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DOT
Research Record



Alternative Pavements for Snowmobile
Crossings

Final Report

Prepared by the New Hampshire Department of Transportation, in cooperation with the U.S. Department of Transportation, Federal Highway Administration

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ALTERNATIVE PAVEMENTS
FOR SNOWMOBILE CROSSINGS

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EXECUTIVE SUMMARY

Excessive highway pavement wear from snowmobile traffic is a maintenance problem for the New Hampshire Department of Transportation (NHDOT). The snowmobiles and trail grooming equipment scar and erode the pavement surfaces, eventually creating wide ruts across the State's highways that cause potential safety issues for vehicular traffic. The damage includes breaking off bits of the pavement's edge until the travel lanes are threatened.

After reviewing studies completed in the states of Michigan and Wisconsin, NHDOT evaluated two surface treatment products, installed to protect the pavement surfaces. Cost, ease of installation, durability and replacement strategies were compared with conventional hot mix asphalt (HMA).

While this project began as a search for a more durable pavement surface, the focus on snowmobile damage to our highways revealed that the Department's Trail Crossing Permit program has not been adequately enforced. Substandard trail approach aprons have contributed to the deterioration of the roadway shoulder pavements, aggravating the overall problem.

The study has resulted in a revised trail crossing detail for use in permitting and constructing new crossings, along with a recommendation for a trail crossing maintenance program using the Cleanosol thermoplastic surface treatment. In addition, a cooperative effort with the recreational vehicle community to implement an enhanced program for constructing, upgrading and maintaining trail approaches is recommended.

INTRODUCTION

Snowmobiling is one of the many winter activities available to New Hampshire residents and visitors. Numerous clubs maintain 6,800 miles of trail through partnerships between landowners, the clubs, the NH Snowmobile Association, the NH Department of Resources and Economic Development (NHDRED) Bureau of Trails, and the NH Department of Fish and Game. The trails cross many State and local roadways. A North Country highway may be crossed by as many as 10,000 snowmobiles during a snowy February.

Most snowmobile skis are equipped with carbide steel skeys to assist in steering on icy surfaces. The drive tracks can be equipped with carbide steel tipped studs for traction on frozen lakes and icy trails. When snowmobiles stop at the highway edge to wait for an opportunity to cross, the high friction characteristics of the skeys on bare pavement make acceleration across the roadway difficult. The large surface area of the rubber track is elevated by its studs providing very little contact area with which to overcome the resistance of the skeys. This requires the operator to accelerate heavily to move the machine forward. The studs rake across the pavement, eroding the finer particles and asphalt cement. In time, a wear rut develops in the pavement. In one or two heavy winter seasons, the rut can wear from ¼ to ½ inch deep, and become a hazard to the motoring public.

Edge damage also occurs on roadways that are not equipped with hardened trail approaches. Sun exposure and deicing chemicals cause the unpaved shoulders of the roadway to thaw. As the snowmobiles accelerate, the track studs "excavate" the shoulder gravel. The loss of support

allows the pavement edge to be chipped away as the track scratches its way up the exposed surface.

Approximately 360 grooming machines are used statewide to maintain the snow surface of the trails. These machines are similar to the machines used to groom ski areas, and weigh approximately eight tons. They are rubber-tracked vehicles, which can be equipped with steel bars and studs for traction on ice. Although their movement is slow as compared with snowmobiles, they also cause significant damage in the form of scarring if turns are made while crossing the highway. A groomer pulls a “drag”, a 2.5-ton frame equipped with blades and teeth to break up the hardened snow and smooth the trail surface. The drags are equipped with wheels, which are engaged when crossing roads.

This study was launched to field test alternative materials for snowmobile highway crossings where snow-traveling vehicles have caused excessive wear in the asphalt concrete pavement. Michigan and Wisconsin DOTs began independent studies in 1997 to evaluate several epoxy polymer products for snowmobile trail crossing applications. Although the materials were successful in resisting wear, their rigid properties require that a relief cut be made at the crossing/HMA interface due to differing thermal properties. The cut must be kept clean and must be sealed to keep incompressible materials out of the joint. Michigan has since shifted to using a thermoplastic material to coat their HMA pavements. Thermoplastics have thermal properties that are similar to HMA, meaning that joint maintenance is not necessary.

