Report No. UT-04.03

Annual Experimental Features Report

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Utah Department of Transportation Research Division

June 2004

UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract

This contains multiple reports from the Experimental Features Program at UDOT. The Final Reports include: Cold Mix Recycling vs. HMA, Mark-163 Flexogrid Polymer Overlay System, San Rafael River Bridge Expansion Joint Replacement, Nippon Carbide High Performance (ULGII) Sign Sheeting, and Weber Canyon Pavement Marking Study. Interim reports include 3M 820 Wet- Reflective Tape on SR-6, 3M LPM 1200 Interim Report, Epoplex Polyurea (LS90), 3M LPM 1500, High-tension Cable Median Barrier (Brifen, Trinity) at UDOT, and Techcrete Pothole Patch Interim Report.

The report also contains a report on the Fixed Automated Spray Technology (FAST) system placed on Knudsen's Corner (I-215) and a study on Pork Chops (right turn only islands).

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Report No. UT-04.03

Cold Mix In-Place Recycling vs. HMA Final Report

Experimental Feature X(98)02 – New Products

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June 2004

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Abstract

The Utah Department of Transportation (UDOT) established a test section in 1998 to evaluate the performance of cold-mix in-place recycling (CMR) topped with 25% hot mix recycled asphalt. The test section is located on I-15 from Summit to Paragonah (Reference Marker 69.7 to 82.6). This report presents preliminary results from the Falling Weight Deflectometer (FWD) readings taken in 1999, 2001, 2002, and 2004. These readings indicate the recycled asphalt products have a higher structural number than designed and have about the same structural number as the Hot Mix Recycled product.

Introduction

Cold mix recycling is not a new process, but has not been viable in the past because of lacking technology. Today the technologies make it a viable process that makes use of existing asphalt roadways for building new sections. Savings occur because some pavement is not removed and the removed asphalt mixed with a rejuvenator (softener) greatly reduces the cost of the in place product.

The design structural number (SN) of the CMR section is around 6.0 and the SN of the 25% hot mix recycled section is around 5.5. This process has been used in Colorado, Utah and Nevada with success. CMR appears to be used more widely, there are 30 reports on it on the web and this process is used universally.

Background Information

UDOT when rehabilitating an asphalt roadway historically has removed the old asphalt pavement and untreated road base then established an adequate sub-grade then install new untreated road base and new asphalt. This wastes the removed product. There is little value in this approach compared to utilizing some of the existing material. Using existing material stresses the environment since there is little waste.

Region Four presented this alternate choice to the Federal Highway Administration (FHWA). FHWA opted to fund this 95% of this $7,000,000 project because of the expected cost savings of recycling material. Background design strengths indicated that these two processes would perform as well as a new asphalt pavement section.

Construction Information

The CMR operation was much like a train of equipment. It begins with a milling machine capable of milling 10' wide path (Fig.1) followed by water tanker (Fig. 2), softening agent tanker (Fig. 3), pickup machine (Fig. 4) to feed the cold mix through a

crusher/screening plant (Fig. 4) to size. The recycled material is wind-rowed (Fig. 5) with the water and softener added. The recycled material is then ready for a pickup machine (Fig. 6) to deliver the cold mix material into a conventional asphalt paver with no heat on the screed. One or two vibrating rollers knock down the material and roll to optimum density and then a light fog of cut-back before traffic may drive on it. This total process to finish is about five hours depending upon the ambient temperature and humidity.

Figure 1-Rotomill Machine

Figure 2-Water Tank

Figure 3- Softener Tank

Figure 4-Screening Machine

Figure 5-Windrow with Water and Softener Added

Figure 6-Pickup/Laydown Machine

Goal

The goal of this experimental feature was to compare the two processes with each other, i.e. 75/25% Hot Mix-Two Courses vs. 4" of Cold Mill Recycling/with Rejuvenator 3" of 75/25% Hot Mix.

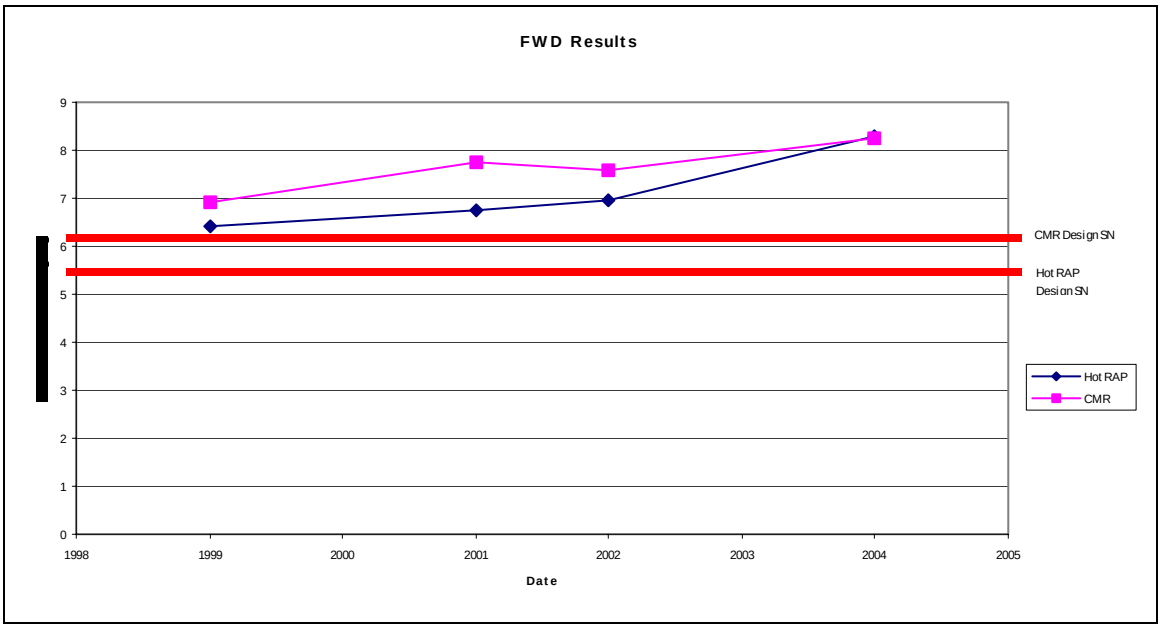
Objectives

1. Test structural strengths using the FWD analysis
2. Pavement condition index evaluation(PCI)

Preliminary Results

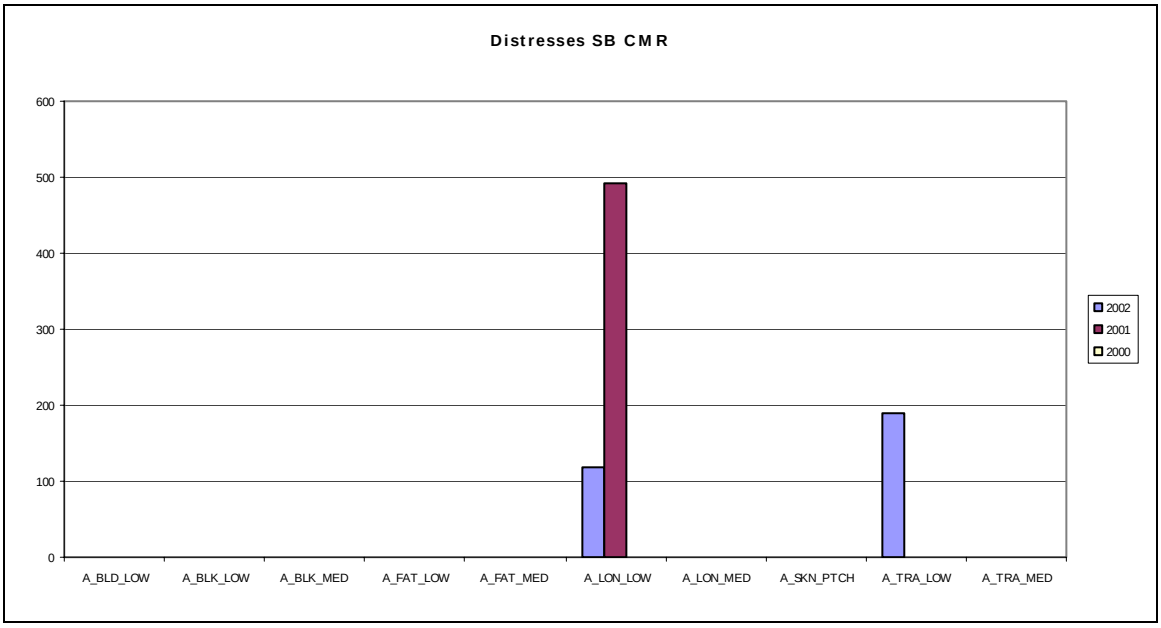
Objective 1: Test Structural Strengths Using the FWD Analysis

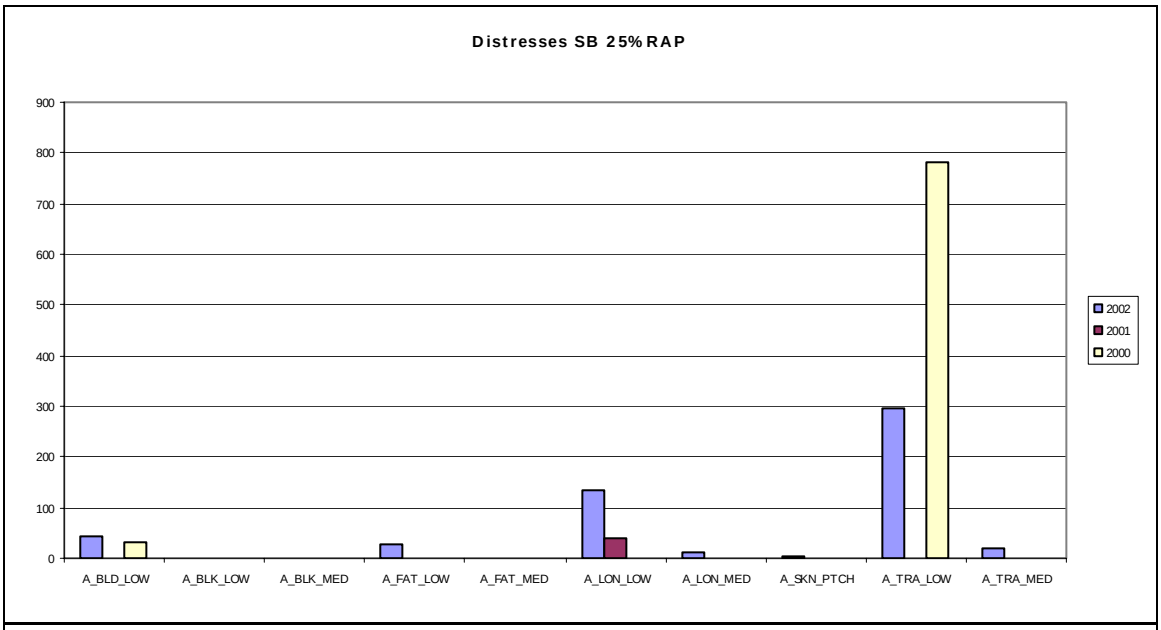
The Program Development unit has taken FWD structural readings for 1999, 2001, 2002, and 2004. The results are presented in the following table with the design SN included for reference.

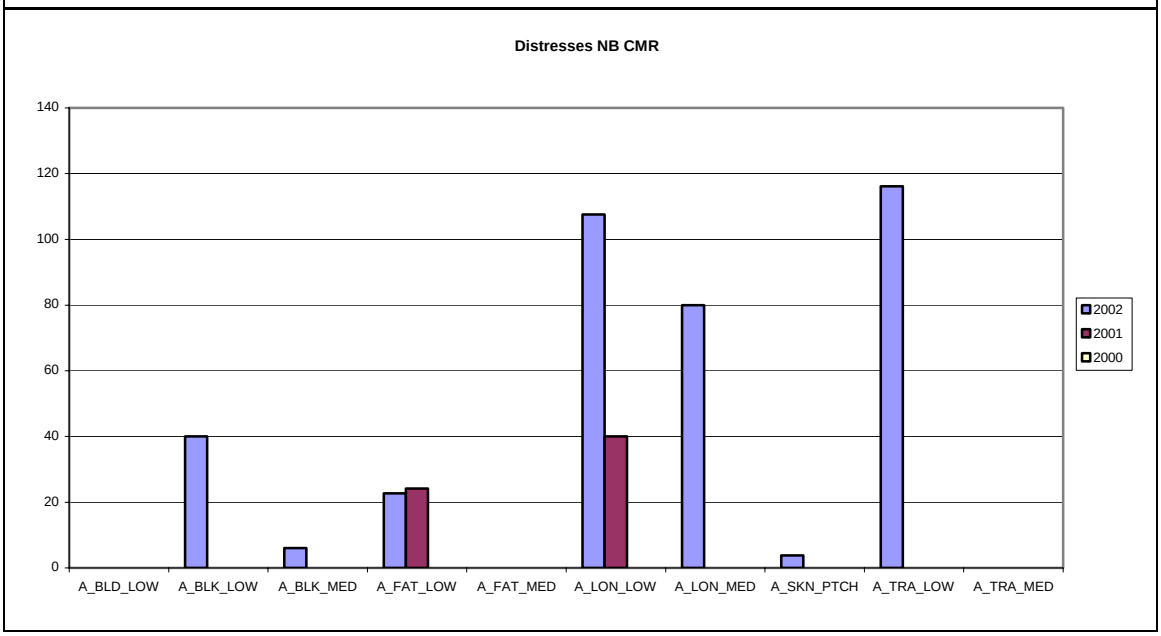


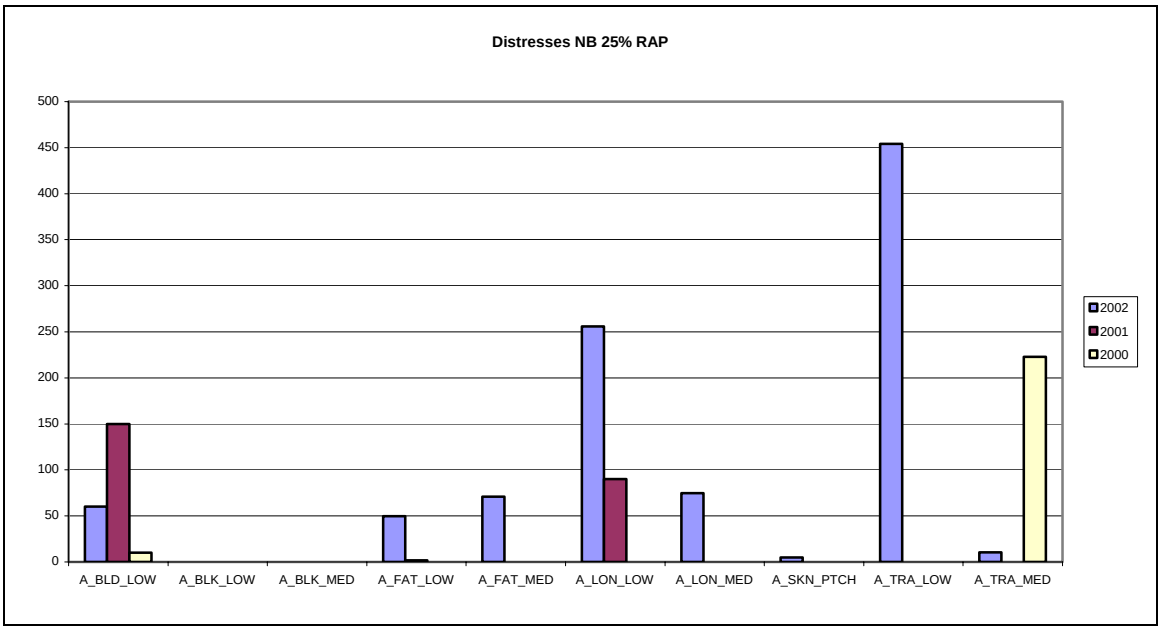
It is clear both designs are performing better than designed.

