Ontario's Transportation Technology Transfer Digest
MINISTRY OF TRANSPORTATION
Road Talk
Article 1 • Summer 2011 • www.mto.gov.on.ca/english/transtek/roadtalk

Glass! Crash! Bang!

Bridge Traffic Barriers Reinforced with Glass Fibre Reinforced Polymer Rebar

In November 2010, Ryerson University, a research partner of the Ontario Ministry of Transportation (MTO), conducted the first North American crash test of a Performance Level Three (PL-3) concrete traffic barrier reinforced with Glass Fibre Reinforced Polymer (GFRP). Conducted in Texas, at the Texas Transportation Institute facility, results from the crash test showed that the PL-3 traffic barrier reinforced with Combar (a German GFRP product) satisfies the *Canadian Highway Bridge Design Code* requirements and may now be used on Ontario's highway bridges.

The Canadian Highway Bridge Design Code, CSA S6-06, already includes provisions for use of GFRP in other applications, including PL-2 barriers. Until now, MTO has only used PL-3 barriers reinforced with steel on provincial bridges. While the Code specifies that bridge barriers can be designed using yield line theory, they must also be crash tested to meet the requirements of NCHRP Report 350 before they can be used on Canadian bridges.

PL-3 barrier tests require impact by a tractor trailer.

Until recently, designs for GFRP bars in barriers required custom bar bends performed when manufacturing. Given bent GFRP bars are much weaker than straight bars due to the redirection and associated rearrangement of the fibres in the bend, the number of bent GFRP bars used for a project must be increased, sometimes doubled. For the Texas crash test, GFRP bars with specially designed anchor heads, developed by Shock in Germany, were used.

GFRP bars with anchored heads.

The Schock anchor heads eliminate the need for custom made bars and reduce their development length in the deck slab. The heads are made of a thermo-setting polymeric resin with a compressive strength far greater than normal grade concrete. The maximum outer diameter of the end heads is 2.5 times the diameter of the bar. The head of the 16 mm bar is approximately 100 mm long, beginning with a wide disk which transfers a large portion of the load from the bar into the concrete. Beyond this disk, the head tapers in five steps to the outer diameter of the bar. This geometry ensures optimal anchorage forces and minimal transverse splitting in the vicinity of the head.

For the crash test, 16 mm nominal diameter GFRP bars were used both for the vertical reinforcement of the barrier face as well as for the horizontal reinforcement.

The Ryerson crash test followed the testing protocol of NCHRP Report 350, for evaluating the strength of a PL-3 barrier during impact. The test requires a 36000 kg gross weight tractor trailer travelling at a constant speed of 80 km/hr to impact the barrier at a prescribed angle of 15 degrees. A successful crash test will contain and redirect the vehicle, which must not penetrate or jump over the barrier.

At impact during the crash test, the tractor trailer began to tip toward the barrier, but resolved once its speed was naturally reduced and redirected as required. The test vehicle remained upright during and after the collision, and did not penetrate, under-ride or override the barrier. There were no detached elements, fragments, or other debris from the barrier that showed potential for penetrating the occupant compartment, or cause undue hazard to others in the area. Occupant compartment deformation did not occur.

After the crash test, only minor cracks on both sides of the barrier were observed. Damage to the barrier was acceptable indicating that the test was successful and the barrier met the required capacity. Cracks, such as those exhibited on the crash tested barrier, would require field repair to avoid possible crack propagation.

In the past, MTO has used black steel and epoxy coated steel in concrete barriers. These forms of steel are susceptible to corrosion, and can result in premature barrier maintenance or replacement. The Ministry's earlier corrosion protection >

Glass Fibre Reinforced Polymer Rebar, *continued*

policy has required the use of stainless steel reinforcement for PL-3 barriers. Use of stainless steel – and now advanced composite materials such as GFRP – in barriers, eliminates the possibility of corrosion and ensures a 75-year maintenance-free design life. As barrier walls with black and epoxy coated steel reinforcements need replacement, MTO will now allow the use of both stainless steel and GFRP reinforcement.

GFRP is competitively priced, making it a viable alternative for reinforcing all types of concrete barriers currently used on MTO highway bridges.

MTO is currently developing a Standard Drawing for PL-3 barriers reinforced with Combar GFRP, for use in future Ontario construction contracts. •

For more information, contact:
Nicolas Theodor, Head Standards Engineer, Highway Standards Branch, at (905) 704-2381, or at Nicolas.Theodor@ontario.ca.
OR
David Lai, Head, Rehabilitation Engineer, Highway Standards Branch, at (905) 704-2347, or at David.Lai@ontario.ca.