The New Hampshire DOT’s research objective was to evaluate the performance of a thermoplastic material and a resin product on its snowmobile crossings. The evaluation would focus on wear characteristics and a comparison of installation and maintenance costs for each treatment.

PRODUCTS

The durability of two products was evaluated in comparison to conventional HMA under the excessive conditions of snowmobile traffic.

Cleanosol is a surface-applied thermoplastic material that has been successfully used to armor snowmobile crossings in Michigan and Wisconsin. Those states have also used polymer products, but appear to prefer the ease of application, asphalt compatibility and 30% quicker set time of Cleanosol. The Cleanosol product is claimed to remain flexible in low temperatures, maintaining its bond to the pavement surface as temperature changes and roadway movements occur. Surface preparations are simple, and the material sets up quickly to allow traffic over the treatment shortly after installation. Cleanosol is a proprietary product, also known as Grade E-5, Norskilt. It is imported from Norway, through Clark Highway Services, Inc., 5743 W. Kelly Road, Lake City, Michigan 49651.

Imprint® is a synthetic surface material developed in the United Kingdom that consists of a hot applied resin-based compound with graded sand and granite aggregate (the aggregate appears to be a uniform fine crushed stone), reinforced with two (2) types of fibers. A selection of 12 colors is available. The color is distributed throughout the mix, making the color as durable as the mix. Imprint is installed as an inlay, and then typically stamped to create a textured surface pattern. At this time, the proprietary product is single-sourced in the United States by Jarvis Infrastructure Services USA (Georgia), Inc., Suite 2320, 3340 Peachtree Road N.E., Tower

Place, Atlanta Georgia 30326. The product is sold, distributed and installed throughout the Northeast by Felix A. Marino Co., Inc., 32 Corwin Street, P.O. Box 431, Peabody, MA 01960. Imprint is marketed for use as a crosswalk treatment and the creation of traffic calming features. It is advertised as highly durable against snowplowing.

TEST SITES

The project Technical Advisory Group (TAG) located three pairs of snowmobile crossings on or near the state highway system for testing. The sites were known for heavy snowmobile traffic and excessive pavement wear at the trail crossings. They are located on NH Route 26 in Errol, on US Route 3 and Brown Road in Groveton, and on Old Groton Road and Halls Brook Road along NH Route 25 in Rumney. The trail crossings in each test pair have similar snowmobile traffic and environmental conditions allowing for durability comparisons between the test products and the control pavement areas. A snowmobile counter was positioned along the trail at each trail-crossing pair to better compare the traffic level impacts on the tested materials. Examples of typical snowmobile damage are shown in Figures 1 and 2.

Route 3, Groveton

Fig. 1 -- Southbound shoulder edge is broken from stud damage during snowmobile acceleration to cross highway.



Fig. 2 – Northbound shoulder edge is broken and pavement surface is worn from snowmobile studs.

On September 29 and October 4, 2005, each crossing was prepared by placing a half-inch thick, 150-foot long, full-width 3/8-inch asphalt mix overlay to renew the surface of each crossing area and create a control area. Excess mix was placed to create an approach apron on the southbound side of the US Route 3 crossing in Groveton.

Later, one of the products would be installed across one half (1/2) of each highway width to establish a 20-foot wide trail crossing. The installation would result in a test area of 240 to 400 SF, depending on the existing paved shoulder width, which was also to be treated.

Cleanosol

This product was installed by Clark Highway Services, Inc. in all three locations on October 6, 2005 on a clear day with ambient temperatures ranging between 41 and 68 degrees F. More specifically, the locations were:

- Eastbound lane of NH Route 26, approximately five miles west of Errol

- Eastbound lane of Brown Road near US Route 3, Groveton
- Northbound lane of (NHDOT maintained) Halls Brook Road at NH Route 25, Rumney

The Cleanosol installation process involved heating bags of Grade E-5 Norskilt brand thermoplastic material to 425° and 450° F in the kettle of a small self-contained heating unit carried by a small flatbed truck. The entire unopened bag is thrown into the kettle, since the bags are made of the same material as their contents. The heated thermoplastic is then transferred to a heated walk-behind applicator.

