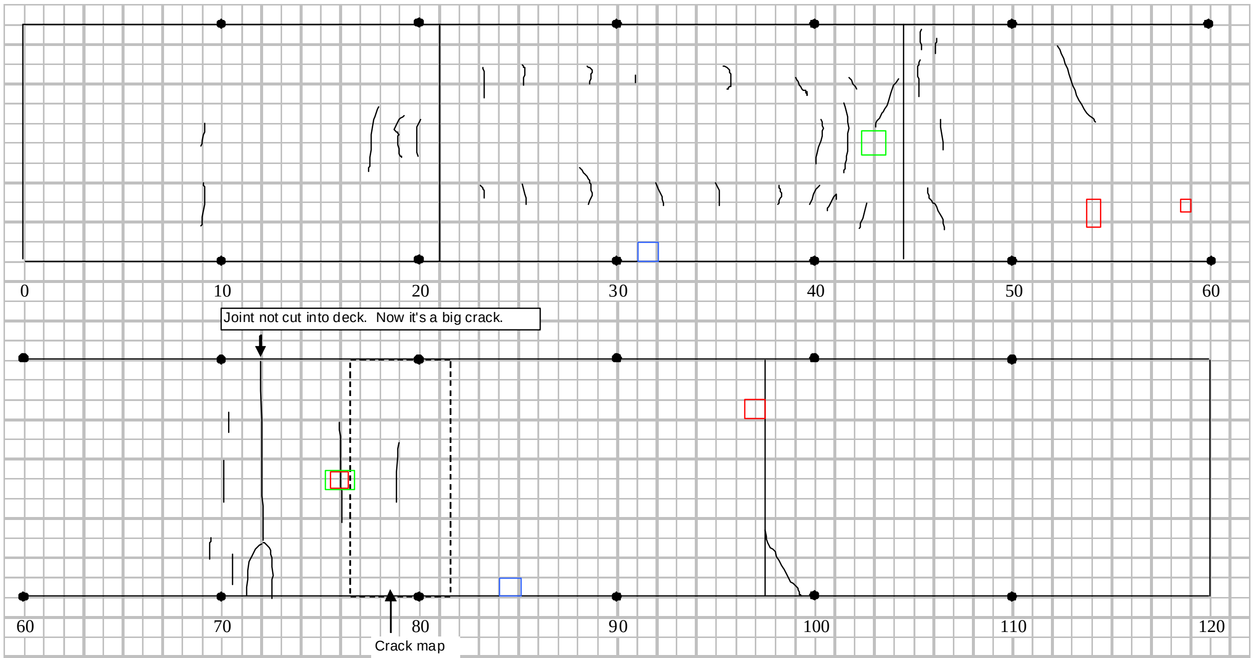

Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction: South (away from McMinnville)

Distance from start of bridge: 182.1'

Section ID: I Flex-O-Lith by Euclid/Tamms

Note: In general, the sections on this bridge showed many longitudinal and transverse cracking. The longitudinal cracks are most noticeable in the wheel paths. The cracking in the wheel paths has the appearance of map cracking.

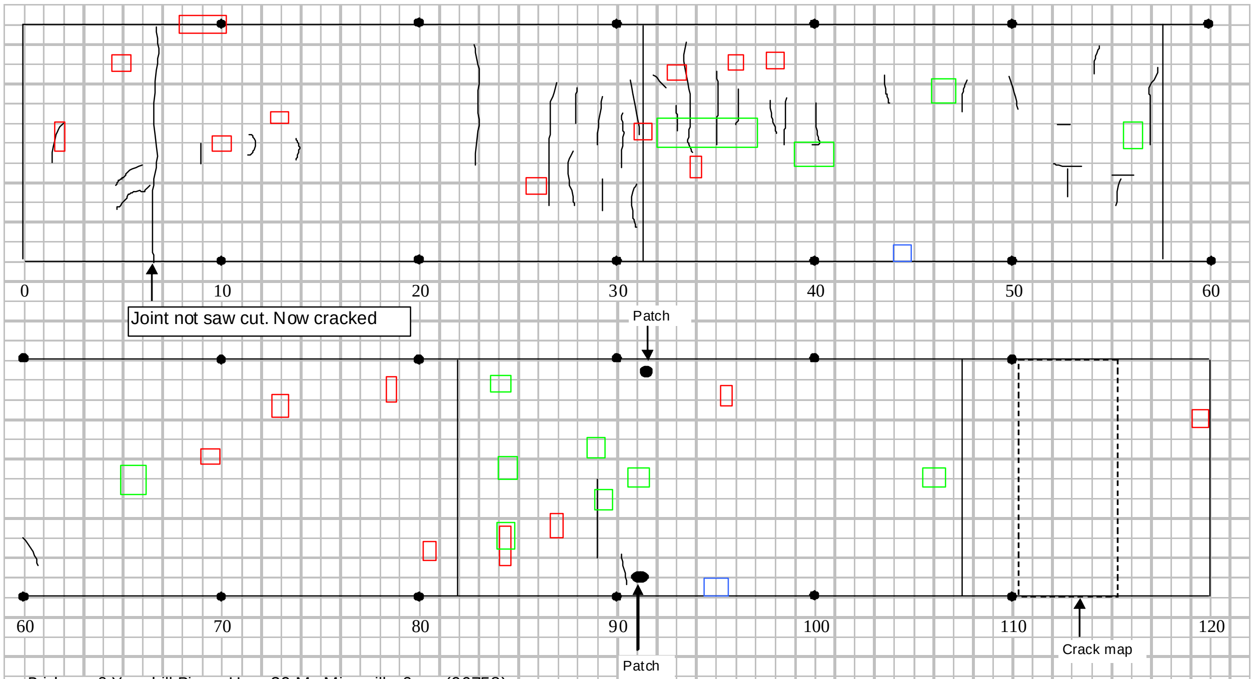



Bridge:  S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction:  South (away from McMinnville)

Distance from start of bridge:  312.6'

