Using Road Weather Information Systems (RWIS) to optimize the scheduling of load restrictions on Northern Ontario's low-volume roads.

Sarah Baiz, M.A.Sc. Candidate
Department of Civil Engineering, University of Waterloo
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
sbaiz@engmail.uwaterloo.ca

Susan L.Tighe, Ph.D., P.Eng.
Canada Research Chair and Associate Professor of Civil Engineering
University of Waterloo, sltighe@civmail.uwaterloo.ca
Phone: (519) 888-4567 Ext. 33152, Fax: (519) 888-4300

Carl T.Haas, Ph.D.
Canada Research Chair and Professor of Civil Engineering
University of Waterloo, chaas@civmail.uwaterloo.ca
Phone: (519) 888-4567 Ext. 35492, Fax: (519) 888-4300

Brian Mills
Adaptation and Impacts Research Group
Meteorological Service of Canada, Environment Canada
Faculty of Environmental Studies, University of Waterloo
Phone: (519) 888-4567 Ext. 35496, Fax: (519) 746-2031
Brian.Mills@ec.gc.ca

Max Perchanok
Maintenance Research Coordinator
Highway Standards Branch Ontario Ministry of Transportation
301 St. Paul Street, St. Catharines, Ontario L2R 7R4
Phone: (416) 235-4680, Fax: (416) 235-4020
Max.Perchanok@ontario.ca

Paper prepared for presentation at the
Preserving Low Volume Roads Investments
Session of the 2007 Annual Conference of the
Transportation Association of Canada
Saskatoon, Saskatchewan

The authors would like to acknowledge the contributions of the Ministry of Transportation of Ontario and the Highway Innovation Infrastructure Funding Program (HIIFP) for funding this research. In addition, the authors would like to acknowledge the MTO Regional staff in particular Ken Mossop, Mickey Major, Brian Scott, Doug Flegel and Vic Lawrence, for their assistance.

ABSTRACT

Seasonal shifts in moisture and temperature within the pavement can affect the bearing capacity of the roadway, especially in Northern Ontario where low volume roads are challenged by frequent freeze-thaw cycles. Seasonal load restrictions (SLR) are implemented every year on Ontario’s secondary and tertiary highways to protect the road infrastructure. However, each time loaded trucks are allowed on a weakened pavement, premature deterioration of the roadway occurs and maintenance expenses increase. Conversely, when the payload is unnecessarily restricted, the transportation and resource industries are penalized. These economic losses are due to the reactive approach of SLR timing, historically based on patrols and expert judgment instead of systematic monitoring of the pavement condition.

Road Weather Information Systems (RWIS) form a network of automated climatic stations designed largely for supporting winter maintenance operations in Ontario. A study conducted by the Ontario Ministry of Transportation and based on two experimental sites located in Northern Ontario found a reasonable correlation between frost thickness in the roadway and RWIS variables. As a follow-up to this analysis, frost predictors have been developed this year and are presented in this paper along with the results of cracking simulations using the Mechanistic-Empirical Pavement Design Guide and typical Northern Ontario conditions.

Based on variables provided by the online RWIS database and Environment Canada forecasts, models would indicate changes in relative pavement strength. Real-time and cost-effective guidelines could then be derived and translated into a decision-support tool that assists MTO engineering professionals in the implementation of load restrictions.

INTRODUCTION AND BACKGROUND

Load restrictions policies in Ontario are mainly targeting the low volume pavements which are generally built to lower standards than those of the King's highways. This analysis focused on the secondary (500-series and 600-series) highways of Northern Ontario, most of which are remote access industrial and resources roads and are thus subject to heavy traffic loading.

These roadways were built to handle year-round unrestricted traffic, apart from specific sites limited by certain circumstances. However, it is the combination of spring thaw cycles with heavy truck loading which is suspected to be responsible for the major part of pavement damage. Therefore, each year, a seasonal reduced load period, namely a Spring Load Restriction (SLR) period, is put into effect on the various low volume routes regrouped as "Schedule 2 Highways", usually throughout March, April and May **[1]**. Also, oversized load permits - Winter Weight Premiums (WWP) -, which are usually allowed as long as the pavement structure is frozen and thus assumed to be able to cope with higher loads, are restricted during an SLR period. Even though load restriction periods are commonly designated as "half load periods", section 122 of the Highway Traffic Act **[2]** specifies the load restriction limit to be 5,000 kg per single axle. Vehicles exceeding this limit have to take alternative routes or be subject to the penalties described in the Act.