A 10 – 12” wide strip of thermoplastic was laid down by the applicator at a constant thickness on the surface of the dry, clean, overlaid roadway. Fine silica sand was metered onto the freshly applied thermoplastic from a hopper mounted on the applicator. Additional sand was added by hand over each layer as it was being completed. The sand helps to reduce the stickiness of the hot surface and provides the material with better friction properties than thermoplastic alone. The strips were butted together to complete the first of three layers. The next layer was offset by one half of the strip width to cover the joints of the preceding layer and to create a ramped condition at the leading and trailing edges of the crossing for a smooth transition to the untreated pavement. The third layer was offset from the second. An additional pass was made across the ends of the strips to complete the installation. The entire process took a two-man crew approximately one hour to complete at each location.





Fig. 3 – Truck mounted heater unit and applicator, Groveton

Fig. 4 – First strip applied, Groveton

Fig. 5 – Third and final layer application, Groveton; note sand hopper at left of photo

Fig. 6 – Edge strip covers ends, Groveton

Fig. 7 – Completed panel, Errol

Imprint

Felix A. Marino Co. (Marino) installed their product in Errol and Groveton on October 12, 2005. They returned to complete the Rumney site on October 17, 2005. Installation time in Errol was approximately 2-1/2 hours. At least 1/2 hour was spent warming the pavement, which was cooler than the air temperature. The day was clear, cool and a breeze was blowing. Initial air temperature was around 30° F and did not go above 35° F at this site. While a cool breeze continued at the Groveton site, the air temperature did reach about 45° F. Weather information was not documented at the Rumney installation. Imprint installations:

- Eastbound lane of NH Route 26 at the “buffalo farm”, approximately three miles west of Errol
- Northbound lane of US Route 3 near Brown Road, Groveton.
- Northbound lane of (town maintained) Old Groton Road at NH Route 25, Rumney

NHDOT had blocked out an area for the Imprint inlay when it placed the asphalt overlay surface preparation. This allowed Marino to apply the Imprint to the existing asphalt surface. The technique saved Marino from having to remove existing asphalt by softening it with infrared heat, Marino’s normal method. It also resulted in a cost savings to NHDOT.

A truck-mounted heating unit similar to the Clark kettle blended pigment, resin pellets, fine aggregate and two types of reinforcing fibers at approximately 425 to 450 degrees F to prepare the product. The hot mixture was then placed and leveled by hand to match the finish grade of the surrounding asphalt pavement. A heated 6” x 6” iron was used to work the mix and smooth its surface. Play sand was broadcast over the surface before the placed material cooled and solidified.

Each trail crossing took 2 to 2-1/2 hours to complete. Marino’s crew consisted of 3 people. Both contractors had similar truck and material preparation equipment.



Fig. 8

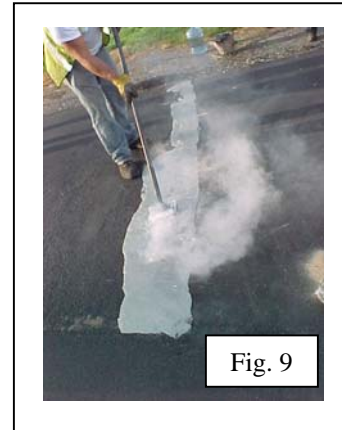


Fig. 9



Fig. 10

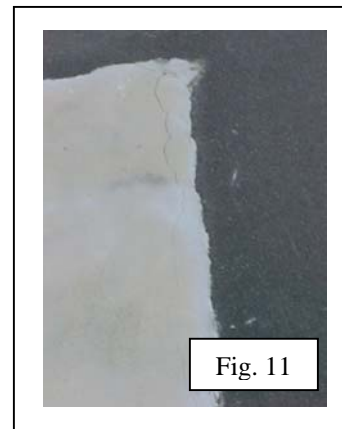


Fig. 11



Fig. 12

Fig. 8 – Blocked out area in overlay for Imprint inlay, Error

Fig. 9 – Application begins, Error

Fig. 10 – Final smoothing with tamper, play sand covers remainder, Error

Fig. 11 – Shrinkage cracks appeared at edges, Error

Fig. 12 – Completed panel with red pigment, Rumney

Installation Costs

The Cleanosol panels were installed at a cost of \$6.00 per square foot. This was a promotional rate, which did not include mobilization. A 2009 quote to treat approximately 6,200 SF of trail crossings was received for \$7.50 per square foot, plus a mobilization charge equivalent to about \$0.50/SF.