Section ID:  J  Mark 154 by Polycarb



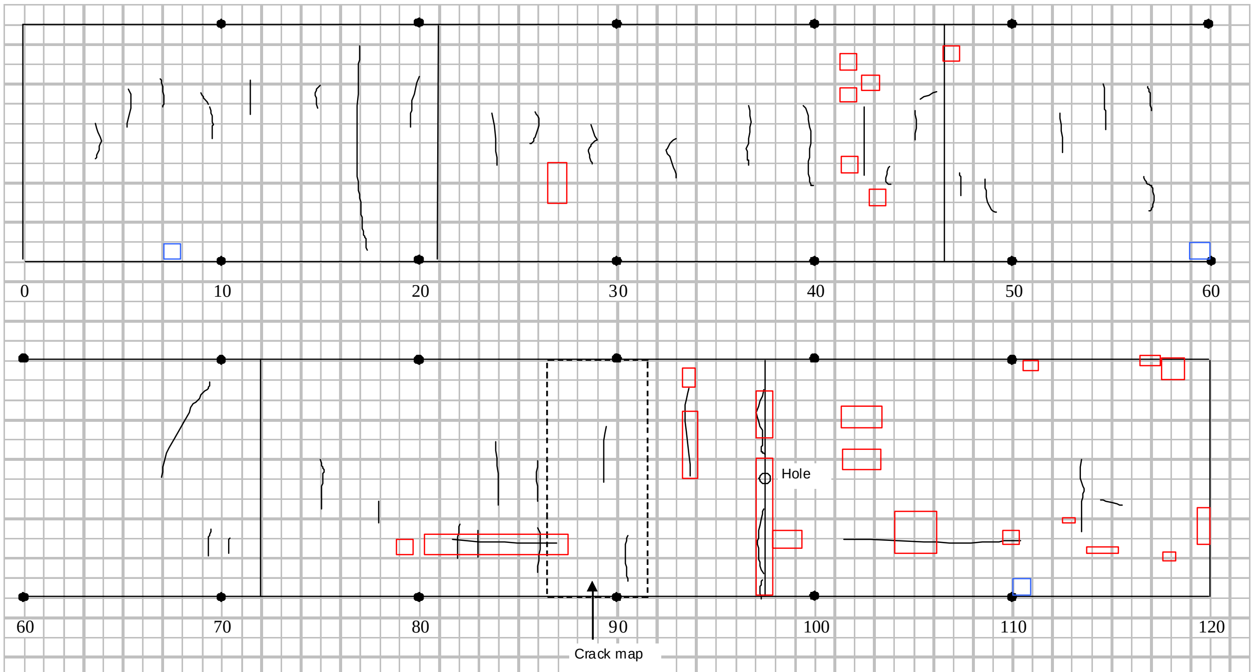

Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction: South (away from McMinnville)

Distance from start of bridge: 603.3'

Section ID: K Unitex Type III DOT by Unitex

Note: Section K generally had less cracking than other sections.



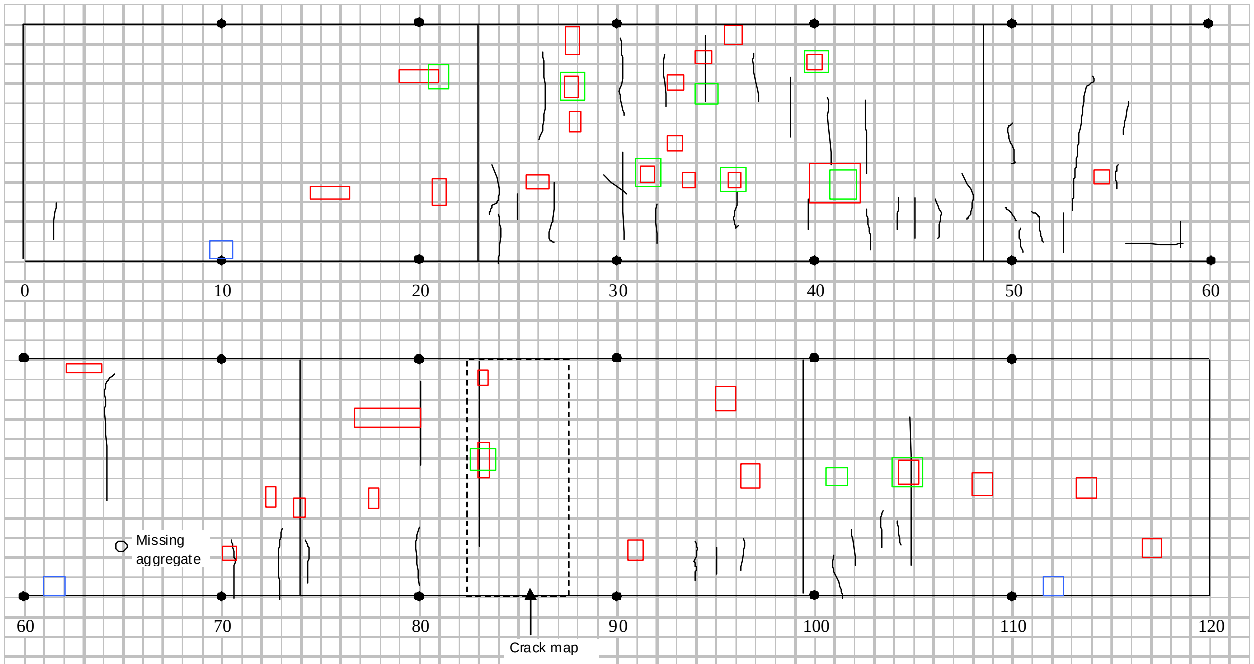

Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Wheel paths have many transverse cracks.

Travel direction: South (away from McMinnville)

Distance from start of bridge: 740.9'