Objective 2: Pavement Condition Index Evaluation




Distresses SB 25% RAP
900
800
700
600
500
400
300
200
100
0
A_BLD_LOW
A_BLK_LOW
A_BLK_MED
A_FAT_LOW
A_FAT_MED
A_LON_LOW
A_LON_MED
A_SKN_PTCH
A_TRA_LOW
A_TRA_MED
2002
2001
2000


Distresses NB CMR
140
120
100
80
60
40
20
0
A_BLD_LOW
A_BLK_LOW
A_BLK_MED
A_FAT_LOW
A_FAT_MED
A_LON_LOW
A_LON_MED
A_SKN_PTCH
A_TRA_LOW
A_TRA_MED
2002
2001
2000



The PCI inspections show the material is beginning to show fatigue and thermal cracking. However, there doesn't seem to be a difference between the two strategies.

Conclusions

The tested structural strengths are higher than the designed strengths indicating a more than adequate design for both the cold mix and the 25% RAP. The cold mix is substantially less costly by about 40%.

Recommendations

Based upon the interim evaluations for structural strengths (FWD), UDOT Research recommends either section strategy is viable depending on circumstances. The most important factor to consider is the structure of the pavement section. CMR should only be considered as an option where the structure of the pavement is still good and the asphalt surface is deteriorated (i.e. thermal cracking, oxidation, weathering, etc.) CMR should not be considered where fatigue cracking or rutting (structure-related) are the cause of pavement failure.

Visual Observation

Figure 7-2003 SB-4 Years After

Figure 8-2001 SB-2 Years After

Figure 9-1999 SB-Just After Construction

Figure 10-1997 SB-2 Years Before Project

Figure 11-1995 SB 4 Years Before Project

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Report No. UT-04.03

Mark-163 Flexogrid Polymer Overlay System Final Report

Experimental Feature X(98)04 – New Products

By: **Dan Avila, P.E., D&I Engineer**
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Utah Department of Transportation Research Division

June 2004

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Introduction

This report will present the AASHTO T 260-97 chloride content tests taken and the skid tests since the installation of this product. Structure F-596 was the only structure tested although two structures were installed with the Flexogrid overlay. All figures and facts presented in this paper will refer to structure F-596. These interim evaluations will continue for two more years and will be presented in subsequent reports.

Bridge deck overlays using a flexible setting epoxy or methacrylate, a crack sealer and aggregate are not a new process but historically they have not been used because of the cost and the early failures of the flexible material incorporated in the overlay. Chemistry of epoxies and methacrylates has greatly improved warranting the general use of these products as bridge deck protection applications.

Background Information

PolyCarb is the manufacturer of the FlexoGrid system. The system consists of an epoxy that is thinly applied to the bridge deck and an aggregate that is applied to the epoxy. The purpose of the epoxy is to seal the bridge deck and hold the aggregate that improves skid resistance.

UDOT applies a Utah road salt during the winter months to keep the highway clear of ice and snow. The chlorides in the salt migrate through the concrete and attack the rebar in the deck and reduce the expected life of the bridge deck. This overlay application prevents chloride intrusion and also benefits the skid characteristics.

UDOT's current preservation strategy for bridge deck rehabilitation is to roto-mill old asphalt, prepare the deck surface, apply waterproofing membrane and overlay with 2" of 3/4 asphalt material. The wearing course of asphalt and the waterproofing membrane provide a barrier to prevent water and salts from intruding into the concrete bridge deck. The use of a flexible epoxy/methacrylate material with aggregate is one of the strategies to replace this system. Over 300 reports using this strategy with some variations are listed on the Google search site.

Construction Information

The bridge deck site had potential early deterioration because of deck cracking and questionable skid characteristics and was selected for these reasons to have a flexible epoxy sealer overlay installed. The deck was shot blasted to clean and remove any surface dirt and oil along with a slight abrading for a better bond. The contractor installed a low viscosity, high modulus epoxy crack seal first and then hand floated the first layer of epoxy on the deck (See Figure 1).

Figure 1-Low Viscosity, High Modulus Epoxy

The aggregate was then applied with a reversed vacuum thus blowing the small aggregate onto the epoxied surface and a reasonable amount and when the first lift had cured the excess aggregate was swept of and a second application of the flexible epoxy was applied and floated and the second application of aggregate was blown onto the surface. When the epoxy cured out the excess aggregate was swept off. The aggregate surface created a non-skid surface and a durable overlay. See Figure 2 to see the application of the aggregate.

Figure 2-Crews Add Aggregate to Epoxy

Figure 3 shows the final product.

Figure 3-Finished Product

The cost to install this product was $55,000 at 14,000 square feet or about $ 4.00 per square foot. The cost is low since PolyCarb contributed to the project.

Goal

The goal of this project is to determine if FlexoGrid is a viable bridge deck overlay.

Objectives

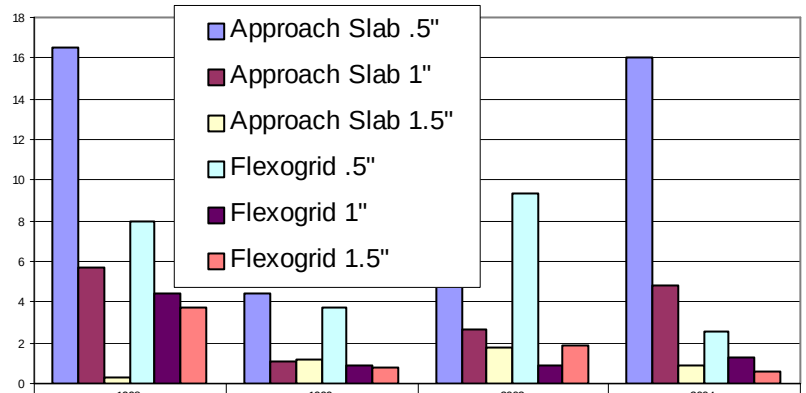
The objectives to reach this goal are:

3. Measure chloride penetration by measuring the chloride content at 3 levels in bridge deck and approach slab. The approach slab is considered the control in this project.
4. Measure skid resistance using the UDOT skid trailer.

Preliminary Results

Chloride Content on Bridge Deck F-596

Figure 4 shows the results of the first five years of chloride content results. The key number is the 1 ½" depth. As long as it is below 3 pounds per cubic yard corrosion is unlikely to occur and the rebar depth is at least 2".

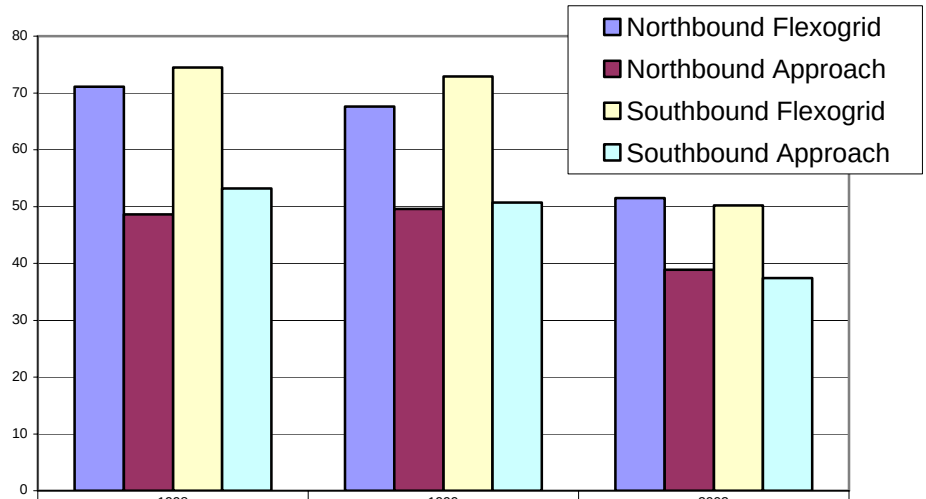


	1998	1999	2003	2004
Approach Slab .5"	16.5	4.47	7.08	16.02
Approach Slab 1"	5.69	1.12	2.65	4.84
Approach Slab 1.5"	0.309	1.16	1.79	0.89
Flexogrid .5"	7.98	3.73	9.32	2.53
Flexogrid 1"	4.42	0.86	0.89	1.23
Flexogrid 1.5"	3.76	0.82	1.9	0.63

Figure 4-Chloride Content Test Results

Pavement Friction Test Results

Figure 5 shows the results from the first five years of skid resistance. Numbers above 45 are considered moderate to UDOT.



	1998	1999	2003
Northbound Flexogrid	71.1	67.6	51.5
Northbound Approach	48.6	49.6	38.9
Southbound Flexogrid	74.5	72.9	50.2
Southbound Approach	53.2	50.7	37.4

Figure 5-Skid Resistance Test

Conclusions

The skid numbers and the chloride penetration numbers indicate, at this time, the flexible epoxy overlay does just what it says it will do by reducing the chlorides and maintaining more than adequate skid numbers.

The high chloride content in the surface of the sealed deck is surprising. However, since the reading is in the first .5", the overlay material may be contaminating the results of the chloride penetration test.

Recommendations

Based upon the results of the testing of the flexible bridge deck overlay it may be recommended for future concrete bridge deck rehabilitation.

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Report No. UT-04.03

San Rafael River Bridge Expansion Joint Replacement (Final Report)

Experimental Feature x(01)01– New Products

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Utah Department of Transportation
Research Division

September 2003

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Abstract

UDOT's Structures Division is interested in investigating new materials for bridge deck joints. The experimental product in this evaluation is Ure-Fast PF-60 elastomeric concrete. The material was placed on a bridge in central Utah on State Route 24 that spans the San Rafael River (Fig. 1&2).

The material was used not recommended by the supplier. UDOT did not use the material as an expansion joint, but rather as a quasi-rigid joint. The material has shown good durability after one and a half years in place. There are signs of problems with the present application of the material. It appears as though the bridge expands more than expected, and as a result, the concrete surrounding the joint is showing signs of failure. UDOT Research estimates this is a compressive failure as a result of the expansion of the bridge. The Ure-Fast PF-60 appears to be stronger in compression than the surrounding concrete. The Ure-Fast PF-60 also appears to be lifting in order to relieve some of the compressive forces. Analysis through the winter will determine if the lip caused by this lift will catch on snowplow blades. The preliminary conclusion is this material alone cannot be used to replace an expansion joint on a bridge with at least the same amount of expansion.

Figure 1-Structure OF 202 over the San Rafael River

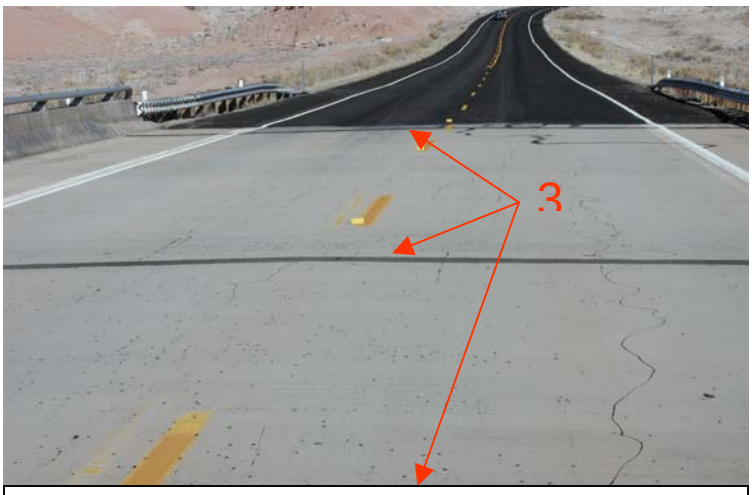


Figure 2-Three joints on the structure

Introduction

UDOT's Stuctures Division manages over 2700 bridges throughout the State. One of the more common problems UDOT has is replacing expansion joints as they wear. UDOT's current practice is to saw-cut the existing joint and replace it with a new one. This process requires setting the new joint into a concrete mix that takes 14-28 days to cure. This delay creates a tremendous traffic control issue, particularly in urban areas.

There are many different types of products that have been developed in an attempt to solve this problem. UreFast PF-60 is a synthetic polyurethane material that is distributed by Sullivan Supply Company (Fig. 3). Cure time can be as little as 10 minutes, which significantly reduces the traffic control problems.

Figure 3-Ure-Fast PF-60 brochure from Sullivan Supply

Background Information

Kleston Laws, Price District Engineer identified a bridge (OF-202) that he would like to test Ure-Fast PF-60 on as an experimental test section. The bridge spans the San Rafael River, was built in 1971, and is located on SR-24 about 6 miles south of I-70 (Fig. 4&5). The approximate bridge span is 215 ft; composed of a pre-stressed concrete girder bridge with a 4 ft concrete parapet railing.

One reason this site was an ideal location is the amount of traffic (AADT = 420). Although SR-24 is a major route to Lake Powell, and the construction took place during boating season, this road experiences little traffic during the workweek. This fact increased the safety of the workers on the project and reduced the necessary traffic control.

