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Evaluation of an Automated Bridge
Anti-icing System



Final Report

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16. Abstract Some bridges and roadways are prone to moisture and icing conditions at times when there is no precipitation or when the rest of the highway system does not require treatment. These occurrences are difficult to predict. They delay the treatment of these surfaces and heighten driver exposure to unsafe conditions. This project involved the installation and evaluation of an automated anti-icing system intended to pre-emptively treat a bridge surface with de-icing chemical and eliminate the icing potential at the site. The three-year observation period and subsequent unofficial monitoring of the system operation has demonstrated that the system is effective in protecting the deck from icing. The system is used in conjunction with normal surface treatments during precipitation events as a cost savings measure. Following six years of service, the deck equipment was salvaged to allow for installation of a hot mix asphalt overlay and then re-installed. NHDOT intends to incorporate the system into the deck replacement project for this bridge, presently scheduled for 2018.					
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EVALUATION REPORT, JUNE 2005 TO JUNE 2008
AUTOMATED BRIDGE ANTI-ICING SYSTEM
I-89, LEBANON, NH

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EXECUTIVE SUMMARY

Some bridges and roadways are prone to moisture and icing conditions at times when there is no precipitation or when the rest of the highway system does not require treatment. These occurrences are difficult to predict. Delayed treatment of these surfaces can heighten driver exposure to unsafe conditions.

This project involved the installation and evaluation of an automated anti-icing system intended to pre-emptively treat a bridge surface with de-icing chemical and eliminate the icing potential at the site. The three-year observation period and subsequent unofficial monitoring of the system operation has demonstrated that the system is effective in protecting the deck from icing.

The system is used in conjunction with normal surface treatments during precipitation events as a cost savings measure. Following six years of service, the deck equipment was salvaged to allow for installation of a hot mix asphalt overlay and then re-installed. NHDOT intends to incorporate the system into the deck replacement project for this bridge, presently scheduled for 2018.

INTRODUCTION

Bridges experience differing environmental conditions compared to highways. Depending on height, wind direction, proximity to water bodies and other physical features, their pavements may be exposed to moisture conditions that do not affect the adjacent surfaces. Bridge decks do not have the benefit of residual ground temperatures to temper quick changes in air temperature, resulting in deck surfaces freezing first. These circumstances can necessitate a bridge deck de-icing schedule that is very different from nearby roadway surfaces.

This research project was developed and funded jointly by New Hampshire and Vermont for use by both states to evaluate the effectiveness of automatic anti-icing systems, also known as fixed automated spray technology (FAST) systems. Expected benefits included quicker response to slippery conditions in isolated areas, fewer maintenance crew dispatches, and reduced motor vehicle accidents. Benefits were measured by assessing the impacts on maintenance crew operations, safety conditions on the bridge, and by evaluating system performance for prediction and treatment of icing conditions in addition to dependability and cost of operation.

TEST SITE SELECTION

Several bridge sites and a roadway were considered for treatment with a FAST system. A site with high traffic levels or a known chronic icing problem was desired. The southbound crossing of the Connecticut River by I-89 was finally selected. A summary of site information follows:

- The 840 LF bridge is co-owned and maintained by the states of New Hampshire (80%) and Vermont (20%).
- The southbound bridge crosses a B&M Railroad bed and the Connecticut River at a 3.00% down-gradient in an easterly direction from Hartford, VT to Lebanon, NH. The I-89 bridge approach between I-91 and the Connecticut River is approximately 5% downgrade.
- The deck has an average height of 70 feet above the river.
- The deck cross section consists two 12-ft. lanes with 2-ft. shoulders.
- I-91 is located within a quarter mile of the bridge in Vermont.

- Two I-91 off ramps are located along the approach to the I-89 bridge. The I-91 northbound ramp to I-89 southbound is greater than 5% downgrade and ends at the Connecticut River bridge joint in a substandard merge taper.
- The lane changes and merges, combined with the high speed and grade of this facility, make for a hazardous condition during icy weather.
- Combined northbound and southbound average daily traffic is 38,000 vehicles.
- Although not frequent, accidents on this structure are generally severe.