Section ID: L Urefast PF60 by LiquidConcrete

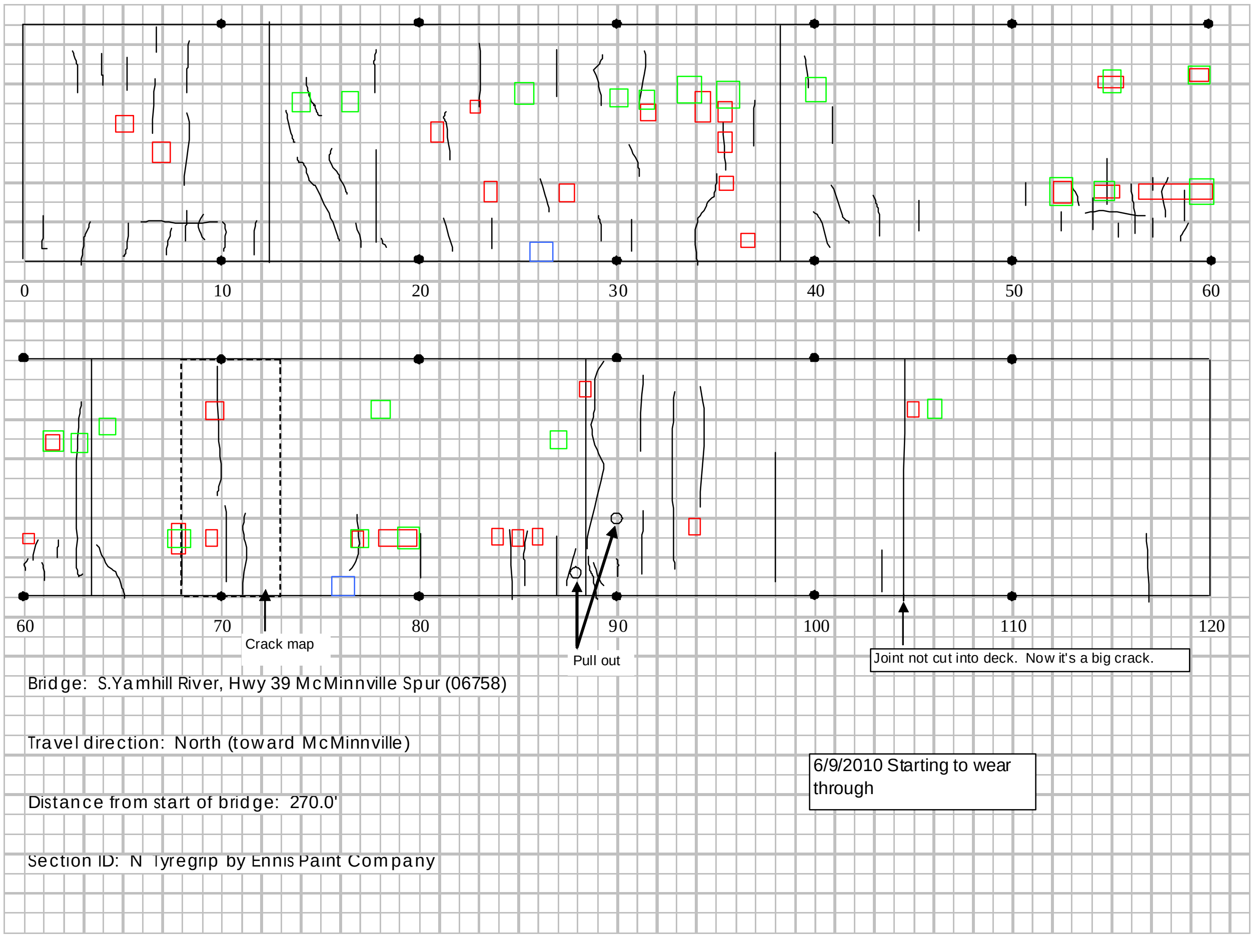


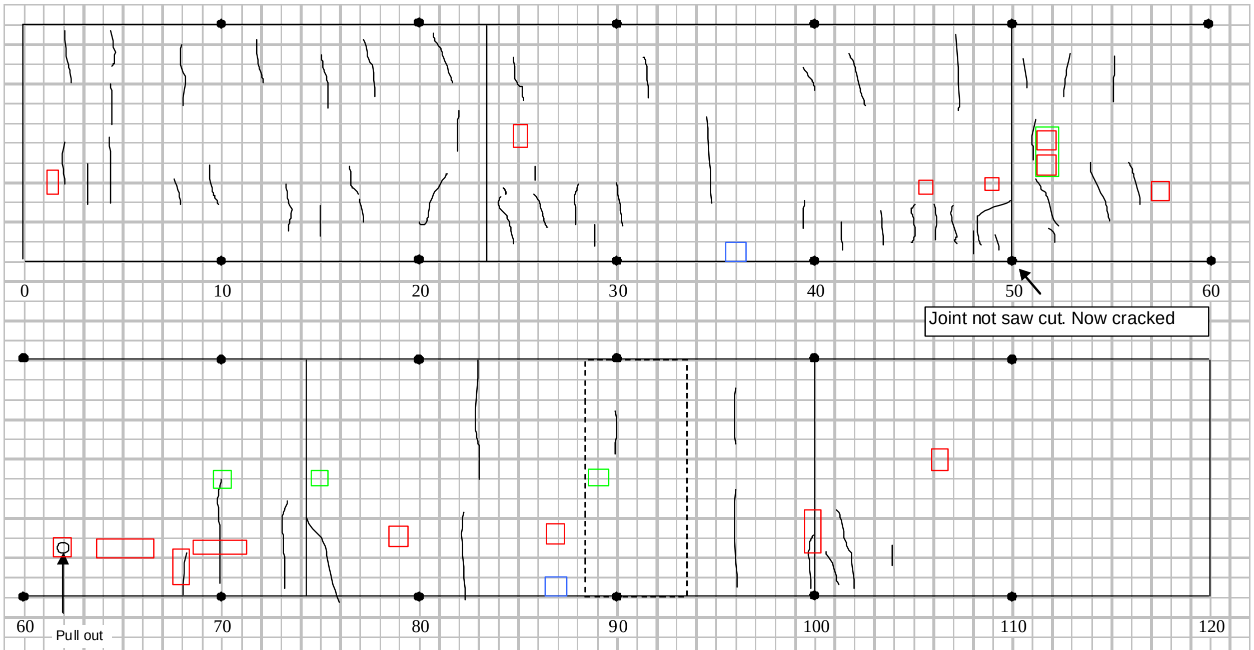

Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction: North (toward McMinnville)

Distance from start of bridge: 132.3'

Section ID: M SafeLane HDX by Cargill


0
10
20
30
40
50
60
60
70
80
90
100
110
120
Crack map
Pull out
Joint not cut into deck. Now it's a big crack.
Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)
Travel direction: North (toward McMinnville)
Distance from start of bridge: 270.0'
Section ID: N Tyregrip by Ennis Paint Company
6/9/2010 Starting to wear through