The existing expansion joints at this structure had failed. Engineers thought the expansion on this bridge was not enough to warrant an expansion joint. Engineers with the advice of Sullivan Supply Company suggested using UreFast PF-60 in place of an expansion joint since they thought the material would be flexible enough to relieve the expansion stresses.

Figure 4-Location is about 6 miles south of I-70

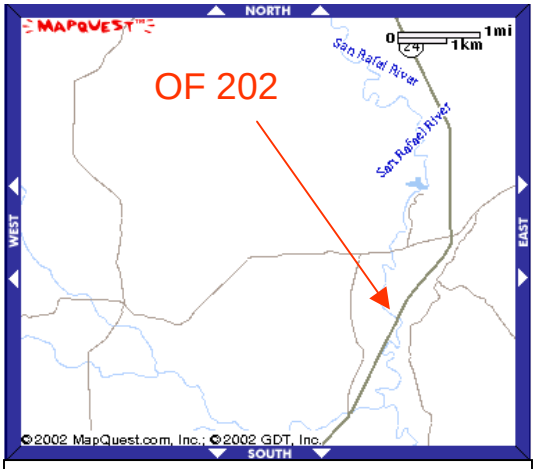


Figure 5-Over the first crossing of the San Rafael River

Construction Information

Ure-Fast PF 60 is referred to as an elastomeric concrete. It is a system that includes gravel, backer rod, and liquid polymer. The installer first completely removes the existing expansion joint system (Fig. 6). This was done in sections on this project in order to allow traffic to pass. The installer then places the backer rod into the expansion joint (Fig. 7&8). The installer laces gravel in the void left by the old expansion joint system (Fig. 9) and then applies the liquid polymer to the gravel (Fig. 10), which forms a polymer-concrete. The final step is to apply a thin layer of gravel to the surface for a gravel finish (Fig. 11). The liquid polymer takes only minutes to cure, so traffic can be released onto it in much sooner than contemporary methods.

Figure 6-Cleaning removed expansion joint channel cut

Figure 7-Installing backer rod

Figure 8-Installing backer rod

Figure 9-Pouring in the gravel

Figure 10-Applying polymer liquid and gravel finish

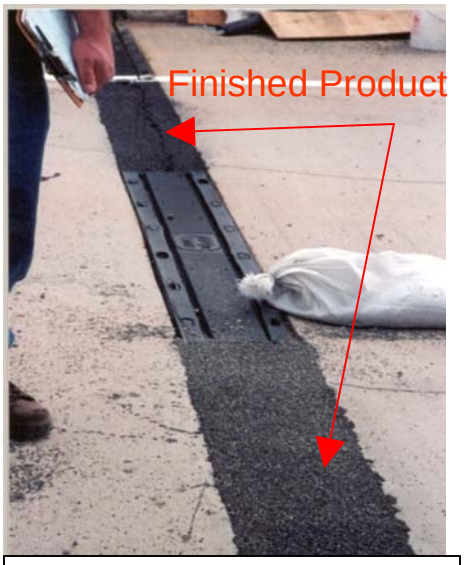


Figure 11-Finished product

Goal

The goal of this research is to determine if Ure-Fast PF-60 performs as well, installs as easily, cures as fast, and endures as well as the manufacturer claims. Also, the goal of this research is to determine if this application of Ure-Fast PF-60 is proper.

Objectives

The objectives of this research to reach the goal are:

1. Review research of this and other products.
2. Research the performance of this product in other states.
3. Evaluate the benefits and limitations during construction.
4. Evaluate the product performance in the field.
5. Evaluate the cost-effectiveness of this product.

Preliminary Results

Objective 1: Review research of this and other products

There has been little research done on expansion joint materials. On this project, the product was intended to actually remove the joint. There have been many studies conducted on integral or semi-integral abutment (jointless) bridges, but none on the removal of expansion joints. UDOT Research can provide the literature search results for jointless bridges if requested.

Objective 2: Research the performance of this product in other states

Sullivan Supply Company gave a list of other states that had installed this product. The list included employee names of the states of Oregon, Washington, and Colorado DOTs.

Oregon DOT: The contact in Oregon was from the Dalles area. He said they use UreFast PF-60 for crack sealing decks before overlaying. When asked if they had used the material in a similar fashion as this project, he responded that his region had not. He said he was impressed with the material and had recently re-visited a site where the material was used as a polymer overlay. The material had held up well for two years even though the region used a lot of studded tires.

The contact also mentioned that his region might not be comparable with Utah since the region does not experience as many temperature extremes as Utah.

Washington DOT: Jim Henderson said they are happy with the product. He said they don't use this product alone as an expansion joint. He will typically remove the extruded metal from the joint, take the joint back about 2" then use the UreFast PF-60 in combination with a polymer expansion joint sealant (Ure-Fast liquid sealant) that supports up to 2" of expansion/contraction. He said they typically only treat bridges up to spans from 40' to 140'. He said they do use the UreFast PF-60 for pothole repairs because of the speed of installation.

Colorado DOT: Tom Young said they are happy with the PF-60. He has used it to replace finger joints on small structures with success. Colorado does not use the PF-60 to fill the whole joint. He said they use the PF-60 to fill the void left by the existing expansion joint, but use the backer rod and Ure-Fast liquid sealant to seal the joint. This method is the same as given in the brochure picture (see Appendix).

Objective 3: Evaluate the benefits and limitations during construction.

The largest benefit of this product is that it required minimal time to construct compared to contemporary methods. The total process took one day to complete. The longest part of the process was the removal of the existing joint and the cleaning of it. The placement and curing of the material took about 1 hour per joint. Contemporary methods could not have been used on this project because it would require at least one lane of a two-lane road to be closed for a period of 14-28 days. Cutting the time down to hours made the expansion joint rehabilitation possible.

Objective 4: Evaluate the product performance in the field.

Figure 12- Pictures of all 3 joints.

The product was placed in April 2001. Research visited the test site on September 2, 2002. The condition of the experimental material was good. The material showed slight signs of cracking and spalling. However, the concrete adjacent to the product was beginning to spall (See Appendix).

The opinion of UDOT Research is that the expansion of the bridge deck had transferred through the product and caused the concrete on either side of the product to fail in compression. It appeared as though the compressive strength of the product exceeded that of the concrete. The Structures Division Inspectors rated the condition of the bridge deck as “satisfactory” on an excellent to poor scale (the condition of the bridge deck was “bad” in the opinion of the evaluators). This may have contributed to the spalling in the concrete.

Objective 5: Evaluate the cost-effectiveness of this product.

The cost-effectiveness was not evaluated since this application was not successful.

Conclusions

- Ure-Fast PF-60 is easy to install and is much quicker than using concrete.
- Ure-Fast PF-60 appears to have a stronger compressive strength than the surrounding concrete although the typical properties given by the manufacturer contradict this.
- Ure-Fast PF-60 has some elastic properties, but not enough to absorb the thermal expansion of the bridge at this location. The result of this is the compressive failure (spalling) of the concrete at the joint.
- Some states use Ure-Fast PF-60 with success, but use Ure-Fast liquid sealant to seal the joint.
- Ure-Fast PF-60 is “squeezing” out of the joint. This may be a problem for snowplowing.
- Ure-Fast PF-60 is not appropriate as a stand-alone product for eliminating expansion joints with this much expansion.

Recommendations

Ure-Fast PF-60 should not be used in the future to replace expansion joints on bridges that have at least as much expansion as this bridge. The material may work alone in another location where the bridge does not expand as much as this bridge.

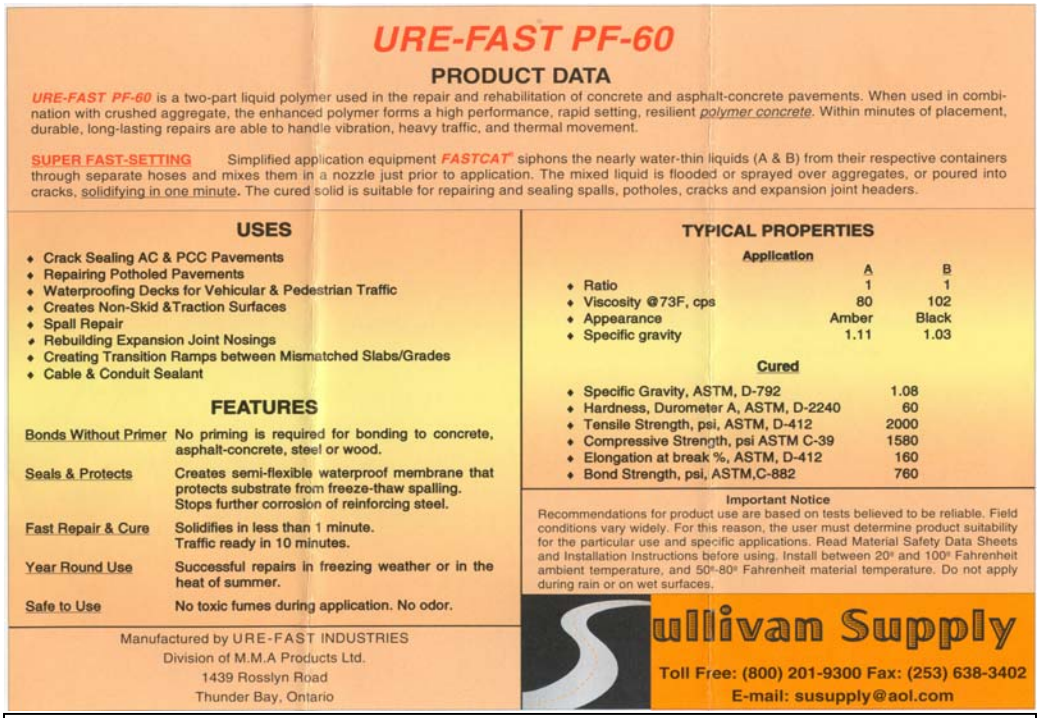
Ure-Fast PF-60 can and should be used with the Ure-Fast liquid sealant to replace the joint (See Appendix). Other states have had success with this combination.

Ure-Fast materials may be a good overlay product for locations where durability of the overlay is a problem. Oregon DOT has had early success with Ure-Fast products as an overlay.

Appendix
Suggested Use

The joint should be carried up through the product and sealed with a liquid sealant.

Notice the material is not continuous through the joint. In UDOT's application there is no joint sealant; the material is continuous.



URE-FAST PF-60

PRODUCT DATA

URE-FAST PF-60 is a two-part liquid polymer used in the repair and rehabilitation of concrete and asphalt-concrete pavements. When used in combination with crushed aggregate, the enhanced polymer forms a high performance, rapid setting, resilient polymer concrete. Within minutes of placement, durable, long-lasting repairs are able to handle vibration, heavy traffic, and thermal movement.

SUPER FAST-SETTING Simplified application equipment FASTCAT® siphons the nearly water-thin liquids (A & B) from their respective containers through separate hoses and mixes them in a nozzle just prior to application. The mixed liquid is flooded or sprayed over aggregates, or poured into cracks, solidifying in one minute. The cured solid is suitable for repairing and sealing spalls, potholes, cracks and expansion joint headers.

USES

- Crack Sealing AC & PCC Pavements
- Repairing Potholed Pavements
- Waterproofing Decks for Vehicular & Pedestrian Traffic
- Creates Non-Skid &Traction Surfaces
- Spall Repair
- Rebuilding Expansion Joint Nosings
- Creating Transition Ramps between Mismatched Slabs/Grades
- Cable & Conduit Sealant

FEATURES

Bonds Without Primer	No priming is required for bonding to concrete, asphalt-concrete, steel or wood.
Seals & Protects	Creates semi-flexible waterproof membrane that protects substrate from freeze-thaw spalling. Stops further corrosion of reinforcing steel.
Fast Repair & Cure	Solidifies in less than 1 minute. Traffic ready in 10 minutes.
Year Round Use	Successful repairs in freezing weather or in the heat of summer.
Safe to Use	No toxic fumes during application. No odor.

Manufactured by URE-FAST INDUSTRIES
Division of M.M.A Products Ltd.
1439 Rosslyn Road
Thunder Bay, Ontario

TYPICAL PROPERTIES

Application

	A	B
Ratio	1	1
Viscosity @73F, cps	80	102
Appearance	Amber	Black
Specific gravity	1.11	1.03

Cured

Specific Gravity, ASTM, D-792	1.08
Hardness, Durometer A, ASTM, D-2240	60
Tensile Strength, psi, ASTM, D-412	2000
Compressive Strength, psi ASTM C-39	1580
Elongation at break %, ASTM, D-412	160
Bond Strength, psi, ASTM,C-882	760

Important Notice
Recommendations for product use are based on tests believed to be reliable. Field conditions vary widely. For this reason, the user must determine product suitability for the particular use and specific applications. Read Material Safety Data Sheets and Installation Instructions before using. Install between 20° and 100° Fahrenheit ambient temperature, and 50°-80° Fahrenheit material temperature. Do not apply during rain or on wet surfaces.

ullivan Supply
Toll Free: (800) 201-9300 Fax: (253) 638-3402
E-mail: susupply@aol.com

Material information brochure provided by Sullivan Supply

Problem Photos

Illustrations of the material “squeezing” out of the joint due to thermal expansion

Illustrations of the adjacent concrete spalling

Notice one section is raised and the other is not. Maintenance crews have sealed the lip for snowplow operations

Report No. UT-04.03

Evaluation of Nippon Carbide High Performance Ultra Lite Grade II (ULGII) Sign Sheeting

Experimental Feature X(02)01 – New Products

By: **Dan Avila, P.E., D&I Engineer**
Barry Sharp, Research Specialist
Robert Stewart, P.E., Development Engineer

Utah Department of Transportation
Research Division

August 2003

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Abstract

UDOT placed Nippon Carbide's High Performance Ultra Lite Grade II (ULGII) sign sheeting on a sign on the offramp from I-15 to Paragonah. The product appeared to be easier than 3M's to install, and has had no durability problems.

Introduction

This report is an interim report for an experimental feature conducted by the Utah Department of Transportation on Nippon Carbide's High Performance Ultra Lite Grade II (ULGII) Sign Sheeting. The product was installed on a sign on the northbound exit ramp from I-15 at exit ramp 82. The product was installed in February 2002 and will be evaluated for fabrication and adhesion to substrate.

Background Information

Signs are composed of three basic components. The first is the mount to which the sign is fastened. This is typically a wooden or metal post, but can be a bridge structure, overhead structure, etc. The second component is the base material, usually ½" to 1" plywood or ¼" aluminum. The base material provides the structural stability of the sign. The third component is the sign sheeting that is fastened by an adhesive to the base material. The sign sheeting is usually made of a reflective material that reflects the light from headlights back to the driver.