SYSTEM SELECTION

A request for proposals in the spring of 2004 attracted two qualified vendors. The proposed fees for the scope of work were three to five times higher than the project estimate and budget. A reduced project scope lessened the cost and resulted in a project award to Boschung America in June 2004. The system's affordability was partly due to the introduction of their new micro spray technology. The system, which had only been used in Europe for two years prior, had never been offered in the U.S. The micro spray technology system provided a project that was within budget if state transportation forces would be responsible for several tasks in the original scope.

An additional advantage of the micro nozzle system was that it is distinctly different from both Boschung's and the competition's standard spray heads. Standard heads are more than two inches thick. Since New Hampshire bridge decks are covered with only two inches of bituminous pavement, penetration of the barrier membrane and the concrete deck would have been required to recess the head into the deck surface. Micro nozzles are only 1.7 inches tall, allowing them to be installed within the existing asphalt surface without damaging the barrier membrane.



Boschung America Micro Spray Nozzle



Standard Nozzle

The proposed Boschung America system installation consisted of 48 Micro Spray nozzles in the bridge deck and eight nozzles in the roadway approach to the bridge. The nozzles were grouped into three spray zones along the roadway centerline, which spray sequentially from north to south (with the flow of traffic). Each zone was controlled by an electrically controlled valve unit located on the median bridge rail. An 8 mm diameter polyethylene tube supplies the nozzles with deicing chemical.

The system is controlled by a computer system and road weather information system (RWIS) located at the pump house near the abutment on the Vermont side. Active and active-passive pavement sensors communicate the deck temperature and projected freeze temperature to the

computer. The system can be monitored and controlled remotely through a desktop computer at the NHDOT District 2 Maintenance Office located approximately nine miles away in Enfield.

FACILITY INSTALLATION

The 2006 construction team consisted of forces from the New Hampshire Department of Transportation (NHDOT), the Vermont Agency of Transportation (VTrans) and Boschung America. VTrans started by clearing the pump house site, and creating a shelf in the steep Interstate embankment where the cast-in-place concrete and concrete masonry structure could be built. They also coordinated permitting with the Town of Hartford and procured the chemical storage tank. NHDOT Bridge Maintenance crews constructed the 12' x 16' pump house, designed with an easily removed wooden roof. This feature would allow for simplified removal of the 10-ft. diameter, 6200-gallon, vertical chemical storage tank, should the need arise.



Cast-in-place concrete pump house foundation doubles as secondary containment for single-walled chemical storage tank.



Removable pump house roof system allows for easy storage tank replacement.

Pump house construction began in August 2006 with completion during October. It houses the storage tank, which stands on the floor slab of the subsurface foundation, along with a 300-gallon water tank used for flushing the system and summer maintenance. The pump system and control computer are accessed from a small interior deck constructed at approximate ground level.

There are few system controls on site except for piping shut off valves and a manual spray switch. Although the system is designed to operate automatically, manual commands can be made from a computer located at the NHDOT Enfield District Maintenance office.

Electrical conduit and chemical supply piping was laid in a shallow subsurface trench from the pump house to the bridge abutment where it was attached to the abutment face to reach the median side of the bridge. Brackets were fabricated and attached to the guardrail posts to support the conduit, piping and control valves.



Pump house storage tank and deck.



Pump house operational systems: pump, control valves and computer system (closed cabinets).

Because traffic levels in this area are too high for a lane closure during daytime hours, bridge deck installation required night work that started September 26, 2006. Similar to storm conditions, the entrance of two Interstate highway ramps from I-91 and the significant traffic speeds due to the I-89 down-gradient toward New Hampshire created additional hazards to the work zone.