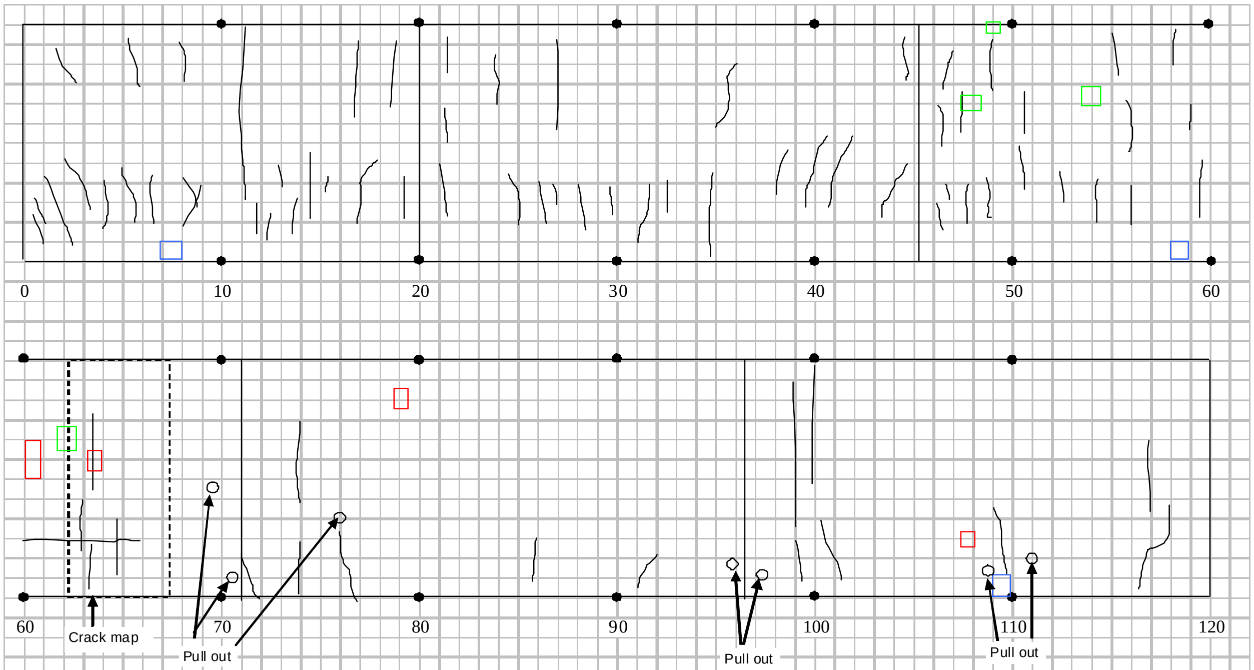



Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction: North (toward McMinnville)

Distance from start of bridge: 559.9'

Section ID: O Kwik Bond MLS




Bridge: S.Yamhill River, Hwy 39 McMinnville Spur (06758)

Travel direction: North (toward McMinnville)

Distance from start of bridge: 690.9'

Section ID: P Safetrack HW - 2 Coat System by Stirling Lloyd

6/24/2009 As noted in May, overlay is wearing through to concrete.
6/9/2010 ~15% of wheel paths have worn through.

# APPENDIX B:
# LABORATORY TESTING

# Appendix B-1 – Aggregate

Product: Flex-O-Lith Aggregate: 3M Indag Basalt

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 3.069 | Sieve Size | Weighted % Loss | % Loss |
| #4 | 100 | S.S.D. | 3.079 | 3/8 - #4 | 0 | 7.4 |
| #8 | 88 | Apparent | 3.100 | #4 - #8 | 0.8 | |
| #10 | | Absorption (%) | 0.32 | #8 - #16 | 0.4 | |
| #16 | 1 | | | #16 - #30 | 0 | |
| #30 | 0 | | | | | |

Product: Unitex Aggregate: #6 – 10 Oregon Emery

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 2.875 | Sieve Size | Weighted % Loss | % Loss |
| #4 | 100 | S.S.D. | 2.911 | 3/8 - #4 | 0 | 5.3 |
| #8 | 70 | Apparent | 2.981 | #4 - #8 | 0.4 | |
| #10 | | Absorption (%) | 1.23 | #8 - #16 | 0.1 | |
| #16 | 16 | | | #16 - #30 | 0.1 | |
| #30 | 2 | | | #30 - #50 | 0 | |
| #50 | 0 | | | | | |

Product: Kwik Bond Aggregate: Basalt + #6 – 10 Oregon Emery blend

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 2.690 | Sieve Size | Weighted % Loss | % Loss |
| #4 | 100 | S.S.D. | 2.714 | 3/8 - #4 | 0 | 8.0 |
| #8 | 50 | Apparent | 2.755 | #4 - #8 | 0.7 | |
| #10 | | Absorption (%) | 0.87 | #8 - #16 | 0.5 | |
| #16 | 0 | | | #16 - #30 | 0 | |
| #30 | 0 | | | #30 - #50 | | |
| #50 | | | | | | |

Product: SafeLane HDX Aggregate: Dolomitic Limestone

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 2.720 | Sieve Size | Weighted % Loss | % Loss |
| 3/8 | 100 | S.S.D. | 2.755 | 3/8 - #4 | 0.5 | 12.9 |
| 1/4 | 98 | Apparent | 2.819 | #4 - #8 | 0.5 | |
| #4 | 67 | Absorption (%) | 1.29 | #8 - #16 | 0 | |
| #8 | 7 | | | #16 - #30 | 0 | |
| #10 | | | | #30 - #50 | | |
| #16 | 3 | | | | | |
| #30 | 2 | | | | | |
| #50 | 1 | | | | | |
| #200 | 0.9 | | | | | |

Product: Safetrack and Urefast PF60 Aggregate: Steilacoom Basalt

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 2.670 | Sieve Size | Weighted % Loss | % Loss |
| 3/8 | | S.S.D. | 2.699 | 3/8 - #4 | 0 | 8.1 |
| 1/4 | | Apparent | 2.748 | #4 - #8 | 0.9 | |
| #4 | 100 | Absorption (%) | 1.07 | #8 - #16 | 0.5 | |
| #8 | 57 | | | #16 - #30 | 0 | |
| #10 | | | | #30 - #50 | | |
| #16 | 0 | | | | | |

Product: Tyregrip Aggregate: Calcined Bauxite

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 3.176 | Sieve Size | Weighted % Loss | % Loss |
| #4 | 100 | S.S.D. | 3.227 | 3/8 - #4 | 0 | 5.1 |
| #8 | 59 | Apparent | 3.346 | #4 - #8 | 0.1 | |
| #10 | | Absorption (%) | 1.6 | #8 - #16 | 0.1 | |
| #16 | 1 | | | #16 - #30 | 0 | |
| #30 | | | | #30 - #50 | | |
| #50 | 0 | | | | | |