Video courtesy of Ryerson University, 2011.


GFRP bars set up for barrier construction.


Barrier cracking as a result of tractor trailer impact during testing.

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Smog: A Nice, Light Snack?

Photocatalytic Concrete Field Trials along Ontario's Freeways

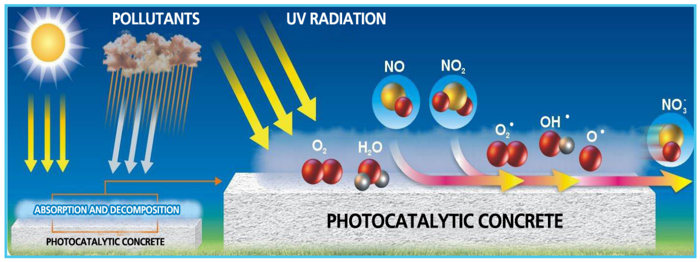
Air pollution is a major global issue affecting our social, economic, and environmental sustainability. The Ontario Ministry of Transportation (MTO) is partnering with the Ministry of Environment, the University of Toronto, Armtec (a noise barrier manufacturer), and Essroc Italcementi Group (the North American division of an international supplier of photocatalytic cement) to conduct photocatalytic concrete field trials. A new "smog-eating" technology, photocatalyic concrete will be applied to a section of noise barriers along Highway 401, near the Highway 404 Interchange in Toronto, starting in the summer of 2011.

Photocatalytic concrete is an emerging green technology which incorporates titanium dioxide particles into Portland cement used to make concrete. Studies have shown that photocatalytic concrete can significantly reduce air pollution and keep concrete surfaces clean. When activated by ultra-violet rays from sunlight, titanium dioxide acts as a catalyst to accelerate the oxidation process that converts nitrogen oxides and other smog components such as fine particulate material, carbon monoxide and sulphur dioxide, to less harmful compounds. Photocatalytic concrete has the potential to significantly reduce smog-forming air pollutants in its vicinity, thus acquiring the moniker "smog-eating concrete".

Italcementi, an international cement producer, has been the industry leader in research and development of photocatalytic cement over the last decade. This technology is being examined by industry and researchers around the world in European, Asian, and North American countries. Positive test results have been generally consistent among industry and researchers. PICADA, a European consortium of manufacturers and research laboratories, has also confirmed industry claims. Prominent technical conferences and workshops have been held, such as the Rilem Symposium on Photocatalysis, Environment, and Construction Materials (Italy, October 2007), and a workshop on Passive Photocatalytic Oxidation of Air Pollution, held at the Lawrence Berkeley National Laboratory (California, June 2007).

Over the last decade, several successful demonstration projects have been completed that involved the application of photocatalytic concrete to the surfaces of buildings, roads, tunnels, and noise barriers. Results show air pollutant improvement ranging from 20 to 70 percent in the vicinity of photocatalytic concrete, depending on sunlight, wind, and other factors. Project costs are minimized since only a thin surface layer of photocatalytic concrete is placed over a conventional concrete base.

Results reported from European trials suggest photocatalytic concrete placed in an area the size of a soccer field can remove emissions equivalent to approximately 190,000 car-km per year. Testing indicates that 1 square metre of photocatalytic concrete removes up to 60 mg of NOx per day. Demonstration projects show that the best pollution reduction occurs when photocatalytic concrete is used in urban areas closest to the source of pollution. The photocatalytic effect is more significant in partially confined spaces such as "canyon" streets. During the photocatalytic concrete demonstrations, the following factors made air pollution abatement more efficient:



Mechanism of decomposition of air pollutants, in presence of photocatalytic cement-based surfaces.
(Image used with permission from Essroc Italcementi Group, 2011).

- Light intensity above 5 W/m2
- Temperatures above 10°C
- Less than 65 percent relative humidity
- Higher pollution concentration
- Concrete surface close to pollution source
- Wind direction blowing perpendicular to concrete's surface
- Porous surface characteristics.

In addition to reducing pollution, the photocatalytic concrete reaction has an established self-cleaning quality found to be most effective on organic stains, in dry conditions and smooth surfaces with minimum porosity. The Ministry plans to evaluate the self cleaning capabilities of the photocatalytic sound barrier Hwy 401 test site.