When a sign sheeting is applied to an aluminum panel all that is required is the surface to be clean. However, Nikkalite requires a light sanding ("kiss sanding") of plywood before their product is applied in order to guarantee it. Other vendors do not require this additional work, so UDOT decided to test preparation methods as well as the product itself.

Fabrication Information

As mentioned above, Nikkalite requires a light sanding before their product is applied. To test this requirement, half of the plywood panel was lightly sanded according to Nikkalite requirements, and the other was just inspected for cleanliness. The Nikkalite sheeting was used for the green background, the letters, and quarter-rounds on the outside stripe. A 3M product was used for the straight sections of the outside stripe.

Figure 1- Sign after fabrication

Goal

The goal of this experimental feature was to determine the acceptability of Nikkalite ULGII sign sheeting.

Objectives

1. Subjectively monitor the ease of fabrication.
2. Subjectively monitor the durability of the product in the field.

Preliminary Results

1. Subjectively monitor the ease of fabrication.

The fabricator in the shop indicated that Nikkalite sheeting was easier to install than 3M's (less tendency to bubble underneath during application). He also indicated that 3M sign sheeting tends to crack along the sheeting seam. Furthermore, the Nikkalite sheeting appears to be more flexible than 3M's, facilitating the process of bubble elimination (air extrusion) during fabrication.

2. Subjectively monitor the durability of the product in the field.

Figure 5- Sign shows no durability concerns.

There does not appear to be any difference between the part of the sign that was lightly sanded and the side that was not. There do not appear to be any noticeable defects in the durability of the product.

Conclusions

The Nikkalite product is easier to fabricate than the current UDOT product and appears to be as durable in the field. Therefore, the product is acceptable to be used at UDOT.

Preliminary Recommendations

Sign sheeting at UDOT is procured using a competitive bidding process. Therefore, the use of this product will be limited to the successful bidding by the manufacturer.

Report No. UT-04.03

Weber Canyon Pavement Marking Study Final Report

Experimental Feature X(03)08 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

Central Maintenance wanted to try two products UDOT doesn't typically use, thermoplastic and methyl-methacrylate (MMA). Interstate 84 at the mouth of Weber Canyon was chosen as the site for this test based on the fact it didn't require any pavement maintenance for the next two years. The pavement at this location is Superpave (PG 64-28) asphalt with a 2" open-graded surface course and is two 12' lanes in each direction separated by a median that primarily is lined with Jersey barrier.

In order to have a control for this test, UDOT decided to place the two experimental products in line with the two primary products UDOT currently uses; waterborne and epoxy. Also, since the pavement was not new, UDOT decided to remove the existing pavement marking and prepare the surface.

UDOT decided to create a 2-mile section. In this 2 miles, each product would be placed for ¼ mile so that each product would be placed twice in the two miles. In addition to this, an additional 2 miles of waterborne paint would be applied where no surface prep had been performed. This would give an indication as to the effectiveness of surface preparation.

Construction Information

The paint crew for Region 1 maintenance set traffic control. One lane was closed in the eastbound direction. Originally, the right lane was closed so the edge line and skip line could be removed/replaced. However, given the narrow width of the shoulder or the left lane it was unsafe for the workers. The right lane had a much wider shoulder, which would allow vehicles (especially large trucks) to cheat away from the workers. Therefore, the decision was made to abandon the edge line work, shift traffic to the right lane, and remove/replace the skip line from the left lane.

The Region 1 paint crew applied the waterborne paint. This truck had been equipped with an automated system that touted the ability to track information such as relative humidity, pavement temp., air temp, location, paint thickness, bead drop rate, etc. The desired dry thickness of the paint was between 15-20 mils. However, a test plate was placed and revealed the paint was only being applied at 7 mils. This problem will more than likely affect the performance of the paint. It was also apparent that the beads did not begin to drop until the second skip line of each of the two waterborne sections.

Pervo placed the thermoplastic material using a walk-behind machine. The thermoplastic pellets were placed in the hopper and melted using a propane heat source while mixing the material by hand. The material was placed by pouring the material into a metal shoe as the operator pushed the machine.

TMT Pathway placed their MMA product using their spray truck. Region 2 Paint Crew applied the epoxy using their spray truck.

Goal

The goal of this project is to recommend a material for Weber Canyon.

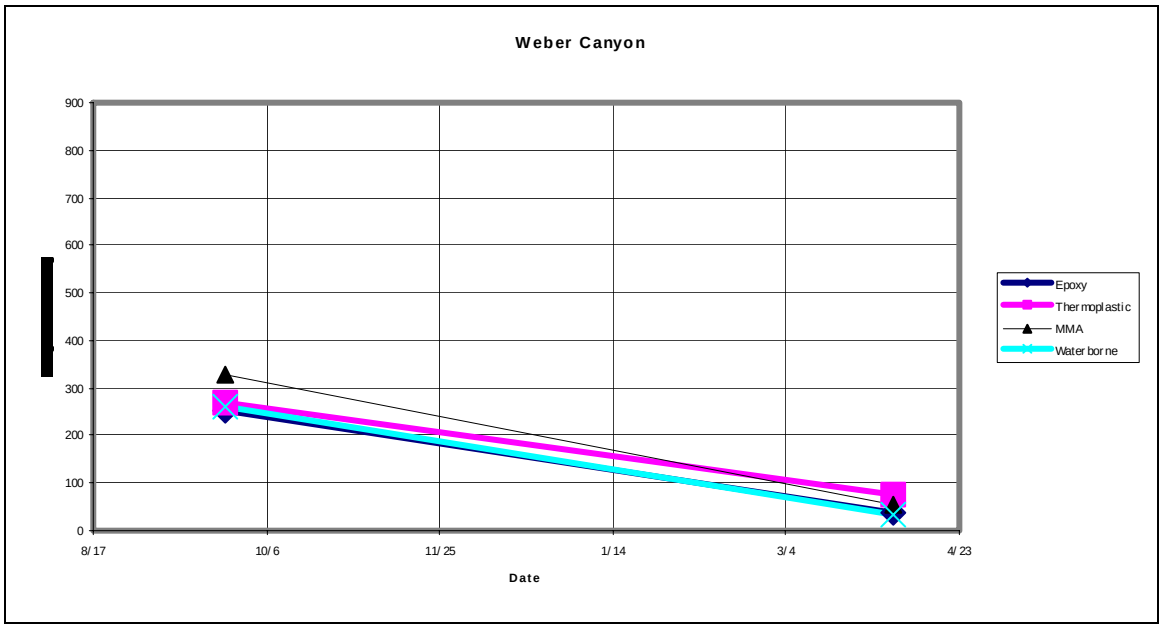
Objectives

The objectives of this project are:

1. Compare the retro-reflectivity of each product over a period of two years.
2. Compare the retro-reflectivity of the waterborne paint applied with surface prep to the paint without.
3. Calculate a life-cycle cost of each product and the waterborne paint without surface prep.
4. Recommend a product based on best life-cycle cost.

Results

1. Retro-reflectivity: All products failed (below 100) after 1 plow season.



Durability

	Epoxy % Remain	Thermo % Remain	MMA % Remain	Waterborne % Remain
1st Section	**70%**	**43%**	**94%**	**10%**
2nd Section	**90%**	**31%**	**77%**	**31%**
	77%	**39%**	**86%**	**20%**

Conclusions

All products failed from a retro-reflectivity standpoint after 1 plow season.

The MMA had the greatest durability. It seemed to be the only material that maintained acceptable presence even though the material was failing for RR. The thermoplastic material retained the highest RR, but suffered the most from a durability standpoint.

In some sections of the thermoplastic region, the asphalt overlay and the thermoplastic material were removed during the winter. The asphalt was only removed directly under the thermoplastic leading to the thought the thermoplastic material may have negatively affected the underlying asphalt. See Figure 1.

Figure 5- Localized removal of asphalt under thermoplastic material.

Preliminary Recommendations

This location may require a groove into the asphalt. This location experiences a high number of trucks, and has an AADT of about 15,000. The road at this location has a lot of curves, which is harsh on skip lines. These materials may need to be placed on the edgelines instead to see if it is the conditions or the material that is the cause of failure. It is evident that waterborne and thermoplastic should not be used on the skip line of this section since the durability was so low. Epoxy and MMA will give daytime presence, but will not be visible at night.

Appendix

Figure 2- Typical Epoxy

Figure 3-Typical Thermoplastic

Figure 4-Typical MMA

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Report No. UT-04.03

Fixed Automated Spray Technology (FAST) on Knudsen's Corner Interim Report

Special Study

By: Robert Stewart, P.E., Development Engineer

Utah Department of Transportation
Research Division

May 2004

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Overview

This paper overviews the selection, design, implementation and performance of UDOT's first Fixed Automated Spray Technology (FAST) system. Engineers at UDOT decided to place the system on a bridge on I-215 at 6200 South. The name of this particular stretch of interstate is named Knudsen's Corner. The bridge is one of the first SPUI installations in Utah. It provides 3 lanes of traffic in both northbound (NB) and southbound (SB) directions; 6200 South runs underneath it.

The system was installed in two phases. The first phase was the NB lanes UDOT equipped in 2000. The bridge requires nine spraying disc placed near the skip line between the center and right-most lanes. UDOT equipped the SB lanes in 2003.

UDOT has been a strong supporter of advanced technology in winter maintenance operations. UDOT has been using a Road Weather Information System (RWIS) for anti-icing for a number of years with great success. UDOT researched other states' experiences with FAST systems and believed the safety at this structure could be improved with this technology.

UDOT chose to use Potassium Acetate (KA) for this system. KA has a low freeze point, is environmentally friendly, and non-corrosive to both the system and the structure. KA is also the most expensive anti-icing liquid.

This report reviews the FAST installation at the site, the roles and partners in the development, implementation, and operation, the system and its performance, and lessons learned.

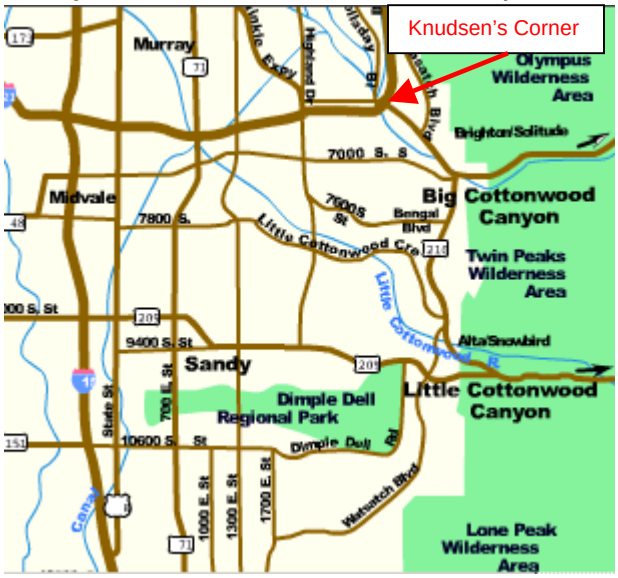
Objective

UDOT is constantly looking to improve its methods; in this case winter operations. UDOT has and is continuing to deploy an RWIS. UDOT believes FAST systems are an extension of an RWIS. Environmental Sensing Stations (ESS) are used to measure atmospheric and surface conditions. These are one component of an RWIS.

The objective of this spray system is to improve safety of a structure. The theory behind the technology is for system to detect a point just prior ice formation. At this point, the system triggers 18 valves to spray an anti-icing liquid onto the bridge deck via deck-mounted spray discs, thus preventing the formation of ice. The focus by UDOT was to make sure that the system would do this automatically. UDOT believes a system needs to be automated since UDOT employees are taxed with doing more work, more efficiently, with less money.

Background Information

Knudsen's corner has been thought of as a treacherous location during snow events and black-ice conditions. It is a location that experiences high winds and heavy snow. These conditions coupled with the fact the bridge is on a corner, provide a high slide-off frequency. Although a maintenance station is located approximately 1 mile from this bridge, it is difficult to focus all effort on one bridge. In fact, this maintenance station is responsible for both Cottonwood Canyons, each of which house two major ski resorts.



This bridge was the home for a study done by the University of Utah. This study was funded by UDOT to determine if a spray system was justified. The experimental spray system was crude and flawed, but UDOT determined a spray system was plausible.

The first phase (NB installation) was funded as a Research project. UDOT decided to put in a Boschung system. However, UDOT did not automate the system nor install Boschung sensors. Instead, UDOT planned on using the existing Surface Systems Inc. (SSI, now part of Quixote) sensors. The sensors would trigger a page on the onset of ice. This setup was always thought to be temporary until phase two of the project.

Many different divisions within UDOT added to the funding of the second phase (SB installation). These were the ITS, Research, Region 2 Operations, and Central Maintenance divisions. A pooled fund project made sense here because all are stakeholders in the system.

Description and Design

Primarily, Boschung performed the design of the system. They were able to use a small portion of the equipment from the study done by the University of Utah (concrete pad, fenced area, etc). From experience with the initial phase of the installation, UDOT required the system to be fully automated using on-location active and passive sensors.

The primary reservoir is capable of holding about 150 gallons of anti-icing liquid. This reservoir is supplied by a 500-gallon secondary reservoir. The reservoirs are linked together but the primary reservoir must be filled manually using a

manual valve. This proves to be laborious and tedious and will be changed but actually proved valuable as explained in lessons learned.

The liquid is carried to the valves via 1” conduit that is installed in 3” conduit that also houses conduit for the valve control wires. All of these components meet in the valve boxes that are hung from the bridge deck directly beneath the spray discs. The valve boxes include both the valve and the valve card. The valve card is responsible for receiving the order to spray and charging the solenoid in the valve.

Boschung has classified this system as being the maximum number of discs that a spray system of this size can handle (18). The system is triggered by both active and passive sensors or by meteorological conditions. For instance, the system can be triggered if the active sensor detects the freezing point of the liquid on the surface to be within 3° F of the passive pavement sensor. Also, if it snows for more than 20 minutes, the RWIS will detect the snow and trigger the system.

Valve and valve box.