Product: Mark 154 Aggregate: Oklahoma Flint

| Sieve Analysis T 27 | | Specific Gravity and Absorption T 84 | | Soundness T 104 | | Microdeval T 327 |
|---|---|---|---|---|---|---|
| Sieve Size | % Passing | Bulk | 2.572 | Sieve Size | Weighted % Loss | % Loss |
| 3/8 | | S.S.D. | 2.601 | 3/8 - #4 | 0 | 9.2 |
| 1/4 | 100 | Apparent | 2.651 | #4 - #8 | 2.4 | |
| #4 | 100 | Absorption (%) | 1.16 | #8 - #16 | 0.2 | |
| #8 | 17 | | | #16 - #30 | 0 | |
| #10 | | | | #30 - #50 | | |
| #16 | 0 | | | | | |

**Appendix B-2 – Abrasion**

The rotating cutter testing was based on ASTM C 944. A force of 22 pounds and a rotation speed of 250 rpm were used. The rotating cutter samples were conditioned prior to testing by dragging a crowbar across the surface for three minutes. This procedure knocked off the aggregate that were weakly bonded to the overlay. Two locations were tested from a single overlay sample panel that was made by the overlay contractor during the field applications. The date of the abrasion testing for each sample is indicated in the tables below.

Mark 154

| Sample 1 (10/11/07) | | | Sample 2 (10/11/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1326.4 | | 0 | 1294.0 | |
| 2 | 1323.0 | 3.4 | 2 | 1290.3 | 3.7 |
| 4 | 1321.1 | 1.9 | 4 | 1288.5 | 1.8 |
| 6 | 1320.2 | 0.9 | 6 | 1287.2 | 1.3 |
| 8 | 1319.2 | 1.0 | 8 | 1286.0 | 1.2 |
| 10 | 1318.5 | 0.7 | 10 | 1285.2 | 0.8 |

Flex-O-Lith

| Sample 1 (10/12/07) | | | Sample 2 (10/12/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1425.7 | | 0 | 1546.8 | |
| 2 | 1423.2 | 2.5 | 2 | 1544.3 | 2.5 |
| 4 | 1421.9 | 1.3 | 4 | 1543.0 | 1.3 |
| 6 | 1421.2 | 0.7 | 6 | 1542.3 | 0.7 |
| 8 | 1420.5 | 0.7 | 8 | 1541.9 | 0.4 |
| 10 | 1419.8 | 0.7 | 10 | 1541.4 | 0.5 |

Safetrack HW

| Sample 1 (10/15/07) | | | Sample 2 (10/18/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 988.3 | | 0 | 860.7 | |
| 2 | 985.1 | 3.2 | 2 | 858.6 | 2.1 |
| 4 | 984.2 | 0.9 | 4 | 857.8 | 0.8 |
| 6 | 983.4 | 0.8 | 6 | 857.3 | 0.5 |
| 8 | 983.0 | 0.4 | 8 | 856.8 | 0.5 |
| 10 | 982.6 | 0.4 | 10 | 856.3 | 0.5 |

Kwik Bond PPC MLS

| Sample 1 (10/9/07) | | | Sample 2 (10/10/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1813.8 | | 0 | 1584.6 | |
| 2 | 1810.5 | 3.3 | 2 | 1580.7 | 3.9 |
| 4 | 1808.2 | 2.3 | 4 | 1579.0 | 1.7 |
| 6 | 1807.0 | 1.2 | 6 | 1577.6 | 1.4 |
| 8 | 1806.1 | 0.9 | 8 | 1576.1 | 1.5 |
| 10 | 1805.3 | 0.8 | 10 | 1575.5 | 0.6 |

Tyregrip

| Sample 1 (10/11/07) | | | Sample 2 (10/15/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1486.7 | | 0 | 1172.0 | |
| 2 | 1485.3 | 1.4 | 2 | 1169.9 | 2.1 |
| 4 | 1484.3 | 1.0 | 4 | 1168.9 | 1.0 |
| 6 | 1483.7 | 0.6 | 6 | 1168.7 | 0.2 |
| 8 | 1483.2 | 0.5 | 8 | 1168.3 | 0.4 |
| 10 | 1482.7 | 0.5 | 10 | 1167.7 | 0.6 |

SafeLane HDX

| Sample 1 (10/10/07) | | | Sample 2 (10/11/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1489.2 | | 0 | 1467.1 | |
| 2 | 1483.2 | 6.0 | 2 | 1461.6 | 5.5 |
| 4 | 1480.1 | 3.1 | 4 | 1459.4 | 2.2 |
| 6 | 1477.3 | 2.8 | 6 | 1457.9 | 1.5 |
| 8 | 1475.4 | 1.9 | 8 | 1456.6 | 1.3 |
| 10 | 1474.1 | 1.3 | 10 | 1455.5 | 1.1 |