Through collaboration between government agencies, industry, and academia, using concrete to "clean" outdoor air could become a reality in Ontario. Many potential applications have been identified, although more project demonstrations and research are required. Certainly, the properties of photocatalytic concrete align well with the Ministry's goal of having the greenest roads in North America, but it remains to be seen whether significant benefits are accrued on site. Over the course of a year, the Ministry of Environment plans to conduct air quality monitoring at MTO's test site to confirm the smog reducing capabilities previously obtained in laboratories elsewhere. The final results of MTO's field trial will be used to determine if smog-reduction is significant enough to warrant further, large-scale applications in Ontario. •

For more information, please contact:
Shawn Smith, P.Eng, Project Engineer, Highway Engineering, Highway Standards Branch, at (416) 235-3598 or at Shawn.Smith@ontario.ca,
OR
David Rhead, P. Eng., Senior Concrete Engineer, Material Engineering & Research Office, at (416) 235-3706 or at David.Rhead@ontario.ca,
OR
Chris Blaney, Senior Environmental Planner – Acoustics, Environmental Services Section, at (416) 235-5561 or at Chris.Blaney@ontario.ca

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Saddle up with Bluetooth

MTO First in Canada to use Bluetooth for Travel Time Monitoring

In 2009, an Ontario law was enacted that banned the use of hand-held devices while driving, creating a corresponding increase in the use of hands-free Bluetooth technology. With greater use of Bluetooth, new devices have been developed that pull information from Bluetooth-active vehicles. One such example is the BluFax Bluetooth Traffic Monitoring unit with BluStats software. In 2010, the Ontario Ministry of Transportation (MTO) was the first in Canada to deploy these units for traffic delay compliance monitoring. Allowable traffic delays are included in the Performance Specifications of MTO's new Design-Build Contracts, which describe the maximum length of time a contractor may delay traffic travelling though a construction zone.

Figure 1: BluFax Traffic Monitoring unit with the case open.

What is "Bluetooth"?

Bluetooth is a proprietary telecommunications industry specification for the interconnection of digital devices through short-range wireless communications. A common example of Bluetooth technology is the interconnection of a mobile phone with a wireless earpiece to permit hands-free driving.

Every Bluetooth device has a transceiver chip which continuously transmits a unique 48-bit ID to establish a link with responding devices. This is called an inquiry mode, which a Bluetooth transceiver carries out even while it is already engaged in communication with another device. All equipped and activated devices transmit inquiries as long as their discovery mode is enabled. Bluetooth information is exchanged within a globally available frequency band of 2.45 GHz and transmission ranges include 10m for a Class 2, and 100m for Class 1 devices. In some devices, these ranges may be increased through appropriate adjustments to receiver sensitivity and device placement.

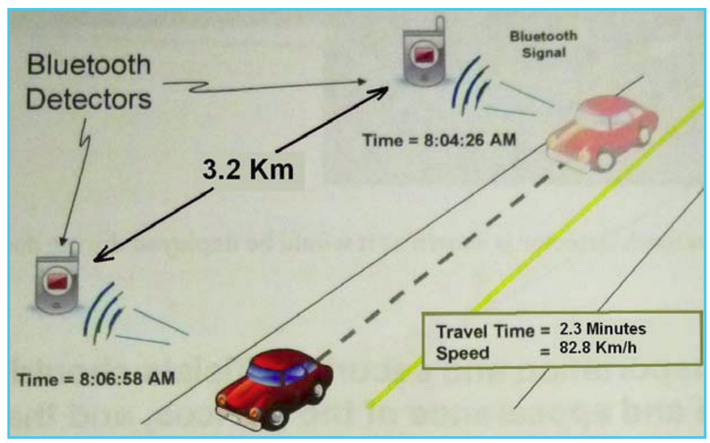

Figure 2: Travel Time Monitoring via Bluetooth technology

Bluetooth Traffic Monitoring

The increased popularity of Bluetooth devices, along with the continuous and long-range transmission of their transceiver IDs, facilitates a new way to gather traffic data. MTO has recently been testing and deploying the BlueFax system to collect data and analyze it with BluStats software. The system collects traffic data through two or more traffic monitoring units located on a freeway in proximity to the roadway. Desired locations for deployment of BluFax devices includes: mounting the devices to a secure elevated location in the right-of-way such as: utility poles, truck inspection stations, or existing Advanced Traffic Management System equipment sites or cabinets, since mounting height and an unobstructed signal path improve detection range.