The Imprint product was installed in the NHDOT-prepared “block out” at a cost of \$25.00/SF. Additional labor and equipment for heating, removal and disposal of a half-inch depth of existing pavement would increase the cost when required.

A hot mix asphalt (HMA) repair of snowmobile damage would require saw cutting or grinding at the edge of the worn area, followed by application of a tack coat and placement and compaction

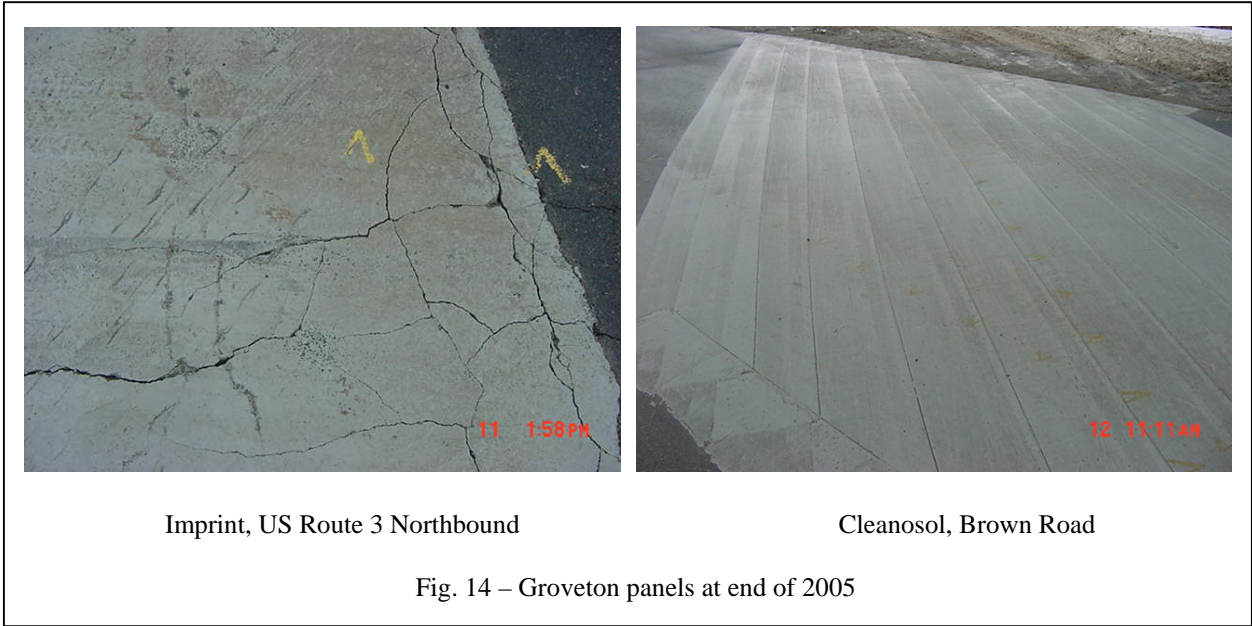
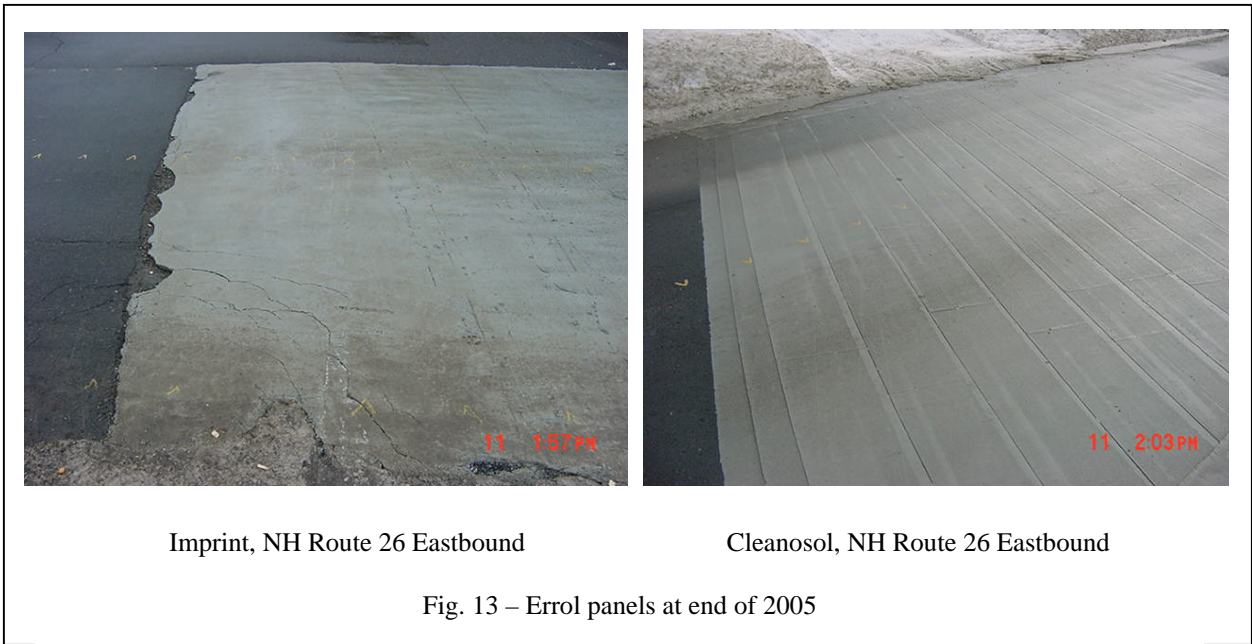
of the asphalt mix. Although the process is relatively simple, costs are controlled by the distance between the site and the asphalt plant, and multiple mobilizations of the paver and rollers to complete repairs at several locations. A comparable cost to complete 6,000 SF of trail repair with HMA is estimated to be \$9.00/SF.