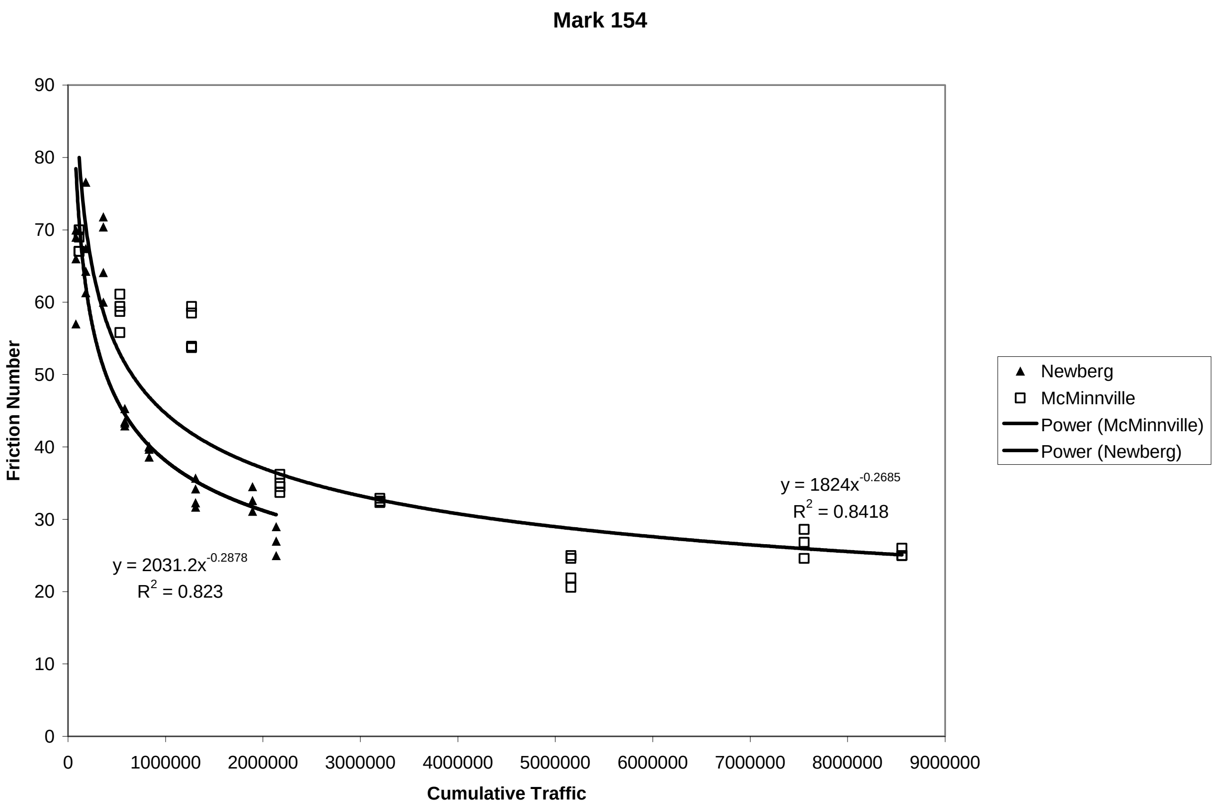
Urefast PF60

| Sample 1 (10/12/07) | | | Sample 2 (10/15/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1521.6 | | 0 | 1523.5 | |
| 2 | 1519.6 | 2.0 | 2 | 1521.6 | 1.9 |
| 4 | 1518.6 | 1.0 | 4 | 1520.6 | 1.0 |
| 6 | 1518.0 | 0.6 | 6 | 1520.0 | 0.6 |
| 8 | 1517.6 | 0.4 | 8 | 1519.5 | 0.5 |
| 10 | 1517.4 | 0.2 | 10 | 1519.0 | 0.5 |

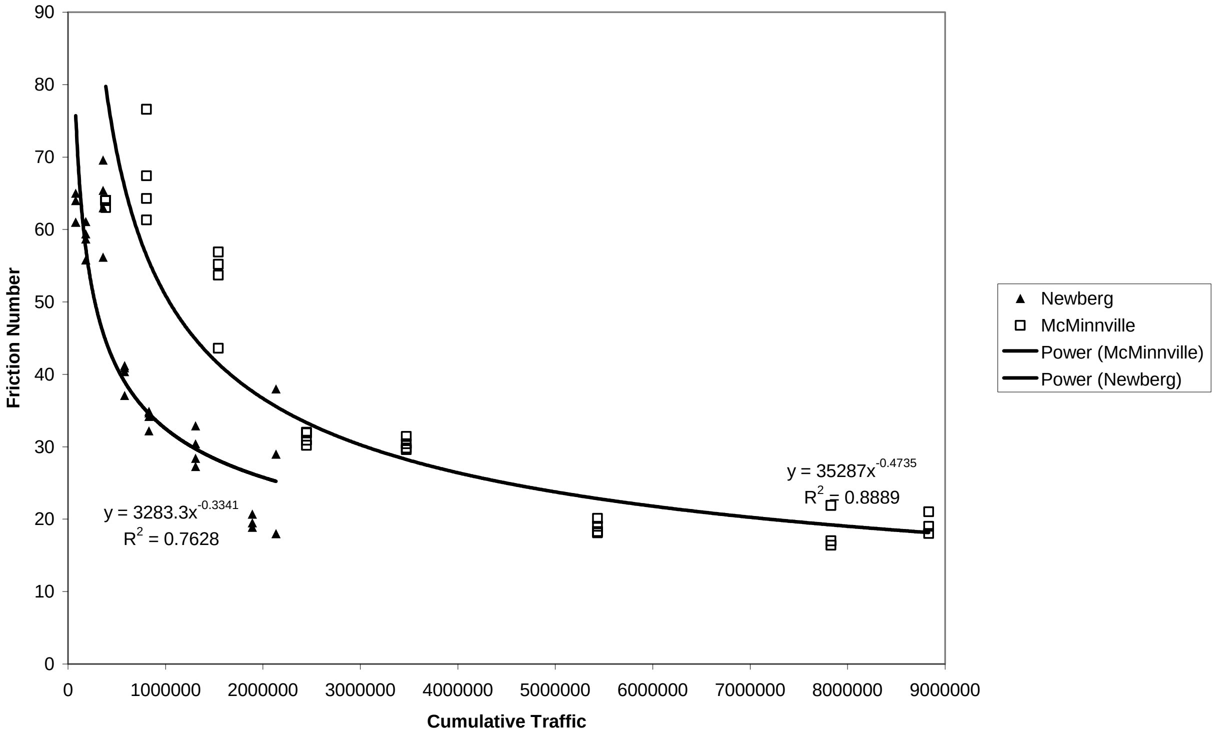
Unitex Pro-Poxy Type III DO

| Sample 1 (10/11/07) | | | Sample 2 (10/12/07) | | |
|---|---|---|---|---|---|
| Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) | Elapsed Grinding Time (min) | Sample Weight (g) | Weight Loss (g) |
| 0 | 1474.7 | | 0 | 1454.9 | |
| 2 | 1472.1 | 2.6 | 2 | 1453.7 | 1.2 |
| 4 | 1471.2 | 0.9 | 4 | 1452.9 | 0.8 |
| 6 | 1470.2 | 1.0 | 6 | 1452.3 | 0.6 |
| 8 | 1469.7 | 0.5 | 8 | 1451.9 | 0.4 |
| 10 | 1469.3 | 0.4 | 10 | 1451.5 | 0.4 |