These weight restriction policies are currently established using historical date thresholds and expert visual observation instead of systematic and real-time monitoring of the pavement condition. Therefore, such policies can either penalize the transportation and resource industries each time that the payload is unnecessarily restricted, or lead to irreversible pavement damage when overloaded trucks are allowed on a weakened roadway. WWP certainly provide increased capacity, but in the absence of proper monitoring of the roadway condition, delayed overloads can further compound pavement damage. To address this problem, this study proposes site-specific models that can relate a few climatic variables to the frost depth and thickness in the pavement on the one hand, and (as part of some future work) to strength thresholds obtained from historical data and from pavement deflection testing on the other hand.

TARGET PAVEMENTS AND TYPICAL DISTRESSES

Northern Ontario roads mainly differ in the surface structure while most of their structural layer (from the base down to the subgrade) generally remains constant between pavement types **[3]**. Apart from a few roads which are still gravel-surfaced since their construction in the 1950s, most of Ontario's secondary highways have now become hard-surfaced (paved) with asphalt-concrete **[4]**. Moreover, bituminous surface treatments may be found on some portions of those low-volume roads where the rejuvenation of old asphalt-concrete surfaced pavements or the use of sealing coats was needed. Therefore, this study addresses pavements that fall under one of the following categories: Gravel-surfaced, asphalt-surfaced or surface-treated roads.

The standard condition rating schemes used in Ontario by the Ministry of Transportation for the evaluation of the road surface condition involve the use of specific indicators, such as functional performance ("riding quality") and structural damage ("extent and severity of the roadway's surface distress") **[5]**. The typical surface distresses associated with each type of road involved in this project were identified to be: Surface roughness, rutting, thermal fracture (transverse cracking), and fatigue cracking, composed of top down cracking (longitudinal cracking) and bottom-up cracking (reflective cracking).

MECHANISTIC-EMPIRICAL ANALYSIS

Part of the work consisted in examining how the performance of low volume pavements was affected by Northern Ontario's specific climatic and traffic constraints, and to evaluate the benefits of implementing load restrictions on those roads. The new Mechanistic-Empirical Pavement Design Guide (MEPDG) software was selected as it is capable of evaluating the performance of new and rehabilitated pavements given their structural profile, and of calculating the damage associated with various climatic and loading conditions. The MEPDG was used to examine how load restrictions influenced the key pavement distress indicators of two types of low volume roads (asphalt and gravel pavements, both surface treated) over a twenty-year design life. The physical condition of the pavement structure was evaluated in terms of fatigue cracking and rutting and the functional performance in terms of ride quality and comfort, using the International Roughness Index (IRI) **[6]**.

Since its first development in 1997 by the AASHTO Joint Task Force on Pavement (JTFP) under National Cooperative Highway Research Program Projects 1-37 and 1-37A **[6]**, the MEPDG software has considerably improved along with progress in model accuracy and computer science, as well as increased amount of available pavement data. The latest version of the software (MEPDG v.0.9) became available online in July 2006 **[7]** and was used to conduct the analysis. This version reflects changes recommended by "the NCHRP 1-40A independent review team, the NCHRP 1-40 panel, the general design community, various other re-searchers, and the Project 1-40D team itself" **[8]**. In particular, the Enhanced Integrated Climatic Model (EICM) was greatly improved. Thanks to this feature, the software is able to calculate hourly temperatures and moisture within each pavement layer and within the subgrade over the entire design period. A final version incorporating additional enhancements (MEPDG v.1.0) should be released in the following months. However, for the purpose of assessment, the available software was deemed to be appropriate and suitable.

The MEPDG impose that the user inputs the pavement structure by layers and with the nature and thickness of each layer. In the case of unbound materials, the site-specific sieve analysis distribution and the compaction state can be entered. In the case of bound materials (asphalt-concrete), the binder and aggregates properties can be specified. In this study, the MEPDG simulations were carried out on a number three level of analysis as it is suited to low volume pavements and allows nationally calibrated values to be adopted when no information is available **[6]**. The main purpose of the MEPDG simulations presented herein was to assess qualitatively the benefit of reducing loads during certain periods of the year in comparison to other periods of year, with the "no restrictions" case as the baseline.

MEPDG inputs of interest

Two typical structures were entered into the software: One gravel road and one asphalt-surfaced road (as illustrated in **Figure 1** on the next page and detailed in **Table 1**). Both roads received a thin asphalt overlay in year number ten of their design life (starting arbitrarily from August 1980), as thin overlays are commonly accepted as one of the preservation techniques for low volume roads pavements **[9]**. In accordance with the Ontario Provincial Standards Specifications (OPSS), a Superpave PG 58-34 binder was selected for these overlays.