Early Observations

The Cleanosol installations were applied directly to the new overlay at a constant thickness. As a result, the new surface reflected whatever shape preceded it. For instance, a closer look at Figure 7 reveals longitudinal scuffmarks at the roadway crown, lane centerline and shoulder caused by early snow plowing on an irregular surface. These are indicators of the wheel rutting typical of the surrounding pavement, which exist in spite of the overlay. The panels are otherwise flat across the uppermost layer of material. The installations provide good ride quality in both high and low-speed environments. A high-speed crossing is little more noticeable than a good quality trench patch. Only cosmetic scrapes from snow plowing had been observed through the end of December. It should be noted that the snowmobile season was only several weeks old at the time of the observation.

The Imprint installations resulted in an uneven surface that was found to be especially unacceptable in high-speed areas such as NH Route 26 in Errol and US Route 3 in Groveton, which have 50 MPH speed limits. A typical Imprint installation is stamped to create a faux architectural surface texture such as brick or cobblestone, which masks the surface flaws of the hand-applied material. The material is also marketed for use in cross walks, gores and traffic calming features, where uneven, textured surfaces are desired to capture the attention of the driver. A surface texture was not conducive to our trail crossing application. Improved installation techniques would need to be developed to attain a smoother finish for snowmobile crossings.

Cracks developed immediately after installation in the Imprint panels. The butt joint between the Imprint and the HMA overlay contracted as well. Some edge cracking (Figure 11) can be attributed to installation at ambient temperatures just below the minimum requirement of 40 degrees F in Errol and just above 40 degrees F in Groveton. The existing pavement was pre-heated with propane torches, but perhaps not adequately to satisfy the needs of the hot-applied material. This matter raised questions regarding the quality of the bond between Imprint and the existing pavement. Additionally, cracks across the central panel areas and edge/joint chipping began to appear by the end of December (Figures 13 and 14). Had Marino heated the entire blocked out area with their infrared heaters prior to placing the Imprint, the greater depth of heating may have helped with bonding and slowed the contraction of the material. The torch method used for this specific installation may have heated the surface somewhat, but it was probably not enough to heat the large mass of the existing pavement layer in the cold environment on the installation date. While the Imprint was hot when applied, the thin layer (1/2" - 3/4") would have cooled rapidly from both the low air and ground temperatures. Stud damage had also been observed at the Errol site by the end of December.