The BluFax devices are equipped with a Class 1 transceiver with a transmission range of about 100m which will detect traffic travelling in both directions on a divided freeway. In its most basic form, the technology calculates travel times by matching public Bluetooth wireless network IDs at successive detection stations. Recorded time difference of the ID matches provides an accurate measure of travel time and an average speed based on the distance between the successive stations. The distance between successive data collection stations is measured using GPS equipment installed in the BluFax units that record location as a header record for the collected data.

Every BluFax unit is equipped with a 12v-30Ah gel-cell battery and operates continuously for about 12 days. Data is stored on a microSD chip which can later be removed for data retrieval. The units continue to record data until the battery voltage drops to the shut-down point. The units are then physically removed and taken back to the office for recharging and downloading of the microSD chip data. In-field downloading is possible through the use of a non-networked Laptop or Netbook. >

MTO First in Canada to use Bluetooth for Travel Time Monitoring, continued

BluStats Software[1]

Once data from the BluFax units has been downloaded, it can be processed by BluStats analysis software which presents the data for users as follows:

- Loads, archives and processes all sensor data in a graphical, user friendly interface;
- Matches Bluetooth ID address between designated pairs of sensor stations, applying robust statistical base filtering for the flagging and removal of outliers and other anomalous data;
- Summarizes travel time data statistically in five minute time intervals;
- Provides input for additional attributes associated with the sensor stations as well as matched sensor pairs, or 'segments';
- Outputs .kml-based files, a file format used to display geographical data, for easy review of sensor locations and attributes;
- Provides graphical displays of travel time, speed, and detection rates; and
- All data, either from sensor stations or travel time on designated segments can be written to standard comma separated ASCII data files that can be easily imported into MS Excel spreadsheets and data bases.

MTO's Use of BluFax for Traffic Delay Compliance Monitoring

In the spring of 2010, the ministry was the first in Canada to deploy BluFax units to monitor traffic for compliance of a Design-Build contract. Two units were set up in the right-of-way on Highway 8, 3km in each direction from the site of the Fairchild Creek culvert replacement project.

Construction on the Fairchild Creek culvert began in August 2010. The BluFax units were deployed in mid-June to allow for possible placement and equipment issues. For two weeks prior to the culvert construction, data was collected to establish a baseline travel time and speed profile. This data was used to verify the travel time value included in the Performance Specification for Traffic and Mobility Management.

When construction began, the units captured delays incurred when motorists navigated through the new construction zone. The units were then removed, downloaded, recharged and replaced for monitoring during on-going construction activities. Travel time and speed profiles were collected throughout the construction to evaluate the contractor's adherence to the Specification. Results were positive; the data showed that the contractor did not exceed the Maximum Allowable Travel Time specified during the Fairchild Creek culvert project. >