Boschung America pre-assembled the micro nozzle system in 100-meter rolls at the factory. The 8 mm polyethylene tubing is laid into a 1/2-inch wide, 1-5/8 inch deep groove, cut into the pavement with conventional pavement cutting equipment. The groove was chiseled to open it to 1-3/8 inch wide and 3-9/16 inch long to accommodate each micro nozzle. A 3/4-inch wide groove serves the 18-mm tubing that supplies de-icing liquid from the median bridge rail.

An installation bracket was temporarily mounted on each nozzle to set its position slightly below the pavement surface. An epoxy product was then poured around the nozzle and once cured, held the nozzle permanently in place. Foam backer rod was pressed into the groove over the supply tubing, followed by crack sealer to hold it in place.



100 m rolls of supply tubing with micro nozzles mounted.



Micro nozzle and tubing laid into pavement groove.



Installation bracket attached to micro nozzle.



Completed nozzle installation, held in place by epoxy product.



Backer foam is inserted over the tubing to protect it from crack sealant.



Crack sealant being placed over backer rod and supply tubing.



Lateral pavement and curb cuts make way for supply tubing from the median side bridge rail.

Conduit and control valve installation on the median side of the bridge. Two control boxes are located on the bridge, and one at the westerly abutment to house the control valves that operate each nozzle zone.



A Boso III sensor and an Arctis sensor were installed in the high speed lane at the approximate midpoint of the bridge. These sensors report deck conditions back to the computer in the pump house. The Boso III is comprised of an active/passive sensor design. It calculates the pavement freeze temperature and activates the deicing chemical spray system. The Arctis sensor works along with the Boso III sensor to determine the actual freeze temperature.



Roadway Weather Information System is installed at pump house. The system measures ambient air temperature, relative humidity and rainfall.

DEICING CHEMICAL

Cryotech CF7 was selected as the chemical deicer to be used in the system. CF7 is at least 50 percent Potassium Acetate by weight with a freezing point of -76°F (-60°C) or lower. It is a clear, colorless, biodegradable liquid with a pH in the range of 10.5 and 11.5. It contains no chlorides and is effective at -26°C (-15°F). The storage tank was sized to accept 4,000-gallon tanker loads, the most cost effective purchase quantity.

OBSERVATIONS

The system was put into service Thanksgiving weekend 2006, but unusually warm weather kept it from operation until early on the morning of December 4. This was followed by several cycles during the night of December 4 and 5. Everything appeared to work as intended. Liquid deicer residue was evident on the deck midday after deployment.

A direct observation method was developed so that plow truck drivers could rate the conditions of the I-89 northbound bridge deck (the control surface), then rate the FAST system deck on the southbound return trip. A rating of 1 indicated bare and dry conditions, while a rating of 5 represented very slippery conditions. A table was created for data collection, which included date, time, surface condition, rating, whether the truck was plowing (versus treating) and the salt application rate. Both decks were treated with rock salt.

A review of the first winter's condition evaluations questioned whether the system had been operating. It was determined that the northbound and southbound conditions were remarkably similar. This may be due to observations being made ahead of the plow truck, rather than behind it. The system is meant to resist the bonding of snow pack to the deck, not to keep the deck clear.

Outside of snow events, the system performed as advertised. Computer displays indicated that the deck was treated just before potential icing conditions developed.

On occasion, the deck was treated unnecessarily. In very cold weather (colder than 15°F), treatment of bridges is not needed during light or blowing snow because it simply blows off the dry highway; however, chemical residue on the bridge deck melted the blowing snow. The Boso

III sensor and Arctis sensor interpret moisture and sub-freezing temperatures as an icing condition, and the deck was treated again, perpetuating the cycle.

The official observation period ended in the Spring of 2009. The Department has continued to operate the system since that time and has since experienced at least four supply line failures and damage to one of the micro nozzles due to an object striking the nozzle. One pavement sensor has also stopped reporting data. Additional component failures are likely as the system ages and as the continued pavement wear and deterioration exposes nozzles and tubing to additional harm.