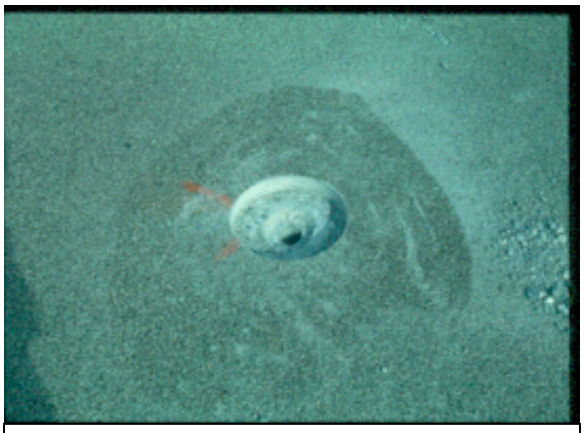
Installed active and passive sensors.

Research and Procurement

The communication between the active and passive pavement sensors is one of the more critical capabilities discovered from initial research. UDOT decided to use the Boschung system because they had the most comprehensive experience in this communication. UDOT procured the system as a Research project.

Construction

Boschung did the bulk of the installation. The only exception was the installation of the conduit and junction boxes. The spray discs are mounted in the bridge deck. A 1” diameter hole has to be drilled through the deck for the supply and a 6” diameter hole has to be cored 1.5” into the surface to recess the actual spray disc. The spray disc is then epoxied into the deck (See Figures)



Cored Holes

Epoxied Spray Disc

Maintenance

The system requires three major steps for maintenance.

Start Up (Fall)

In the fall the system should be checked and refilled with chemical and the RWIS station serviced. The entire system should be checked for damage and repaired including replacement of any failed sealant around the spray discs.

Operation (Winter)

The system needs to be monitored to ensure there is adequate liquid for another event. The Boschung software needs to be closely studied during the season. It will give warnings when sensors are malfunctioning or when the reservoir is out of liquid. Also, the software tells when the system fired so that estimates can be made of the liquid level so that maintenance crews can refill it.

Shut Down (Spring)

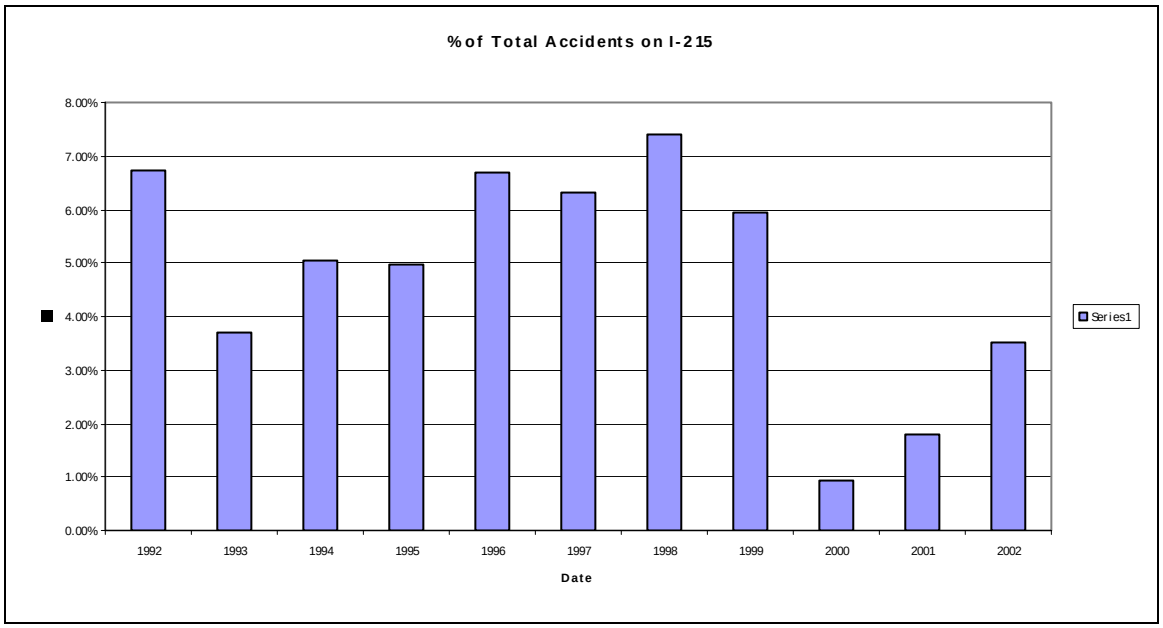
Once there isn’t a chance for snow or ice conditions, the system needs to have the anti-icing liquid removed and the reservoir filled with water. The reason this is necessary is to keep the valves working during the off-season, and water is cheaper to spray than KAc. The system should be fired once every one to two weeks.

Costs/Benefits

The total cost for the installation of both phases of this system were about $250,000. This did not include traffic control, which amounted to about $7,000 at this site. The operational cost has been only KAc and system improvements. The first full year of operation has cost 1,500 gallons, or about $4,500. The only other significant cost has come from labor for filling and monitoring the system.

There is no easy way to estimate the benefits of the system. This isn't because it is difficult to count the number of crashes once the system is installed, but rather measuring the number of crashes before the system was installed. This is mostly due to the referencing system used by law enforcement for filling out crash reports. The Highway Patrol usually references the accident by approximate mile post plus offset, but this isn't accurate enough tell whether the crash started on the structure or finished on the structure or both.

Also, weather is the major force that drives accidents in winter. The severity of the weather needs to somehow be incorporated into the analysis. Therefore, crashes were summed for a ¼ mile section around the structure. Crashes were then gathered for the entire I-215 corridor. The thought is that if the % decreases, then some of that can be attributed to the FAST.



This graph basically sets a baseline, since 2003 data hasn't yet been processed and it is the only year where the system has been fully automated. It is interesting to note that the polymer overlay was placed in 2000 (in conjunction

with half the system) and that appears to be the year with the fewest % of crashes.

During the 2003-2004 season, there wasn't a single crash reported by the Maintenance station that was a result of the structure. This may be the best indicator the system is working. The maintenance crews believe it has prevented crashes on the structure.

The system was triggered 52 times the first season (mid-January 2003 to April 2003). The system sprayed 99 times the 2nd season (2003-2004 season). There were 17 times the system should have sprayed (the freezing point of the liquid was higher than the pavement temperature) but didn't the first year (due to insufficient liquid), and there were 15 times the second season. Because of these times the system should have sprayed but didn't, UDOT will be connecting allowing the 500 gallon tank to automatically fill the 150 gallon reservoir. This should eliminate these instances next season.

Lessons Learned

Ontario installed a similar FAST. They placed a report online at: http://www.mto.gov.on.ca/english/engineering/anti_ice/anti_ice.htm . The lessons learned that applied to UDOT's installation are listed below.

Lessons Learned

Design and Installation

A number of lessons were learned through the process of designing an installing the FAST system at the 416/401 interchange:

- Feasibility studies are necessary to identify and address technical design and systems issues; structural and aesthetic concerns; costs and warrants for the installation of a FAST system. The rationale for installing a FAST system should be based on a benefit/cost analysis, which takes into account the accident statistics for the site.

- Appropriate coordination for utilities and an allowance for lead time, and cost when extending services to a remote site, is required.

- Licences for proprietary user interface software must be flexible enough to allow for access by the full range and number of interested parties. Internet Browser enabled access using secure passwords is the preferred mode. Both dial up and WAN access must be available.

- System data server must allow for full access to atmospheric, pavement and FAST data to allow for data mining by the system administrator(s).

- The Vendor should make a full description of the FAST system decision logic, programs and default variables available to the Owner.

Operations

It was expected that adjustments in "operations" would be required as a result of implementing FAST. Operational adjustments would take place on two fronts: physical operation of the FAST system, and in business processes for the contractor and owner's winter maintenance activities.

A number of changes have been made in the system and team operations, which include the following:

- Sufficient storage reservoir for chemical must be provided on site. Originally the vendor had indicated that the reservoir tank should have sufficient chemical capacity to last most of the season, however early in the monitoring season it became apparent that his would not be the case. The system regularly reported alarms for low chemical levels in the reservoir. The maintenance contractor modified operations in that he would on a weekly basis top up the pump station reservoir on site and ensure the on site storage tank was refilled. After an intense event such as a freezing rain storm, the levels would be checked, and during the fall, despite there not having been precipitation, chemical levels may be down as a result of firings to address early morning frost.

- The upper edge of super elevated bridges should be cleared of snow. During the early part of the operating season it was observed on site that the plowing operations left some residual snow and ice on the upper shoulder (east side of the structure) and that on sunny days it melted and ran across the structure. The pavement sensors detected the moisture and since the air temperature was below freezing triggered firing of the system. The snow and ice was removed on a regular basis and no further unexpected sprays were recorded. Icicles were observed on the structure during one early winter event however the phenomenon was not observed again and was therefore attributed to a unique weather phenomenon.

- Adjustment of operating parameters versus successful reduction in accident statistics. The Monthly Report Process afforded the opportunity to review and potentially adjust vendor

suggested default parameters so as to optimize the use of deicing chemical and customize it for agency or local preferences. As an example, it was found that the system did indeed deactivated one particular program in the event of a heavy snowfall, however it continued to fire using another program once it's threshold parameters had been met. The rationale for implementing the FAST system was to determine if this technology could reduce the number of weather related accidents. The installation has been a complete success effectively eliminating accidents during a severe winter season. The cost of chemical supply however was in the order of $12, 000 verses an original estimate of $5000-7000. …

- The extent of people requesting access to the system using the vendor's proprietary user interface software has far outreached the number initially anticipated. The Vendor has only allowed a limited number of licenses, which is insufficient to address the large number of team members and staff who would like to view the relevant pavement, atmospheric and system information.

- It takes time to achieve "buy in" from both the owner's staff and the maintenance contractor. The contractor must be motivated to embrace the technology via either the carrot or stick. Full integration into business processes will not occur the first season, but only as confidence in the system is developed. Training, suitable to address a variety of levels of expertise, will be required on an on going basis as a result.

- Potassium Acetate has proven to be an excellent deicing chemical for this limited area. Significant tracking of the chemical has been observed after the structure and the residual adheres well to the driving surface once it dries.

Here are some additional things UDOT observed:

- Traffic control under a SPUI was one of the major problems on this project. The whole concept behind a SPUI is that all traffic flows through a central point. Installing a spray system required a manlift to close down this point. A traffic control plan should be submitted by the contractor in the future.

- The only problem thus far on the system has been chemical contamination. Somehow, Magnesium Chloride was introduced into the Potassium Acetate. The result was a thick precipitate (See Figures) was formed that caused the valves to stick in the open position. With the valve open, all of the liquid

was sprayed onto the road. The Boschung people had to come and clean every valve on the system requiring traffic control to be set up under the SPUI for a second time.

Figure 5- Precipitate formed by mixing KAc with MgCl

- An experimental thin polymer overlay was placed on this structure at the same time the system was installed. One of the benefits of the overlay is improved skid resistance. Therefore, UDOT cannot say whether it was the polymer or the spray system that prevented crashes. It seems intuitive given the successes from other states that the system played a large part in the crash elimination, but this study cannot be certain.

- The system was placed on about a ½ mile corner. It was assumed the high number of crashes were occurring at this location due to the large structure (which the system was installed) freezing. However, it is now evident this structure wasn't the only hazard at this corner. There are still a high number of crashes that began before the structure, yet ended on the structure. In safety reporting, the location isn't very specific so it may seem as though the structure is still a hazard and the FAST is useless, yet it has been successful.

- KAc is cheaper if bought in bulk. In fact, on this project, it was about $1/gallon cheaper if bought in 5000 gallon quantity. Therefore, a 5000 gallon tank was placed onsite to handle the delivery. The savings paid for the installation of the tank and the concrete pad. Also, although the discount quantity is 5000 gallons, KAc has a specific gravity of 1.29, which means that roughly 4,500 gallons can be delivered due to road weight

restrictions. Procurement contract should be limited to 4000-4500 gallons.

Conclusions

The maintenance crew believes the system has eliminated structure-related crashes. However, it is impossible to set a definite cost-benefit ratio for a couple of reasons. The first is there isn't a separation of variables between the FAST and the thin polymer overlay. It is therefore, impossible to say that the FAST is the reason for the reduction in crashes. Second, it is risky to assign value to crash reduction because emotions become involved.

There have still been crashes at this location, just not on the structure. This is due to the size of this radius. The structure only represents about 1/10 of the total distance.

The system has required very little maintenance. All parts have functioned well aside from the liquid contamination that plugged the valves. Most time has been spent in filling the system during storms.

Recommendations

UDOT should continue to deploy these systems. However, care should be taken to make sure the structure is the major cause of crashes. The money spent on this system may have better been spent on improving the skid resistance of the entire corner.

It is also important to keep in mind these systems are designed to be anti-icing, not de-icing technology. Future locations should be places where frequent frosting or blackice occurs where the rest of the road isn't affected. Otherwise, normal anti-icing measures would probably be sufficient.

Report No. UT-04.03

Pork Chop Study

Special Study

By: **Barry Sharp, Research Specialist**
Robert Stewart, P.E., Development Engineer

Utah Department of Transportation
Research Division

June 2004

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Introduction

This paper presents the findings of an informal study conducted for the Utah Department of Transportation (UDOT), Region 2 Permits office on the effectiveness of pork chops in Utah during the winter of 2003. Access management is a growing concern among DOTs. Businesses would like to have full access to their parking lots, however, full accesses can provide dangerous traffic movements as well as reduce the capacity of the road.

As mentioned, this study is not a formal research project. Limited funds prevent formal research to be conducted on a number of projects submitted to the Research Division every year. Research studies are intended to produce scientific results. This study, however, is only intended to give informal information to the Permits office.

Research was asked to look at some pork chop designs throughout the Salt Lake Valley and determine their effectiveness of restricting left-turn movements and also see if any particular design seemed to be superior to the rest.

Background

Pork chops are right-turn only islands typically used at business access points. Left-turns can have a couple of negative impacts on traffic. Gap-acceptance for turning across multiple lanes is complicated. Therefore, queue time can increase significantly even in light traffic, which can lead to increased queue length. This can lead to insufficient storage length and, unlike signalized intersections, no option for a dedicated left-turn phase to empty the storage.

Increased queue times and thus queue length can have a two-pronged safety impact. First, as queue time increases, gap acceptance decreases. This presents an unsafe condition where frustrated drivers lose patience in maneuvering through an already complicated turn (in multilane movements). The other safety implication is a queue backing into thru lanes when lane storage is exhausted.