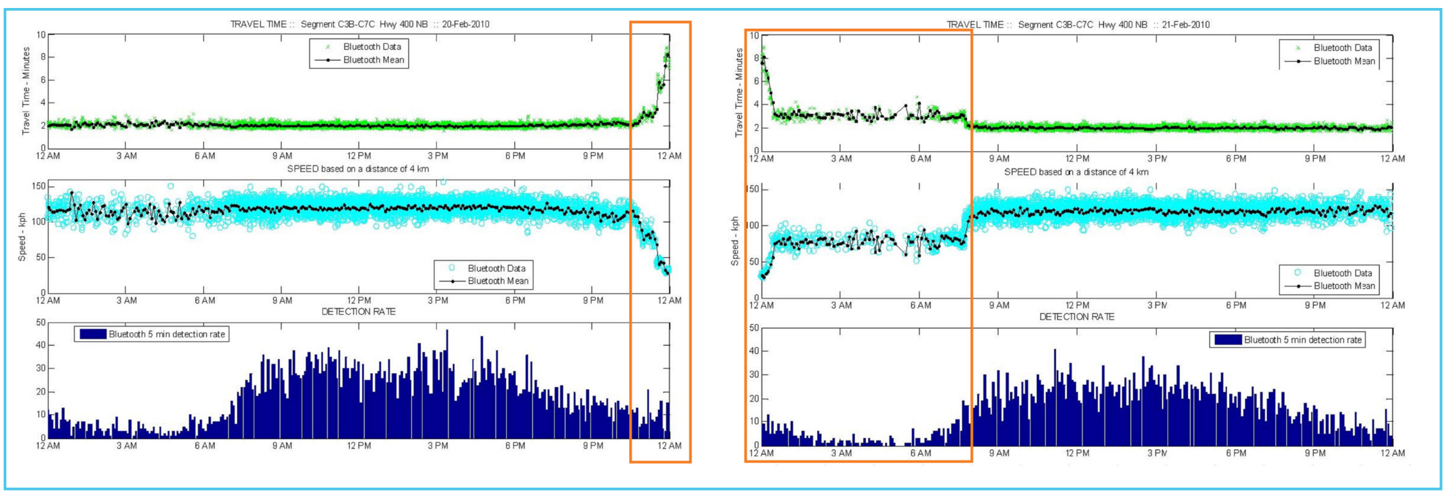

Figure 3: Travel Time Graphs
BLUSTATS graphic output displaying traffic travel time, mean speed, and BluFax sensor detection rate on Highway 400 northbound, before, during, and after detours for MTO's demolition of the old King Road Bridge in York Region, north of Toronto. The orange rectangles superimposed on the two graphical outputs indicate the period during which the northbound lanes were closed and all traffic was detoured. Reading left to right, the green line shows travel time with an initial peak as traffic was diverted onto the detour for the first time. As traffic volumes lessened, vehicle travel times decreased. The light blue line shows vehicle speeds as they travelled through the construction zone. The dark blue graph shows the number of blue-tooth detections in five minute intervals.

[1] *Source of information on the BluFax & BluStats products:* http://www.tpa-na.com

MTO First in Canada to use Bluetooth for Travel Time Monitoring, continued

Modifications and Additional BluFax deployment in Ontario

During the monitoring of the Fairchild Creek culvert project, MTO identified additional measures to improve continuous real-time data collection in future applications. These measures included:

- Informing the Ontario Provincial Police and local police services about the use and typical placement of the new devices, including labelling units to avoid "suspicious package" complaints.
- Determining whether the BluFax units could be modified to accept remote solar powered battery charging.
- Investigating whether a cell phone or wireless modem module could be added to the units for data transmittal back to the office.
- Investigating whether a larger MicroSD chip with a capacity greater than 2gigabytes can be used for data collection.

These improvements are now available on newer units and have been used in later deployments. Battery charging was enhanced by connecting the unit to solar panels, and data was sent back to the office by a modem, eliminating the need for a larger MicroSD chip. These modifications resulted in fewer trips to the field for maintenance.

MTO has also deployed the BluFax units for travel time studies. To date, the units have been used on Highway 400 northbound during the demolition of the old King Road Bridge in York Region (February 2010); during pavement marking operations at Talbot Road and Highway 4, near London (May 2011); and for a Border Crossing Travel Time study during the 2010 Boxing Day Weekend at the Canada/USA border crossings in Niagara.

MTO plans to continue deploying BluFax units for future travel time studies and compliance monitoring of Design-Build Contracts.

For more information, please contact:
Lance Dutchak, Traffic Supervisor, Central Region Traffic Office, Highway Standards Branch, at (416) 235-5596,
or at Lance.Dutchak@ontario.ca,
or
Roger Browne, Senior Project Engineer, Central Region Traffic Office, Highway Standards Branch, at (416) 235-5009,
or at Roger.Browne@ontario.ca