Following the first winter, the condition of the Imprint panel in Groveton prompted the NHDOT Maintenance District to replace it full width with HMA containing Gilsonite, a pavement stiffening additive used to control rutting and shoving conditions.

DATA COLLECTION

A Trailmaster Model TM1550-16K infrared game monitor was installed between each pair of trail crossings to record a monthly count of snowmobile trips from December 1 to March 15. NHDRED had successfully used these devices to count snowmobiles for trail management. A passing sled is identified by the length of time the infrared beam is interrupted, which would differ from interruptions by wildlife.

Traffic counts were measured to generate comparison data that might show if the rates of wear varied relative to weather conditions, since the Rumney site was considerably south of and at a lower elevation than the other two sites. These environmental differences result in a shorter snowmobile season, and perhaps more instances when the roadway pavement is bare or “softer” due to warmer weather conditions than the northern locations. Table 1 contains the collected traffic data. Several monthly traffic counts appeared unreasonable or were simply missing. These data sets were estimated by calculating a value in the same proportion as the adjoining month. The initial plan was to collect field data for two years. However, the 2005/06 and 2006/07 winters produced little snow. These lean winters resulted in inadequate snowmobile travel to generate measurable wear. Data collection was extended through the 2007/08 season, which yielded a record snowfall and between two and four times the snowmobile traffic compared to the combined previous two years.

NHDOT used field survey methods to measure surface wear of the test panels. The electronic survey equipment was capable of reading elevations to 0.001 foot. Six profile lines were established for each crossing. Five (A through E) were laid out parallel to the roadway alignment, beginning with the test panel) to measure elevations along the roadway and lane centerlines and the two outer lane lines. The sixth profile (F) measured the trail centerline across the roadway in order to observe any rutting across the test materials. Measurements were made at one-foot intervals along the profile, and adjusted for frost movement. Graphic plots of the first-year survey data indicated that the incremental wear was not significant enough to measure on a monthly basis. Data were only collected in the fall and spring for the subsequent years, since little was learned from the intermediate data. Evaluations and conclusions were based on comparisons of the base and final measurements.

Table 1: Snowmobile Traffic Counts (Approximate)

	Dec.	Jan.	Feb.	Mar.	2006 Totals	Cumulative Totals
Errol	0	8,623 ^a	2,759	6,072	17,454	17,454
Groveton	0	133	71	133	337	337
Rumney	0	222	132	0	354	354
					2007 Totals	Cumulative Totals
Errol	0	1,587	4,147	6,000	11,734	29,188
Groveton	0	394	855	545	1,794	2,131
Rumney	0	948	1,681	1,312	3,941	4,295
					2008 Totals	Cumulative Totals
Errol	3,930	6,001	9,983	4,702	24,616	53,804
Groveton	N/A ^b	382	5,248	6,000 ^c	11,630	13,761
Rumney	202 ^a	1,508	5,702	2,178	10,896	13,885

^a Validity of value in question

^b Counter malfunction

^c Lots of deer tracks at counter location

The first portion of Table 2 contains the most significant wear measurement from each profile parallel to the roadways. These are net values that have been adjusted to minimize the effect of frost heaving at the sites. Several exceptions are noted, where the measurement was too large to be realistic for incremental surface wear. Shaded data indicate measurements that were located on the test panels. Unshaded data were collected from the control areas. The trail centerline data are not provided, as they showed no significant rutting. The second portion of Table 2 converts the net wear data into a unit rate of wear (feet per 1,000 snowmobile trips), based on the traffic at each site.

Note that the Cleanosol installation in Errol was abandoned for the 2007/08 (third) season due to sale of the adjoining property and relocation of trail.

Wear rate comparisons are only valid between products at a single site due to occasional invalid traffic count data.

Table 2: Data Summary -- August 2008

	Test Area		Control			
	Net Wear (feet)*					
	Line A Lane Edge	Line B Lane Ctr.	Line C Centerline	Line D Lane Ctr.	Line E Lane Edge	Comments
Errol						
Imprint	0.033 ^b	0.03	0.035	0.05	0.043 ^c	
Cleanosol	0.025	0.01	0.01	0.025	0.02	
Groveton						
Imprint	**	**	**	**	**	Season 1
HMA w/Gilsonite	0.025	0.027	0.024	0.021	0.032	Seasons 2-3
Cleanosol	0.023	0.014	0.015	0.022	0.022 ^a	Seasons 1-3
Rumney						
Imprint	0.03	0.016	0.043	0.039	0.018	
Cleanosol	0.06	0.04	0.041	0.043	0.046	

* Measurements were adjusted where beginning and ending plots did not match to estimate true net values.