The above problems have been stated assuming a driver making a left-turn into an access. However, left-turns out of an access can be more difficult. First, the driver must not only estimate gaps coming from the left, but now must blend this acceptance with traffic coming from the right as well as stored vehicles in the turning lanes (assuming one exists). Moreover, to eliminate this complicated movement, many drivers will turn left into the turning (middle) lane in order to wait for a gap in the other direction (some will actually use the turning lane as an acceleration lane).

Goal:

The goal of this project was to give Region 2 Permits information relating to the effectiveness of pork chops on preventing turning movements.

Objectives:

1. Measure the number of left-turn-in violations.
2. Measure the number of left-turn-out violations.
3. Evaluate the geometry of the pork chop.

Test Locations:

Region 2 identified 4 locations where pork chops have been installed:

Home Depot at 90th South and Redwood Road (2 Locations):

South Entrance: The south entrance is located on 90th South. 90th South is a 2 lane (each direction) collector with a turn lane in the middle. There are 3 entrances to this store; a west entrance from Redwood Road and 2 southern entrances. The location with the pork chop is the west-most entrance. UDOT has since installed a signal at the east-most (main) entrance.

90th South experiences high volumes (AADT 37,430) of traffic with the majority coming during the peak hours with the AM commute heading eastbound and the PM commute heading westbound. There are many businesses in the area and this Home Depot shares this corner with multiple businesses although their accesses are separate.

The following figure shows the pork chop as seen by an exiting driver.

Although hard to see from this picture, there used to be a no-left-turn sign on this location, but was not present during this study.

West Entrance- This entrance services both the Home Depot and a Village Inn. This pork chop, however, is only intended to restrict left-turn-out movements. This is the only entrance for the Home Depot from the west.

This section of Redwood Road is 3-lanes (each direction) with a left-turn lane in the middle. Redwood Road is a high-volume collector (AADT 26,445).

Maverick on 78th South and 40th West

The Maverick gas station is located on the southeast corner of this intersection. 78th South is a 2-lane (each direction) arterial with a turning lane in the middle. It is high-volume (AADT 20,000) for an arterial. 40th West is low volume. The pork chop in this area is on 78th South. There is a sign at the exit for this location, but it isn't large enough to be noticed.

No LH Turn Sign

Wallgreens on 5600 West and 4100 South

The Wallgreens is located on the Northwest corner of a business center that also includes a Lowes, a Smiths, and a strip-mall. 5600 West is a two-lane each direction with a turning lane arterial and experiences heavy AM and PM traffic during commuting hours as well as weekends (AADT 23,000). There are no signs restricting left hand turn movements at this location.

Fazoli's in Tooele (SR-36)

This location is at a business access where there is a Fazoli's, a Panda Express, and a mailing store. This entrance also connects with a WalMart lot. The WalMart parking, however, is located about 400 yards NW of this parking lot.

SR-36 experiences heavy traffic during both the a.m. and p.m. commutes and is moderate otherwise (AADT 28,000). It is two lanes each direction with a turning lane in the center. Traffic turned out to be very slow at this location because the Fazoli's had just closed. This location is signed for left turns out of the parking lot.

Results

1-2. Research set out to observe pork chops to see how effective they are at preventing left turn movements. The only measure was violations of the pork chop. The reason for this is difficulty in determining if a right-turn vehicle intended to turn left but was deterred. Each location was visited and studied for ½ hour. 3 of the locations were visited twice. The following matrix shows the results of the observations:

	Traffic	Left-turn In	Left-turn Out
Wallgreens 1	Light	2	1
Wallgreens 2	Moderate	0	1
Home Depot West	Moderate	n/a	9
Home Depot West	Moderate	n/a	2
Home Depot South	Moderate	6	3
Home Depot South	Light	6	5
Maverick	Light	7	0
Fazoli's	Light	6	0

3. Not yet evaluated

Conclusions

It is very difficult however to determine the level of effectiveness. For instance, the Wallgreens entrance didn't have much traffic, but another entrance about 300 yards away was very busy. It is difficult to say the reason the other entrance was busy (left-turn movements) was due to the pork chop and not the relative trip generation of different businesses. However, it seems the pork chop does more effectively deter drivers from turning left out more than turning left in. This confirms the use of pork chops as a placeholder for left turns until an island can be placed.

Even so, there were some vehicles that obviously were deterred by the pork chop. This is seen when a vehicle makes a turn in order to enter via another access. It is also seen when a vehicle is seen making a U-turn within the vicinity of the business. There was at least 1 such instance in ½ hour at every location. This implies the pork chops are effective for some drivers.

The geometry of the pork chop seems to affect the violations. The farther a vehicle had to turn right while leaving the access, the fewer the violations. There is a safety problem with turning the vehicle too much because the driver is forced to look over his/her shoulder before entering traffic. One negative effect of this is this design gives the appearance to the driver the pork chop divides right turn out from left turn out. At most locations (except Maverick), there was at least one violation where a car made a left turn out via the left side of the pork chop.

There was no apparent relationship between the height of the pork chop and the # of violations. Most entrances were designed such that no vehicle seen had to mount the pork chop.

Recommendations

Pork chops should continue to be placed in locations where an island will later be placed. However, they should not be used in locations where impeding left turns is critical. They show only mild effectiveness at reducing the number of left-turn movements.

When designing a pork chop, the geometry should be such that it forces the vehicle to turn right as much as possible without compromising lookout safety. However, when doing this, pavement markings should be placed that tell the driver the left side of the pork chop is an entrance, not an exit. Along with this geometry change, signs should be placed that restrict left turns. However, these signs should not be placed on the pork chop because they tend to get hit. Placing it on the stop sign (as at the Fazoli's location) seems to be the best location.

It is recommended that Research further study pork chops. Region 2 has recommended placing temporary islands using cones in the turning lane to see the effects (positive or negative). Also, Region 2 recommends studying the effect of signing.

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Report No. UT-04.03

3M 820 Wet-Reflective Tape on SR-6

Experimental Feature X(02)12 – New Products

By: **Barry Sharp, Research Specialist**
Robert Stewart, P.E., Development Engineer

Utah Department of Transportation
Research Division

June 2004

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Abstract

Introduction

Pavement markings continue to be a developing field in transportation. The most challenging property of pavement marking is its ability to provide delineation during wet-night conditions. Although Utah is the second driest State in the Union, wet-night reflectivity can be a concern. UDOT's Traffic and Safety Division identified 2 such locations; US-6 near Soldier Summit and I-215 (300 East to 1300 East).

UDOT's Traffic and Safety Division along with the local maintenance division decided to install 3M's wet-reflective tape on these two locations. The section on US-6 was installed in August 2003 and the section on I-215 was installed in September 2003. UDOT's Research Division has been asked to monitor these sections for durability, retro-reflectivity, and wet-night retro-reflectivity. This study will last three years and interim reports will be written each fall and spring.

Background Information

This 8-mile stretch of US-6 is primarily a three-lane (two EB, one WB) highway (see Figure 1), however it constricts to a two-lane highway at the beginning and end of the section.

Figure 1-Typcial Section of US-6 (Heading WB)

Interstate 215 is the belt route of Salt Lake City. At the test section location, the road is a six-lane divided interstate (see Figure 2).

Figure 2-Typical I-215 section

Table 1 gives the properties of each section of this Experimental Feature.

Table 1		
	US-6	**I-215**
AADT	6,855	116,251 - 58,000 Each Direction
Material	PG Asphalt	PCCP
Elevation	1,900m - 2,250 m	1,300 m

Construction Information

Both installations required the product to be placed below the profile of the road. For the US-6 project this was accomplished in two ways. First, a chip seal was

placed over the existing asphalt surface, but the oil sprayers were turned off over the tape location. This allowed the excess chips to be swept away and a trough was left where the tape was going to be placed. Then, a Roadpro asphalt grinder was used to increase the depth of the inlay and to make a more precise groove. The surface was then sprayed with the 3M primer, the paper backing removed, and the product placed. Compacting rollers were not used on this job; instead, a car wheel and a truck wheel were driven over the product to press it. Figure 3 shows the end product.

The SR-6 project included only the edgeline of the two-lane rural road. The I-215 project included both white edgeline, yellow edgeline, and skip lines.

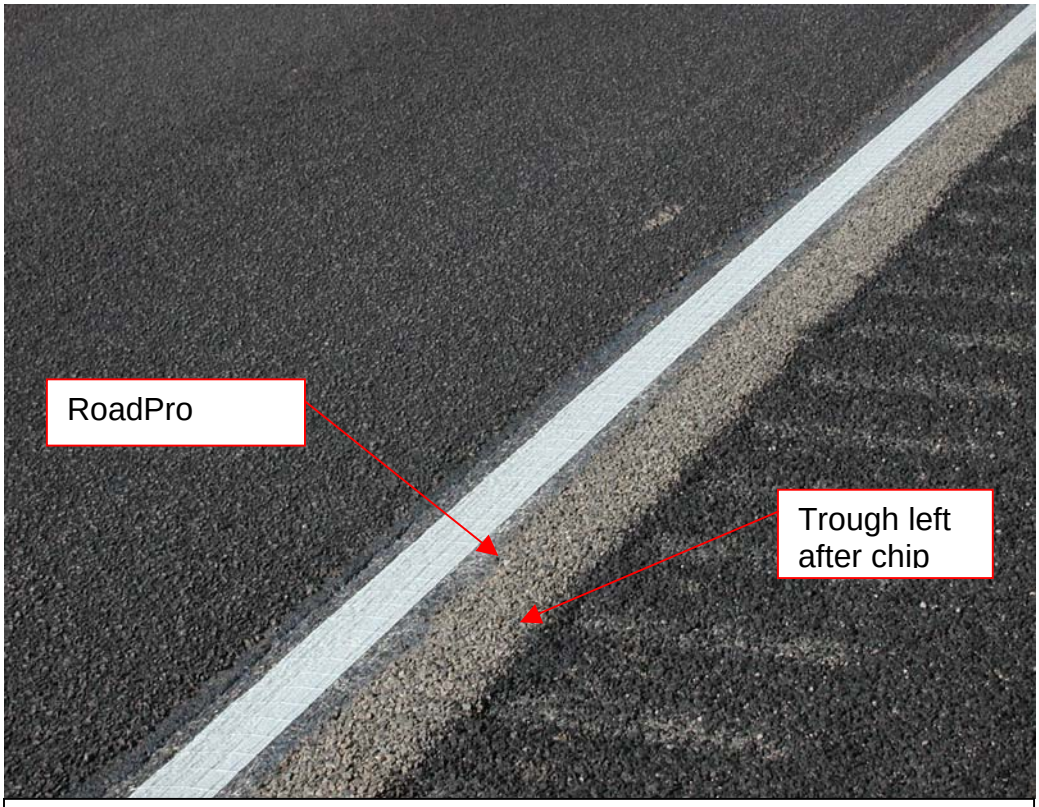


Figure 3-Installed tape on US-6

Goal

The goal of this project was to determine the effectiveness of this tape.

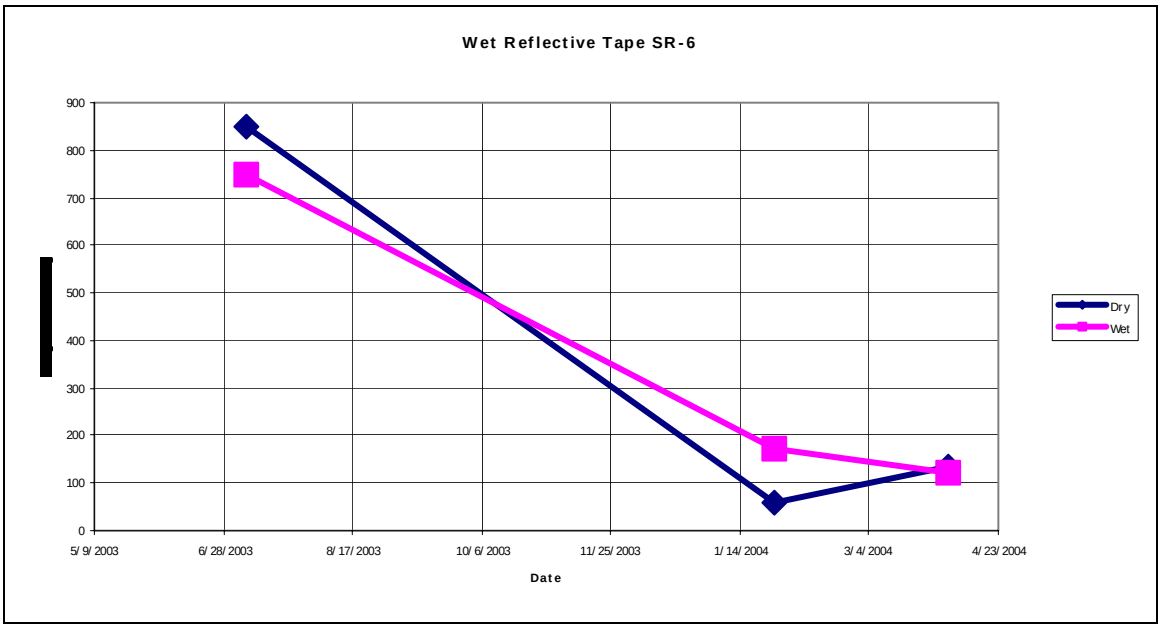
Objectives

The objectives are:

1. Evaluate the retroreflectivity over time (mcd/m^2/lx).
2. Evaluate the durability over time.

Preliminary Results

1. The initial retro reflectivity was very good. However, there was a large standard deviation in the data. The data shows a dramatic decline in the RR over the first season. The wet-night retroreflectivity was measured using the LTL 2000 and showed good results.



The chart shows the dramatic decline. Interestingly, the values doubled or sometimes tripled if the RR was measured against the flow of traffic. This hasn't been explained, but may indicate the product is more sensitive to snow plow abrasion than other markings.

2. There was a major problem with the durability. In both locations there were major portions that came up. The total loss amounted to about 10% of the total project. The reason for the loss isn't yet known. Warranty work will be done to replace the failed tape.

Preliminary Conclusions

The tape lost its much of its RR after the first season. The product also suffered heavy loss in durability after the first season. However, subjective descriptions of

the product during wet-night conditions were extremely positive indicating the product works under the conditions for which it is designed.

Preliminary Recommendations

The product should be further studied to see if the durability and RR problems are resolved before larger sections are applied.