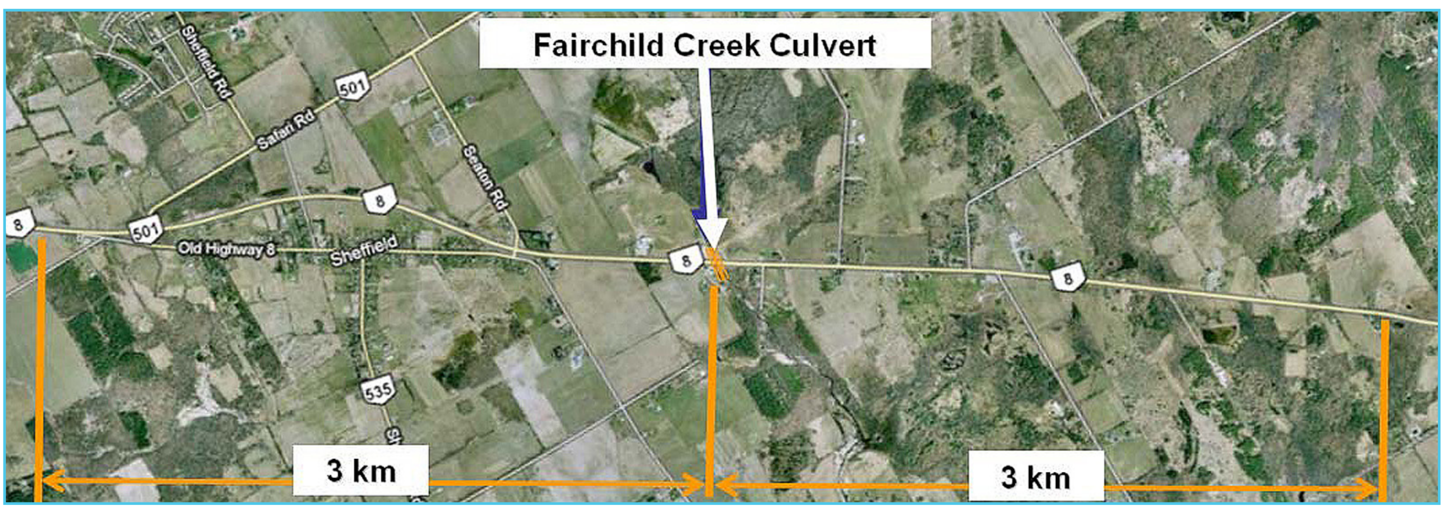

Figure 4: Site of the Fairchild Creek culvert replacement project, where BluFax Traffic Monitoring units were deployed.

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The Scoop on Snow

On the Road to Performance-based Winter Maintenance

In 2009, funded by the Highway Infrastructure Innovation Funding Program, the Ontario Ministry of Transportation (MTO) began collaboration with the University of Waterloo and the AURORA Partnership of Highway Agencies on a multi-year research project to create predictive models to estimate the relative benefits of different levels of winter maintenance. The study is intended to assist the ministry in setting performance-based standards for winter road safety and mobility.

The research project includes the following components:

- Review and comparison of automated technologies for objective and consistent measurement of winter snow conditions;
- Analysis of corresponding data on weather, snow cover conditions, weather-related crashes and traffic flow, to develop models that predict trends in collision occurrence and traffic flow in response to winter conditions; and
- Use of predictive models to better understand the relative effort and benefit associated with different levels of winter maintenance.

By late 2012, a simulation tool will be available to road agencies for use in evaluating the cost/benefits of alternative winter service standards.

Automated Road Condition Monitoring During Winter Storms

This portion of the study includes assessing and comparing the accuracy of measurements, feasibility, and the cost/benefits of implementing each condition monitoring system as standard. Significant progress has been made in this area of the research, including an inter-calibration exercise in which various remote monitoring technologies are compared with each other and then with manual reporting results, to identify areas of consistency or difference. >

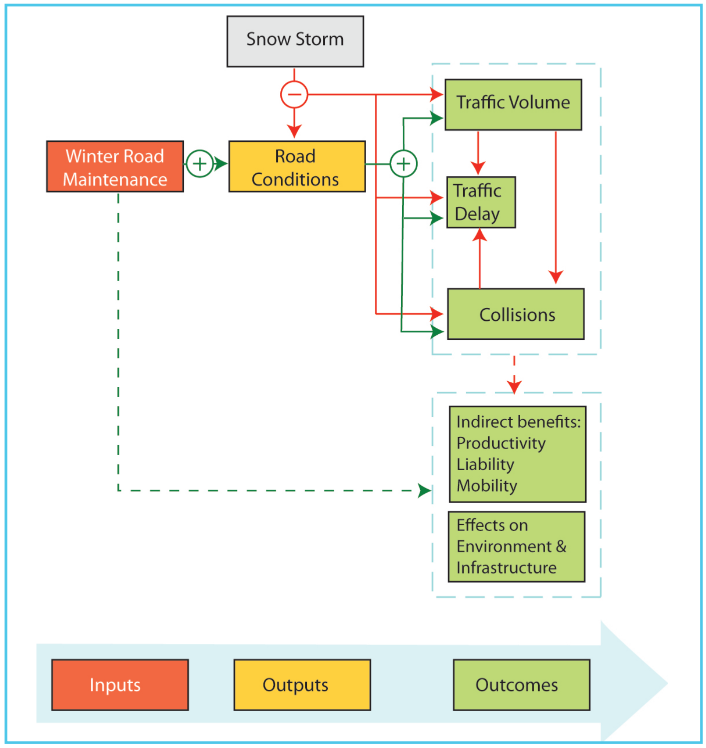

Figure 1: Framework for Highway Performance under Winter Conditions

+ increases or improves - reduces or makes worse

Inputs: maintenance actions such as plowing, salting, sanding

Outputs: the result of the inputs: snow removed, bare pavement restored

Outcomes: benefits from winter maintenance; reduced number or severity of snow-related crashes and travel delay.