** Wear not measurable

^a Atypical local measurement of 0.032' ignored.

^b Atypical local measurement of 0.060' ignored.

^c Measurements between 0.065' and 0.13' deemed to be within chipped edge of pavement rather than wear

	Test Area		Control			
	Wear Rate (Ft./1000 trips)					
	Line A	Line B	Line C	Line D	Line E	
Errol						
Imprint	0.0006	0.0006	0.0007	0.0009	0.0008	Seasons 1-2
Cleanosol	0.005	0.0002	0.0007	0.0005	0.0004	Seasons 1-2
Groveton						
Imprint	**	**	**	**	**	Season 1
HMA w/Gilsonite	0.0019	0.0020	0.0018	0.0016	0.0024	Seasons 2-3
Cleanosol	0.0017	0.0010	0.0011	0.0016	0.0016	Seasons 1-3
Rumney						
Imprint	0.0022	0.0012	0.0031	0.0028	0.0013	Actual wear rates
Cleanosol	0.0043	0.0029	0.0030	0.0031	0.0033	Actual wear rates
Imprint	0.0011	0.0006	0.0015	0.0014	0.0006	Normalized for 2-way traffic
Cleanosol	0.0022	0.0014	0.0015	0.0015	0.0017	Normalized for 2-way traffic

Additional Observations

Two wear patterns were observed at the crossings. Where the trail width was constrained by forest or narrow trail, a wear trough developed in the center of the trail crossing, where most sleds traveled. In areas where the trail approach was broader, two-way traffic movement caused the heaviest wear to occur in a diagonal pattern across the trail. Heavy wear was observed in the first highway lane crossed, where quick acceleration took place. Lesser wear was noted on the second lane crossed.



Center Wear Pattern



Two-Way Traffic Pattern

Severe erosion of the shoulder gravels and chipping of the pavement edge was observed on the NH Route 26 crossings. The poor shoulder drainage conditions contributed to the susceptibility to erosion. Shoulders with better drainage suffered less chipping damage. Conversely, the Groveton US Route 3 paved approach, described earlier, protected the highway shoulder from erosion and the pavement edge from chipping. The approach surface was heavily scratched. Less damage was noted at crossings located on the side roads, which were located near intersections with the numbered highways. This may be attributed to the safer traffic environment on the side roads. Traffic is both lighter, and slowing for a stop sign in each of these locations, rather than traveling at 50 MPH. The snowmobile drivers may not be stopping fully at the highway, and not accelerating as harshly to make the crossing.



**NH Route 26 Shoulder
Erosion and Edge Chipping**



**US Route 3 Approach Apron
Surface Wear, Limited Loss of Edge**



**US Route 3 Approach Apron
Surface Wear, Minor Loss of Edge**



**US Route 3 Approach Apron
Surface Wear, No Loss of Edge**

EVALUATIONS

Installation and Cost

Cleanosol was the easiest and quickest product to install as compared with Imprint and HMA repair. This is primarily because it is applied directly to the surface without the need to remove existing pavement to inlay new materials. Its thin-lift application also makes it possible to reapply as the material begins to wear. Imprint and HMA both require additional preparation steps, equipment and personnel. All three methods are sensitive to environmental conditions for successful installation. Cleanosol and Imprint have the advantage of being heated on site, eliminating temperature losses during transport to distant sites.

Cleanosol was the least expensive product to install; approximately 11 percent less than HMA, based on 2009 estimates. Adding Gilsonite increases the cost of HMA by approximately \$12 per ton, or \$45 per crossing. The cost of Gilsonite is currently (2009) on the rise.

Ride and Aesthetics

The Cleanosol installations had the ride impact of a well constructed trench patch. The Imprint panels were uneven and developed numerous cracks shortly after installation. Although less noticeable on the side roads or near a stop sign, the Imprint ride was undesirable at high speed.