Appendix

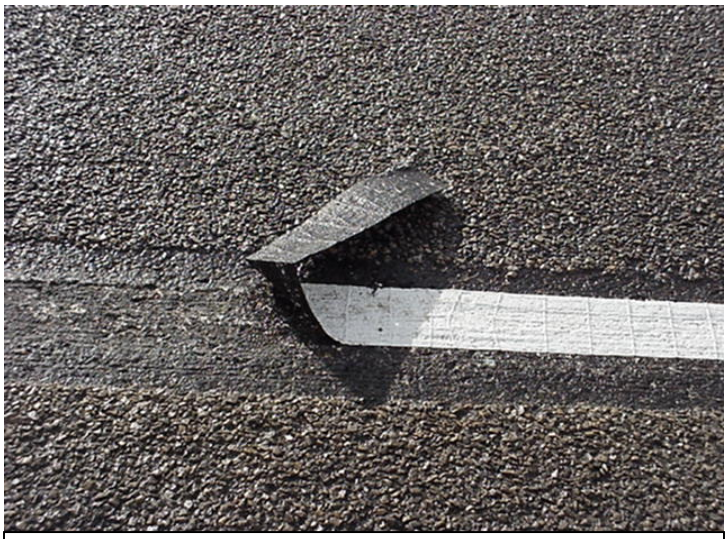


Figure 5-Failed tape on SR-6

Figure 5-Failed tape on SR-6

Figure 5-Failed tape on SR-6

Figure 5-90% typical tape on SR-6

Report No. UT-04.03

3M LPM 1200 Interim Report

Experimental Feature X(02)13 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

This is an interim report for an experimental feature conducted by the Utah Department of Transportation on a polyurea pavement marking material manufactured by 3M and labeled LPM 1200. Another experimental material used in this test section was a ceramic element that is used with class A glass beads to improve the retro-reflectivity of the marking material.

The material was placed in July of 2003 on Bangerter Highway (SR-154) between 3500 South and the South Frontage Road (MM 19.6 to 21.6). All longitudinal lane lines were removed by diamond grinding, then the concrete was grooved anywhere from 40-70 mils so that the pavement marking material could be inlayed.

Background Information

Durable pavement markings continue to be a problem for transportation departments. UDOT typically has used waterborne paints, epoxy, and 3M 380 Tape for longitudinal lane lines. UDOT has experimented with thermoplastic materials with varying success. Epoxy has been the “durable” material of choice for concrete, but UDOT has found that epoxy is not a good material for remove/replace projects. Therefore, UDOT is still searching the market for a durable material that will last in the urban environment.

Construction Information

The process for applying this pavement marking material is similar to most other pavement marking materials. The first step is to remove the existing epoxy. This is done using a diamond grinder. The second step is to sweep the section. The third step is to blow the surface to remove fines, and finally place the material using a paint truck. There are, however, some unique features to this product. First, the product must be inlayed 40 mils. The contractor on this project was not aware of this and the grinding took 4 times as long as planned.

Second, the product is exceptionally sensitive to water or other contaminants present on the pavement surface at application. There was a place on the project where water began pumping out of the pavement joints as the paint truck passed. The applied material immediately debonded from the concrete surface. Figure-1 shows the result.

Figure 6-Debonded material due to pumping problem

The blower that runs in front of the spray gun on the paint truck spread the pumped water. This problem area was only on a small section of the total project.

The last difference this application has is the specialized paint truck. The truck mixes three components at the nozzle and drops both class A beads and 3M ceramic elements simultaneously.

The only real problem on this project besides the pumping water was the speed of grinding. The primary grinder broke the first 20 minutes of operation leaving a huge job for a secondary grinder. The grinding comprised 95% of the total time (5 nights) on this project.

Goal

The goal of this research is to determine the success of 3M's LPM 1200 polyurea pavement marking material.

Objectives

1. Measure the retro reflectance over time of the pavement marking material.
2. Calculate the life-cycle cost of the material.
3. Measure the color (Yxy) over time.

Preliminary Results

1. RR (mcd/m^2/lx) readings were:

NorthBound

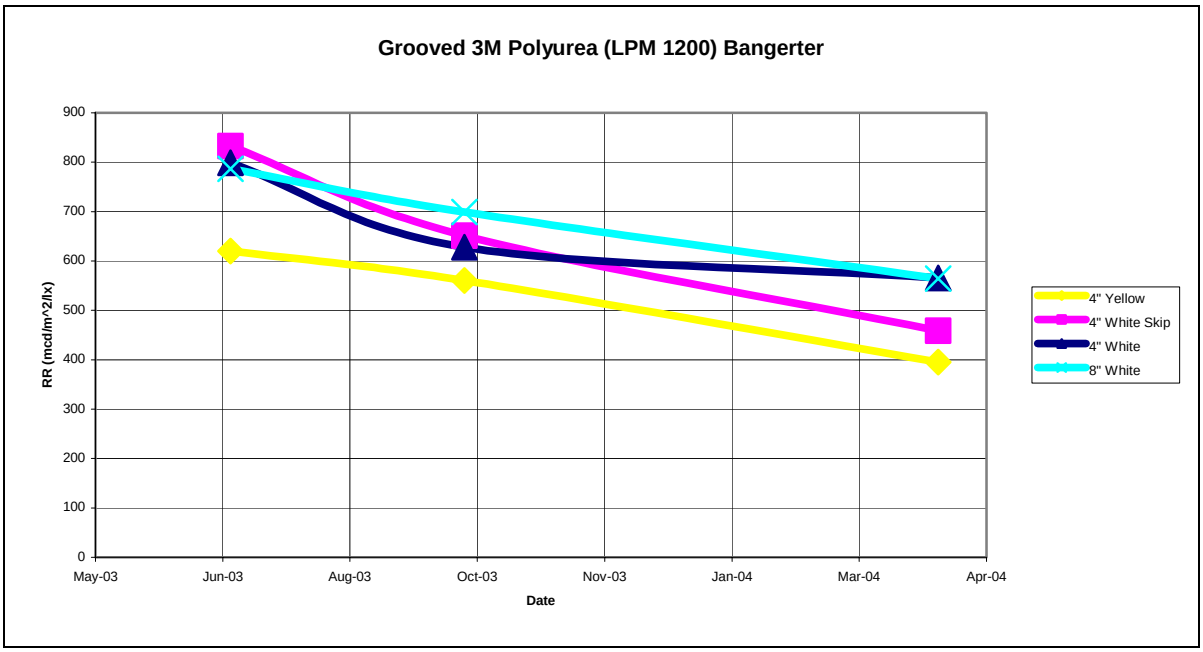
	4" Yellow			4" White Skip		
	Jul-03	Oct-03	Apr-04	Jul-03	Oct-03	Apr-04
Mean	**562**	**549**	**363**	**766**	**641**	**472**
Standard Deviation	**86**	**91**	**128**	**149**	**110**	**207**
Allowable Error =>	22	22	32	26	19	36

4" White			8" White		
Jul-03	Oct-03	Apr-04	Jul-03	Oct-03	Apr-04
768	**659**	**620**	**807**	**738**	**657**
143	**137**	**142**	**77**	**77**	**209**
35	33	35	30	30	68

SouthBound

	4" Yellow			4" White Skip		
	Jul-03	Oct-03	Apr-04	Jul-03	Oct-03	Apr-04
Mean	**678**	**572**	**423**	**899**	**661**	**440**
Standard Deviation	**118**	**83**	**158**	**100**	**77**	**165**
Allowable Error =>	29	20	40	18	13	29

4" White			8" White		
Jul-03	Oct-03	Apr-04	Jul-03	Oct-03	Apr-04
830	**597**	**516**	**767**	**660**	**472**
143	**102**	**149**	**123**	**105**	**183**
36	25	37	47	34	60



2. Not yet evaluated.
3.

Preliminary Conclusions

The standard deviation of the product has increased dramatically through one plow season. Observations conclude this is probably due to the variance in inlay depth. As mentioned earlier, the contractor did not plan on inlaying this product. Therefore, he did not take care to make sure the inlay depth was consistent. It is evident at places where RR values are low that the material is being ground off, probably by snowplows (see figures below).

Preliminary Recommendations

This material appears to be susceptible to snowplow damage. For future applications, the inlay depth should be monitored closely to ensure the snowplow blades will not come into contact with the material. Also, the contractor should use an inlay grinder that gives a smooth depth and surface when complete.

Report No. UT-04.03

Epoplex Polyurea (LS90)

Experimental Feature X(02)14 – New Products

By: **Barry Sharp, Research Specialist**
Robert Stewart, P.E., Development Engineer

Utah Department of Transportation
Research Division

May 2004

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Introduction

This report describes the installation and performance of Epoplex's LS90 product. UDOT allowed Epoplex to demonstrate their polyurea product on 500 South between 300 and 400 West. The product was installed in September of 2002.

Background Information

Epoplex's product data sheet explains the product:

> "Epoplex LS90 is a two component, 100% solids polyurea coating designed as a fast setting highway marking coating that provides durability and abrasion resistance. Epoplex LS90 is formulated to provide a simple volumetric mixing ratio of two volumes of Component A (amine) to one volume of Component B (isocyanate)."

The location provides severe conditions for pavement markings. It is the entrance to the interstate system from downtown Salt Lake City. This location presents a high AADT, high occurrence of weaving, and high snowplow rate. There is also a business where many trucks turn in and out so a large portion of the yellow edgeline and one set of skips is exposed to scrubbing.

The price on poly urea ranges from $ 0.50 to $ 0.75/ lf. The beads that were used are Swarco Virgin and a double drop of small and large beads. 18-20 mesh large and 30-40 mesh small.

Construction Information

The material was placed over existing epoxy. Figure 1 shows the shadow of the epoxy. Figure 2 shows the markings after installation.

Figure 1- Polyurea over epoxy

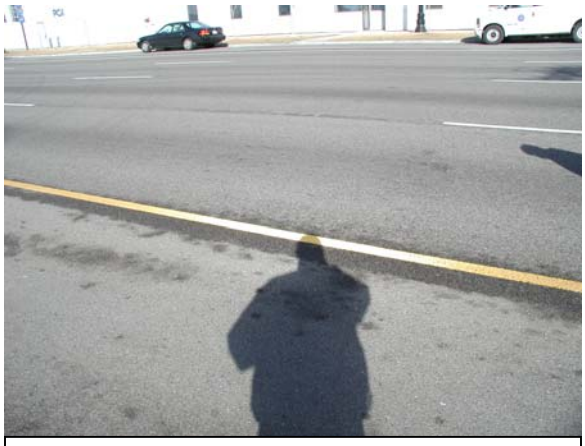


Figure 2- Just after installation

Goal

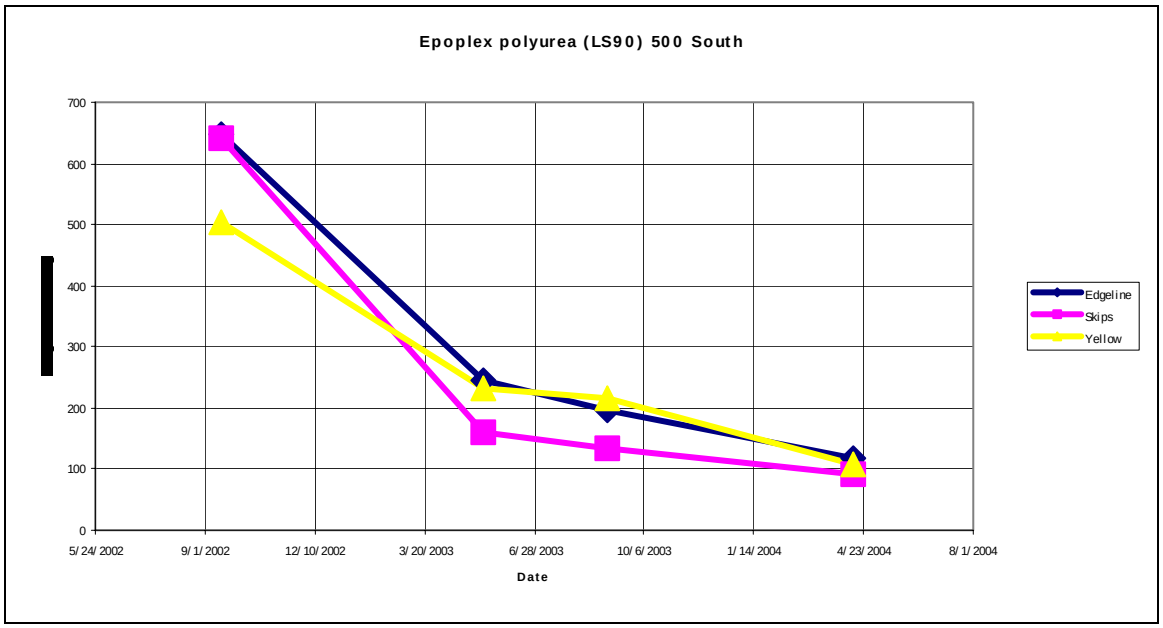
The goal of this study is to determine whether or not UDOT should use the LS90.

Objectives

1. Measure the retro-reflectivity over a period of 3 years.
2. Measure the life-cycle cost of this product at this location.

Preliminary Results

1. Two snowplow seasons yielded the following retro-reflectivity results:



	9/16/2002	5/13/2003	9/2/2003	4/14/2004
Edgeline	647	246	197	116
Skips	642	161	133	92
Yellow	503	231	215	107

Preliminary Conclusions

The material has shown excessive wear, especially on the skip lines. However, at this location, the material has performed well. The material is at UDOT's trigger value for re-striping.

Preliminary Recommendations

This material has shown its ability to provide good durability at a location where conditions for pavement markings are severe. UDOT should use this product in severe applications. The cost of the material is prohibitive, but may be cost-effective in severe conditions.

There was no control set up at this location. Because of this, there can be no comparison, cost or otherwise, to UDOT's current material. For future test sections, the current practice should act as a control.

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Report No. UT-04.03

3M LPM 1500

Experimental Feature X(02)10 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

Transverse pavement markings are subject to more shear forces (tires and plows) than longitudinal lines. Because of this, stop bars and crosswalks often wear faster than longitudinal lines. 3M developed their Liquid Pavement Marking (LPM) 1500 especially for these markings.

LPM 1500 is a polyurea that and uses standard beads. Retro-reflectivity is not measured on this marking since UDOT only considers durability for these markings.

Construction Information

The project location was the intersections of Bangerter Highway (SR-154) with 5400 South, 4700 South, and 3500 South. The total square footage was about 6500 ft^2. The surface was prepared by grinding the existing markings from the surface. The marking was applied by Peck Striping at 20 mils on October 13 and 14, 2002.