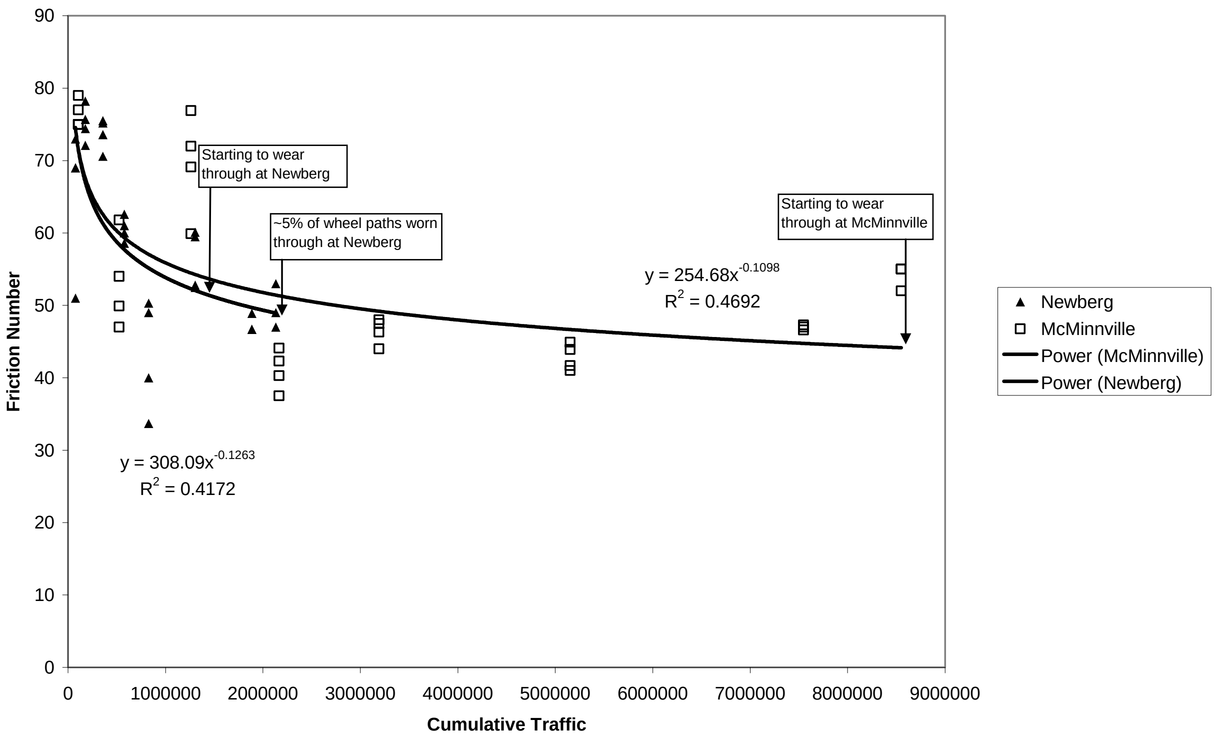
# APPENDIX C:
# SKID RESISTANCE GRAPHS

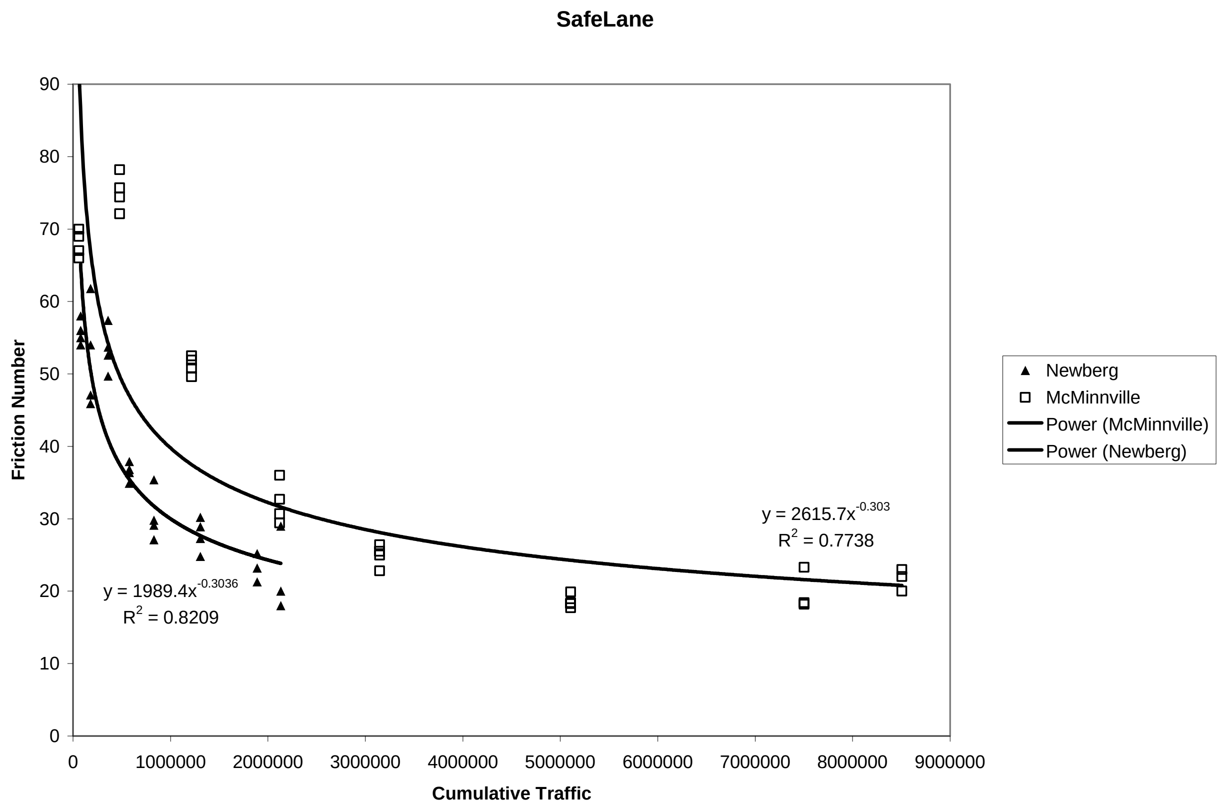

Mark 154
Friction Number
Cumulative Traffic
0
10
20
30
40
50
60
70
80
90
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
8000000
9000000
Newberg
McMinnville
Power (McMinnville)
Power (Newberg)
y = 1824x^-0.2685
R^2 = 0.8418
y = 2031.2x^-0.2878
R^2 = 0.823