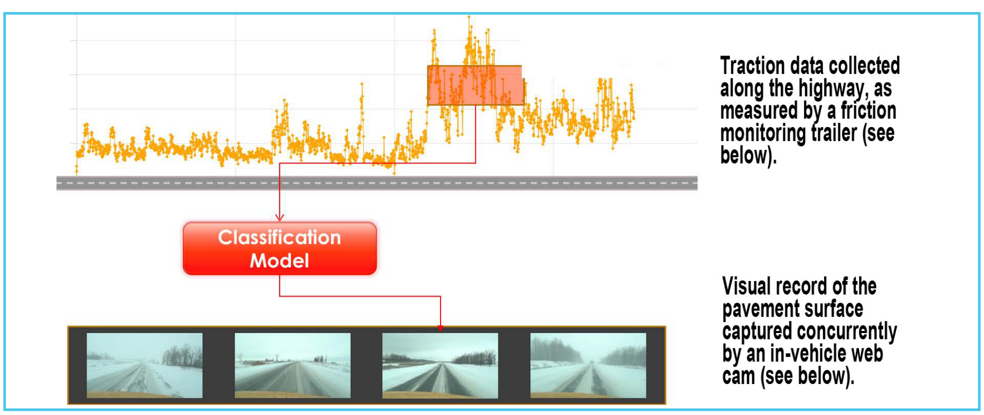

Figure 2a: Automated conversion of traction measurements to snow cover class. Traction data at a specific location (red box) classified as partly snow covered, corresponding to the visual record at that location.

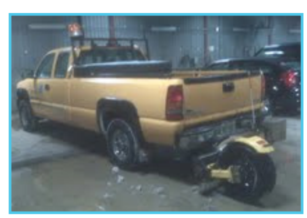

Figure 2b: Friction monitoring trailer.

Figure 2c: In-vehicle web cam.

Ontario

Performance-based Winter Maintenance, *continued*

MTO is currently evaluating the following proven automated technologies:

- Haliday RT3 continuous friction monitoring trailer
- PonCat TWO continuous friction monitoring trailer
- Pole-based Vaisala DSC111 sensor
- Pole-based video camera
- Vehicle-based video camera

Winter Road Conditions and Collision Occurrence

This research component established quantitative relationships between road weather/surface conditions and collision rate/severity, in order to develop a storm-based model and an hourly collision frequency model. Preliminary models are currently being calibrated and tested. Calibration involves using a multi-level, longitudinal database of historical collision information, including: collision numbers, severity, hourly traffic count, winter maintenance standards and operations, weather conditions, and road surface conditions. The data was originally collected between 2000 and 2009, on 31 Ontario highway segments. A numerical estimate of road conditions related to hourly traction levels was developed based on highway patrollers' qualitative observations of snow cover conditions during winter storms.

Initial analyses showed consistent relationships between collision numbers and three factors: road surface condition; traffic level; and visibility. Establishing these relationships identified monthly trends in collision rates, with higher incident numbers early in the winter. Analysis of additional factors, such as highway type, traffic levels, and maintenance service class, will provide MTO with a more complete understanding of collision number and factor relationships. Future work will investigate relationships with collision type, and severity, as well as the effects of road geometry and other characteristics.

Winter Road Conditions and Traffic Flow

Developing relationships between winter conditions and travel delay has involved measuring traffic flow and speed under various classes of winter surface and weather conditions, compared with traffic flow and speed under clear dry conditions at the same day and time in other years. The traffic flow research has used longitudinal analysis and simulation to estimate build-up of congestion following a snow fall, with data similar to the collision occurrence study, as well as continuously-monitored speed and flow data from permanent counting stations. However, available traffic data has limited the traffic flow research to fewer sites in Ontario. The Departments of Transportation in Iowa and Michigan have provided traffic data to supplement this research component. A preliminary model has been developed and is currently being calibrated and tested. Results to date have provided winter maintenance benefit estimates and the future model is anticipated to show incremental benefits on traffic flow associated with changed winter standards.