EVALUATIONS

Overall, the Boschung America FAST system performed well. Drivers appear to be unaware of the treatment cycles. No accidents were reported on the southbound bridge since its installation. Unfortunately, this is not a conclusive statement, in that every winter has not resulted in accidents at this location.

With that said, it is estimated that an early morning icing of the deck could expose drivers to a hazardous condition for as much as 90 minutes before conventional treatment could become effective. The pre-emptive treatment of this deck reduces the exposure to zero while it is in operation. Whereas the system may not provide an operational cost savings, it is clear that the safety level at this bridge has been significantly elevated.

The NHDOT continues to operate the FAST system nearly five years after the end of the observation period. When all is in working order, the operation of the system is relatively simple. Periodic visits to the pump house are necessary during the operational period (October to April) to ensure that there are no problems in the system. The control PC at the District Office provides a history of how the system has operated and the relevant weather and pavement conditions.

Maintenance crews maintain normal snow & ice control operations for the given weather conditions. They do not treat the southbound bridge with the FAST system differently from the northbound bridge or other area bridges. Treating with sodium chloride addresses the conditions and tends to preempt operations of the spray system. At an application rate of 0.5 gallon of potassium acetate per 1000 square feet, it takes approximately 12 gallons per treatment, which, at the current cost of \$5.32 per gallon, totals \$63.84 per spray treatment. Sodium chloride at 300 pounds per lane mile and \$65 per ton costs \$3.61 per treatment. In this comparison, potassium acetate is nearly 18 times more expensive per treatment than sodium chloride.

When reports of leaks arrive at the District Office, undertaking a repair is not a simple effort. Site constrictions (traffic volumes, speeds, lack of shoulders) inhibit determination of the nature and location of the reported problem. These same constrictions affect the Department's ability to initiate repairs without coordinating adequate traffic control. This includes two police units and a left-lane closure with the Interstate maintenance crew. The work needs to be completed between 9 am and 2 pm weekdays, or after 7 pm weeknights.

One unexpected problem occurred after the first winter of operation when restriping of the centerline stripe resulted in clogging of a number of nozzles. This problem was not discovered until the fall when the system was being prepared for winter operations. A small hand drill and bits was purchased to drill out the 0.5 mm nozzles. This cleaning operation was undertaken

numerous times while other maintenance and repairs efforts were underway on the FAST system.

The FAST system was originally installed in 2006 on a bridge deck that was last paved in 1986. Since installation, the pavement has continued to wear away under traffic and plowing operations with carbide blades. Some FAST components, especially nozzles, have been shaved away flush with the pavement surface, rendering them inoperable.

NH DOT repaved the southbound bridge deck in October 2012. The deteriorating pavement was likely to become a maintenance problem as surface distresses continued to evidence themselves. Patching and repairing the pavement has the same traffic control issues as maintenance of the FAST system. Rehabilitation and widening of the Connecticut River bridges is scheduled for 2018, so an interim solution was desirable. The I-89 Exit 20 reconstruction project was in its final weeks and the Department elected to have that project repave the deck while it was paving wearing course for the interchange beginning right at the easterly bridge joint. (The project had previously repaved the northbound deck early in the Exit 20 project schedule.)

The Department also decided to maintain operation of the FAST system by salvaging what it could of the system's deck components, including spray nozzles, deck sensors and fittings, and purchasing and installing spray tubing along the deck's centerline. The salvaged nozzles were reused in the new tubing and nozzle bodies. With this new pavement and spray system, the Department will be able to maintain the FAST system until the planned bridge rehabilitation and widening takes place in 2018 at the earliest.

RECOMMENDATIONS

The New Hampshire representatives of the Technical Activities Group recommend that the Department continue operating the FAST system. The Connecticut River bridges of I-89 are scheduled for deck widening and rehabilitation in 2018. It is further recommended that a piping and nozzle system be incorporated into the design to facilitate replacement of the FAST system in at least the southbound direction.

IMPLEMENTATION

The successful operation of the system has resulted in instantaneous implementation through continued operation during the four winters following the observation period of this evaluation.