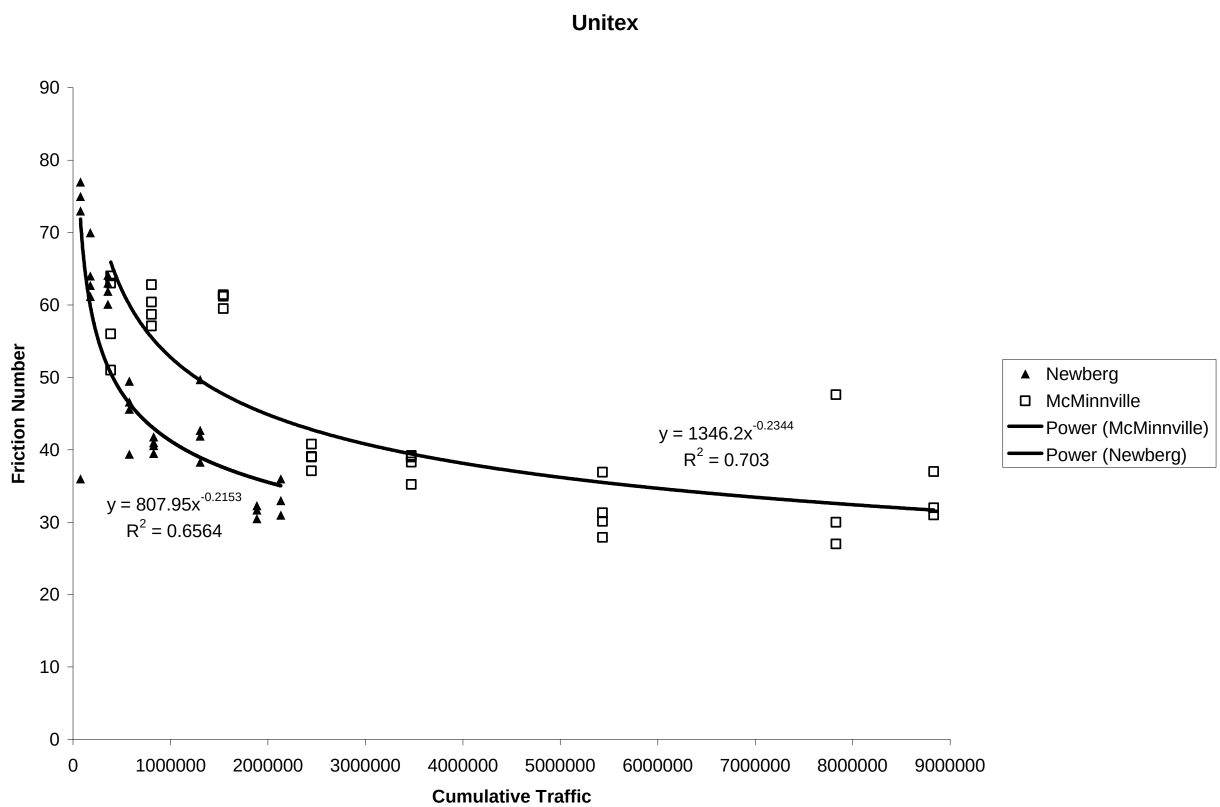
**Flex-O-Lith**



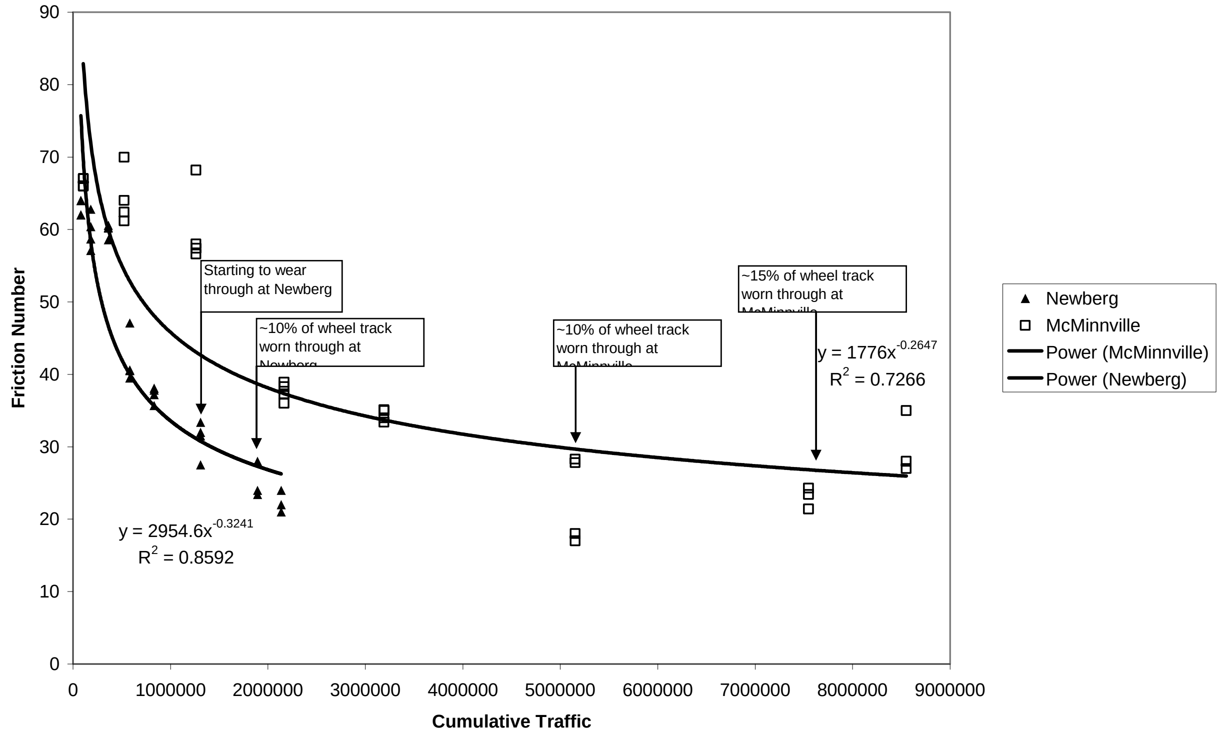

**Tyregrip**




SafeLane
Friction Number
Cumulative Traffic
Newberg
McMinnville
Power (McMinnville)
Power (Newberg)
y = 2615.7x-0.303
R2 = 0.7738
y = 1989.4x-0.3036
R2 = 0.8209


Unitex
Friction Number
Cumulative Traffic
Newberg
McMinnville
Power (McMinnville)
Power (Newberg)
y = 1346.2x-0.2344
R2 = 0.703
y = 807.95x-0.2153
R2 = 0.6564

**SafeTrack**




**Kwik Bond**