An initial simulation analysis was applied to a case study on the Queen Elizabeth Way near Toronto. Simulation was based on two assumed scenarios: bare road and snow covered road under four precipitation intensity conditions. As precipitation intensity increased, travel delay increased for both surface conditions, with a growing relative difference in travel time between bare and snow-covered road surfaces. The highest maintenance benefit was attained under moderate volume conditions. High traffic volumes affected vehicle speed before factoring in road conditions and in low volume traffic, large vehicle separation distances provided drivers with a sufficient buffer to avoid collisions when driving at reduced or varying vehicle speeds. >

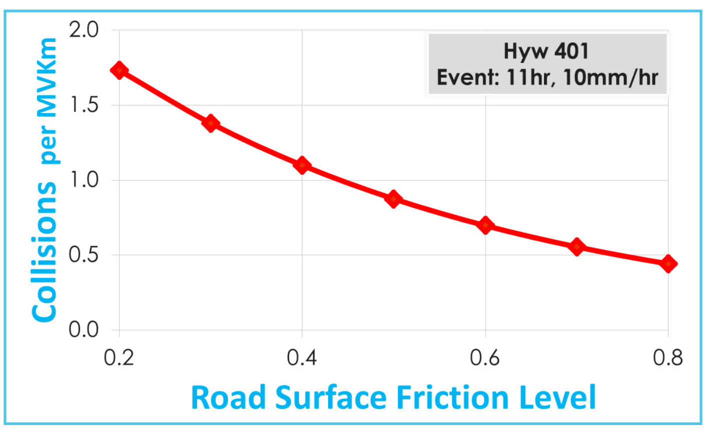

Figure 3: As traction levels increase, rate of collision is reduced.

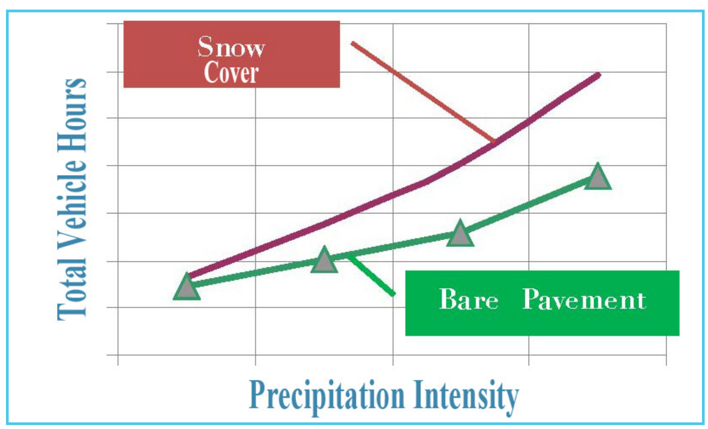

Figure 4: Mobility benefit of achieving bare pavement.
Note the base traffic congestion level under good conditions.

Performance-based Winter Maintenance, *continued*

Predicting Benefits of Winter Maintenance Levels

The first step in predicting the safety and mobility benefits associated with alternative service standards is to predict the road conditions that result from different levels of winter maintenance. Models are in development for this exploratory stage of the research. In one study, a simple pavement temperature time-series model was used to demonstrate the feasibility of predicting road conditions over short time periods. In another, a seasonal archive of road reports was used to estimate the differences in road surface conditions under existing maintenance standards and a proposed alternative standard.

More work is underway to develop a more comprehensive model that predicts road condition outcomes, associated collision rates, and travel delay for given initial road surface/weather conditions and maintenance inputs such as pre-storm anti-icing spray, salt spreading, and plowing.

When the maintenance input and road condition output model is fully developed, it will be combined with road safety and mobility predictors to estimate the safety and mobility outcomes achieved by various service standards. The model will be incorporated into an analytical tool that assesses the benefits and costs of alternative winter maintenance standards.

Review and Recommendation of Alternative Performance Measures

Performance-based standards can be established using a variety of criteria, including: resource inputs such as plowing cycle times; end-result outputs such as the time allowed to restore bare pavement or a baseline traction level; or outcomes such as travel delay and collision rate. When this project is completed in 2012, alternative performance measures and standards will be reviewed to identify and recommend those that can be used reliably and affordably in winter maintenance contracts.

The ministry is sharing project results with other highway agencies as the study matures. Early results of the studies are available. ●

For more information, please contact:
Max Perchanok, Research Coordinator,
Design and Contract Standards Office,
Highway Standards Branch, at (416) 235-4680,
or at Max.Perchanok@ontario.ca.