Goal

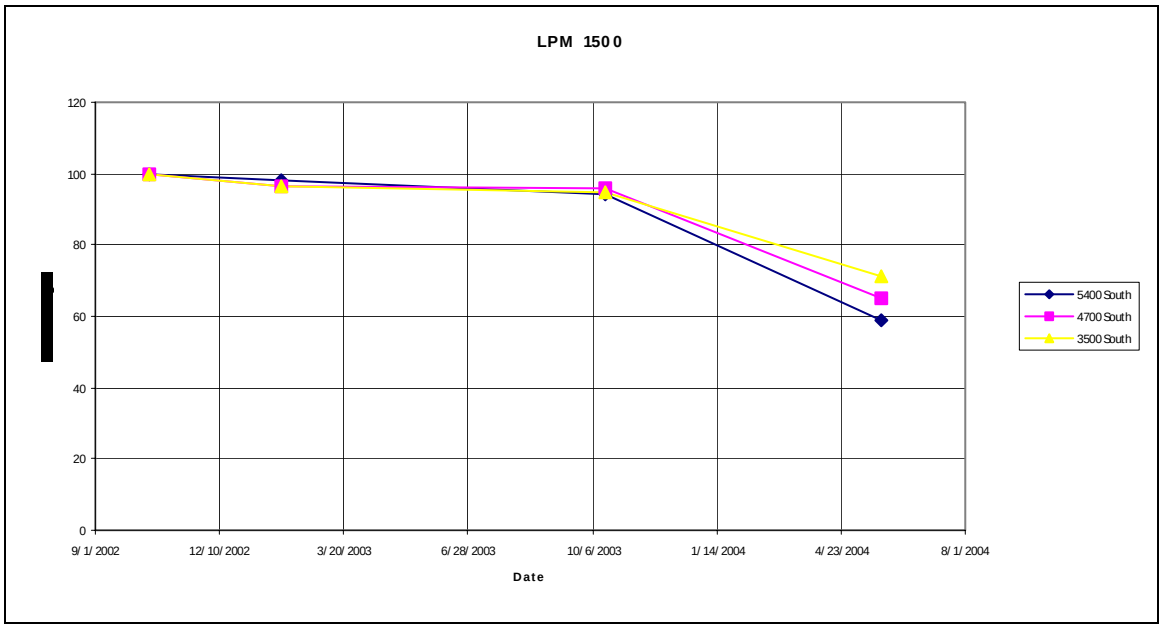
The goal of this study is to determine whether or not UDOT should use the LPM 1500.

Objectives

3. Measure the durability.
4. Measure the life-cycle cost of this product at this location.

Preliminary Results

1. Two plow seasons yielded the following results:



2. The total cost for this product was about $2.00 per ft^2. Assuming the product only lasts one more season, the cost will be about $.66/$ft^2$/season for this marking.

Preliminary Conclusions

The material has performed well for the given conditions. The AADT for this area is about 50,000 and these areas experience a lot of wear from braking and acceleration. The price is a high, but may be justified because most other markings would probably not make it through a season.

Preliminary Recommendations

There wasn't a control set up on this project. It is recommended that this product be installed next to the product that would typically be used for these locations. This is the only way to determine whether or not this product is more cost-effective than the current practice.

Polyurea is extremely sensitive to contamination. The only premature failures that were experienced with this project were in the "oil-drip" path. Even though the surface was grinded, it is apparent the material was not able to adhere to the concrete at these locations. It is recommended this product not be used in a location where it would be difficult to reach non-contaminated concrete through surface preparation.

Appendix

Figure 6- Middle of 1st Season (1/28/03)- Shows oil drip locations

Figure 2- After 1st Season (6/27/03)- Notice that the stop bars is in good shape while tips of markings are gone.

Figure 3- (6/27/03)- Typical picture after 1st Season

Figure 4- After 2nd Season (5/24/04)- The marking shows the 1st signs of wear. Until this point, there were problem areas, but most areas showed no signs of wear.

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Report No. UT-04.03

High-tension Cable Median Barrier (Brifen, Trinity) at UDOT

Experimental Feature X(03)05,06 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

Crossover crashes are considered one of the most fatal due to the likelihood of a head-on collision. Solutions to these crashes range from extended-width medians to cast-in-place concrete barrier. Wire Rope Safety Fence (WRSF) or high tension cable barrier is a relatively new concept in the United States.

UDOT investigated the benefits of these systems in 2002. Studies showed the Brifen WRSF to be a lower cost solution to crossover crashes than concrete barrier. UDOT decided to install and study a 1-mile section of the Brifen system in 2002. Since the installation, other companies have begun manufacturing high-tension systems. Trinity Industries was successful in bidding for a larger section (8-miles) on I-15 about 5 miles south of the Brifen installation. Both systems have been successful at preventing head-on collisions, but UDOT wanted to evaluate the maintainability and cost per hit of each system. This report presents the initial results.

In the 20-mile stretch these systems are place, there have been 22 crossover fatalities in the past 5 ('96 to '02) years and that has accounted for 10% of all fatal crossovers in Utah. These crashes have involved over 50 cars with the most involving 5. These systems only cover 9 of the 20 miles, but have begun to make a difference already.

The systems will be studied for one more year.

Background Information

Cable barrier is not a new technology in the United States. The US 3-wire system is similar to the studied systems except the cables are only subject to low tension. These systems have proven successful in reducing the number of crossover fatalities where installed. However, problems arose with these systems due to their maintainability. Cars often became tangled in the cable requiring the cable to be cut and spliced. Also, the entire system went down after the 1st crash leaving the crossover potential unless maintenance crews immediately repaired them. This proves extremely difficult especially in winter when crews are busy with winter operations although winter conditions heighten the crossover potential.

Oklahoma DOT researched possible alternatives in a location where they were experiencing a high number of crossover fatalities. The conclusion from this research was to experiment with the Brifen WRSF citing good results at a fraction of the cost of concrete barrier along with aesthetic and maintenance concerns. A 1000' section was installed after FHWA approval. The success of the system was so great, ODOT moved to the second phase of the project which was to install another 7 miles of the system.

Construction Information

The installation of these systems are similar. The first step is to determine the location of the system in the median. Although not considered in the Brifen installation, it is not recommended to place the system at the bottom of the median. The reason for this is geometry of a cut median lends itself to the possibility of a car bumper to go underneath the cables. The preferred alignment is just outside the clear zone in a location that is as flat as possible.

The basic installation procedure for both systems is the same. Postholes are drilled, sockets are placed in fresh concrete, posts are placed in the sockets, the end sections are installed, and the cable is placed and tensioned. The construction on the Brifen system and part of the CASS system was slow. However, the Contractor was soon was able to double or triple his pace.

Goal

The goal is to collect information for future installations of these systems.

Objectives

The objectives are:

1. Collect accident data to determine the effectiveness of these systems.
2. Collect maintenance input to determine the maintainability of each system.
3. Collect the approximate cost per hit of each system.
4. Collect lessons learned from construction.

Preliminary Results

1. There have been no crossover fatalities in the two sections to date. However, two cars were able to penetrate the Brifen system. One was caused by the placement of the system and the other was due to a near 90^0 hit, which the system isn't designed to prevent. In both cases there was no damage any other vehicle.

   There have been at least 18 crashes on the two systems; 6 on the Brifen and 12 on the CASS. Both systems have been hit before a previous hit could be fixed and both systems were successful in preventing the second hit from penetrating. In fact, there was an instance where 4 successive cars hit the CASS system and each car (although allowing more deflection) was redirected back onto their side of the barrier.

2. From conversations with both maintenance supervisors who have been asked to maintain these, both systems are not difficult to maintain. One of the reasons for this is a maintenance crew doesn't need to fix the system immediately after impact. The systems seem to be able to withstand multiple hits without a compromising service. The CASS system was even hit during

construction where the ends of the cables hadn't yet been secured; the car still didn't penetrate the system.

3. The two systems are similar in maintenance costs. The labor has proven to be about 1 man-hour for each hit, which is negligible. The major cost comes from post and accessories, which is about $500 for a typical hit of 4-5 posts.

4. Some of the construction lessons learned have already been discussed. The system should not be located in the bottom of the median, it should be place to one side or the other.

   Both systems claim to be able to be suited for a slope of 6:1 or less, but it is recommended to fill the median to as flat as possible before placing the system. This has two effects. The first is it smoothes the terrain so that an approaching vehicle has the best probability of striking the system as designed. The second is an approaching vehicle will have a better chance of controlling the car, thus avoiding a collision altogether.

   A guardrail-drilling rig should be used to bore the holes. This is one trick the contractor found to speed the drilling and also better control the alignment.

   One crash into the Brifen system resulted in a post foundation failure. The only conclusion reached was the car (most likely the axle or frame) was able to hit a lip of concrete of the foundation. The foundation then sheared off at the bottom of the socket and flew across 3 lanes of traffic. Nobody was injured, however there were two lessons learned from this incident. The first was explained earlier to make sure the system is not placed at the bottom of the median. The other is to ensure the foundations are finished to grade (not level).

Preliminary Conclusions

These systems have proven to be effective in preventing crossover fatalities. The picture bellows shows tire tracks that show that if the cable barrier had not been in place, there would probably have been a collision.

Preliminary Recommendations

UDOT should look into placing more of these systems in locations where concrete barrier is cost-prohibitive. Systems that are installed should have pre-stressed cables. Non-stressed cable would require more maintenance due to the need to re-tension after a hit.

Report No. UT-04.03

Techcrete Pothole Patch Interim Report

Experimental Feature X(03)07 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

The Utah Department of Transportation is continually searching for a viable concrete spall repair material that allows for a shorter turn around than wet concrete. Techcrete is a hot applied polymer repair material that has a very short set time and allows traffic on the product within two hours. Crafco, Inc., David Allshouse, furnished some product for a test repair on concrete. A favorable condition exists because UDOT Maintenance has the heater applicator that may be used to produce this heated product.

.

Location

This product was installed in concrete on northbound I-15 just south of Beaver, Utah at MM 101 +/-.

Installation July 30, 2003

Product was heated, mixed and installed in a saw/cut prepared section of old concrete pavement using the traditional saw cut and jackhammer. The only installation problem is that the product is self leveling and if place on a super elevated roadway it tends to level off and leave a slight depression on the high side of the super. The solution to this problem was handled by placing the material to the level of the lowest point in the prepared patch and letting it set then adding a thin wedge of product and allowing this thin section to cure more rapidly preventing the slough of the product. A small stone evenly graded material is then broadcast on the cooling product, thus a skid is developed.

TESTING

Product was reviewed in the fall of 2003 and then was reviewed again this late spring of 2004 and one more time in 2004. Review is accomplished by visual inspection to determine surface failure and bonding at the interface for separation and checked with a straight edge to see if product has deflected. The 2004 test shows no sign of early failure and is as good as when it was installed. Local Maintenance Shed crew performed this review.

Preliminary Results

The 2004 test shows no sign of early failure and is as good as when it was installed. Local Maintenance Shed crew performed this review.

Preliminary Conclusions

The product has had excellent performance for the first year.

Preliminary Recommendations

The product should be reviewed for at least another year before recommendations.

Report No. UT-04.03

Gilsonite Construction Report

Experimental Feature X(03)09 – New Products

By: **Barry Sharp, Research Specialist**
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Utah Department of Transportation
Research Division

May 2004

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Introduction

The Utah Department of Transportation, Region Three Construction sponsored a limited application of an old product, powdered gilsonite with melting reducing polymers to be used as an anti-stripping agent in Hot Mix Asphalt (HMA). The Utah Department of Transportation (UDOT) now specifies a slurried hydrated lime. The success of this application will offer two rather than one type of anti-strip used in HMA. Often choices produce economies in price paid for HMA. The goal in this application is to make available another anti-stripping product.
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Construction Information

TEST SECTION AND PRODUCT INSTALLATION

Location

The project is located on Southbound US/SR 40 from MM 149.77 to MM 151.1. A 2" overlay using gilsonite was installed. The overlay was 24' wide on the outside traveled way heading southbound the full length of the project. The 2" overlay of HMA with gilsonite was placed on 2" HMA with lime.

Installation-October 21, 2003

The powdered gilsonite was introduced in the asphalt mix at the plant at a 1% by weight rate. The gilsonite was introduced into the counterflow continuous mix asphalt plant where the recyled asphalt is usually added. There was little problem with this application and the mix was not changed. The gilsonite people asked for a little hotter mixing temperature, about 335 degrees Fahrenheit. According to the plant operator he estimated the capacity was increased at least 10% and this does not include the BTU consumption of the heater/dryer that has decreased. The HMA was delivered to the jobsite and placed with normal paving procedures. Paving equipment consisted of shuttle buggy, paving machine and two vibrating rollers. Paving conditions mirrored that of lime slurry treated HMA.

Figure 1-Tacked HMA/Lime

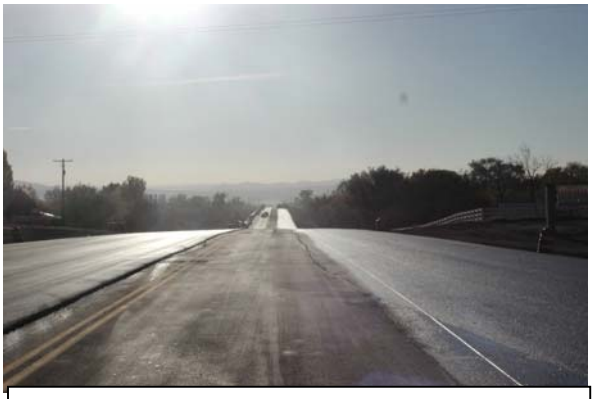

Figure 2-Southbound US 40 Prepped

Figure 3-HMA Mat

Figure 4-Aggcoat Feed Process

FIELD AND LABORATORY TESTING

1. Nuclear density testing was performed by QA/AC testing laboratory
2. Sample testing for gradation, VMA, Voids, VFA, Hamburg, Rut and Fatigue was performed by UDOT Materials-Central
3. Obtain roadway samples and test for stripping-Hamburg Test will be performed by UDOT Materials-Central

Note: FWD, Structural Adequacy, Rut Depth, Road Profile and IRI, Pavement roughness will not be performed as stated in the work plan because there is no full depth HMA that includes gilsonite on the project. The HMA with gilsonite is a 2” overlay on HMA with lime for anti-stripping. Tests obtained each year for the Hamburg Wheel will only result in how this 2” gilsonite treated overlay works placed on 2” of lime treated HMA.

An interim report will be furnished upon receipt of the test results requested with regard to the initial installation.