Wear Characteristics

This study showed no distinguishable wear trends from the data. The tested products do not appear to be more durable than the hot mix asphalt control areas. Table 3 displays a comparison of the average wear rates of each test and control panel. Occasional suspect traffic counts only allow for the comparison of products at an individual site. Cross-site comparisons are not valid.

Imprint showed less wear than its control in Errol and Rumney, while Cleanosol showed less wear at all three sites. HMA with Gilsonite had no individual control, but the test panel showed more wear in two winters than the Cleanosol control at this site after three winters. Comparisons between the Imprint and Cleanosol panels at the respective Errol and Rumney sites contradict

each other. The Rumney panels experienced single-lane traffic, effectively doubling the wear compared to wider, two-lane patterns. This traffic intensity wore completely through the surface treatment and exposed the underlying HMA layer.

Table 3: Comparison of Average Wear Rates (ft./1000 trips)

	<u>Lines A - C</u>	<u>Lines D - E</u>
Errol		
Imprint	0.0006	0.009
Cleanosol	0.0003	0.004
Groveton		
HMA w/Gilsonite	0.0014	0.0020
Cleanosol	0.0009	0.0016
Rumney		
Imprint (Actual)	0.0016	0.0021
Imprint (Normalized)	0.0008	0.0010
Cleanosol (Actual)	0.0025	0.0032
Cleanosol (Normalized)	0.0013	0.0016



**Halls Brook Road, Rumney
Single-lane and Edge Wear
(Note Steep Slope Grade and
Erosion of Shoulder Materials)**



**Brown Road, Groveton
Edge Wear of Cleanosol
(End Strip is Worn Away Due
to Lack of Shoulder Material)**

Edge damage ranged from heavy surface treatment and control mix erosion (Rumney and Groveton) to pavement chipping and loss (Groveton and Errol) extending into the travel way (Errol). The broad range of edge damage can be mainly attributed to varying traffic levels. Shoulder grade and shoulder materials are also contributors.

The addition of paved aprons to the approach ramps would greatly improve the performance of any material used on the roadway. The shoulder and slope protection in Groveton was effective

in preserving the roadway edge. As the apron wears, replacement pavement could be readily placed, since the off-roadway approach would not require the quality finish that highway surfaces demand.

RECOMMENDATIONS

After a review of the collected data and performance observations, the Technical Advisory Group determined that the wear characteristics of the tested products were not significantly better than the control materials. However, the convenience and lower cost of installing Cleanosol makes it a better choice for the repair of snowmobile trail damage across the State's highways. The following recommendations are made to implement the findings of this study:

1. The Department should adopt Appendix A - Motorized Recreational Vehicle Trail Crossing detail for use in permitting new trail crossings. Its requirements are valid for wheeled vehicle trails as well as for snowmobiles.
2. The Highway Maintenance Bureau should work with the recreational vehicle clubs to begin improving existing trail crossings to bring them into reasonable compliance with the Motorized Recreational Vehicle Trail Crossing detail.
3. The Highway Maintenance Bureau should develop a statewide program for treating snowmobile crossings. Various options are available to implement this program:
 - a. Hire Clark Highway Services for repeat applications.
 - b. Hire local traffic marking contractors with this equipment. There may be a savings by reducing the mobilization distance. A smaller annual program may be more practical than a large-scale program every three years. There may be a need to purchase the Cleanosol product through Clark Highway Services.
 - c. The Department's Traffic Bureau uses similar application equipment to apply thermoplastic pavement markings such as stop bars. They do not have the manpower or equipment availability to perform trail-crossing work on behalf of the Department; however, it demonstrates that we have the ability to bring this function in-house if desired. As stated above, Clark may be our only source for the tested product.
 - d. Identify and evaluate alternative thermoplastic materials to provide flexibility, promote competition, and improve cost effectiveness.

APPENDIX A

STATE OF NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

TYPICAL MOTORIZED RECREATIONAL VEHICLE TRAIL CROSSING

SITE SPECIFIC CONDITIONS MAY REQUIRE THAT THE FOLLOWING ITEMS BE ADDRESSED:

- PRESERVATION OF EXISTING DRAINAGE COURSES
- STABILIZATION OF THE TRAIL BEYOND THE PAVED APRON
- EMBANKMENT GRADING FOR THE TRAIL APPROACH