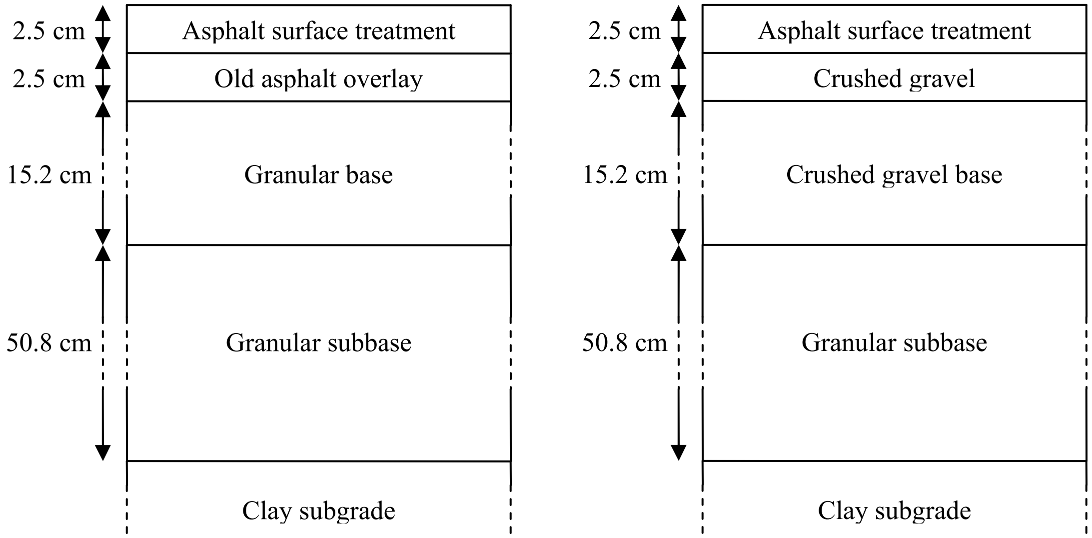

Figure 1 Target pavements (left: "asphalt road"; right: "gravel road")

The typical traffic volumes were retrieved from the Ministry of Ontario historical archives, in which the Annual Average Daily Truck Traffic (AADTT) is defined as "the twenty-four hour two-way traffic volume, averaged for the period of January 1st to December 31st"**[10]**. The traffic volumes were then converted into equivalent single axle loads with default load distributions for each of the 4 to 13 traffic classes. Simulating seasonal variations of traffic loading throughout the twenty-year design life of the pavement was achieved by setting the monthly axle load distributions factors equal to zero for all the loads exceeding 5,000 kg (11,000 lbs to 41,000 lbs). Since the total volumes were kept constant, the axle load distribution factors had to be adjusted for loads 3,000 lbs to 10,000 lbs so that the sum of all the factors equalled 100 per cent. It should be noted that the MEPDG software does not allow the user to change the distribution factors for periods of less than one month.

Table 3 illustrates the various scenarios that were selected and simulated with the MEPDG software and performed for each of the four typical sections presented in **Table 1**. A total of sixty-four MEPDG runs were performed. The outputs of interest and their associated design thresholds (as assumed in the MEPDG Guide for Flexible Pavements **[11]**) are summarized in **Table 2**. These thresholds are commonly used as triggers for pavement repair, rehabilitation, and reconstruction decisions. To account for the various uncertainties in predicting future pavement deterioration, a reliability level of 75% was selected in accordance with the Design Guide recommendations for low volume pavements **[12]**.

Results of the MEPDG analysis

For each of the performance criterion used in the analysis (IRI, longitudinal cracking, reflective cracking and total rutting) and for each of the four typical sites (Northeastern asphalt road, Northeastern gravel road, Northwestern asphalt road and Northwestern gravel road), time to failure was computed and is presented in **Table 4**. Values greater than twenty years indicate that the parameter limits were not reached during the twenty-year design life.

In **Figures 2 and 3**, the baseline case ("no load restrictions" scenario) is compared to the other load restriction scenarios defined in **Table 3**, using the terminal values (values at year twenty) of two of the performance criterion (IRI and rutting). The purpose of **Figures 4, 5** and **6** is to evaluate and compare the ability of each load restriction scenario to increase the pavement service life. In short, none of the scenarios quantitatively increased pavement service life more than six years. The results indicated that in general, longer periods of load restrictions could protect the pavement infrastructure, but one should keep in mind that longer SLR periods might not have an overall economic benefit. Nevertheless, the time to failure variations observed were qualitatively relevant and a few conclusions could therefore be drawn from the results of this MEPDG analysis.

Firstly, it was found that the performance criteria providing us with the most information about the impact of load restrictions duration and scheduling on the pavement service life for both asphalt and gravel roads in Northern Ontario were surface roughness, rutting and longitudinal cracking. The IRI reached its associated critical threshold with up to two years variation depending on the loading scenario. Longitudinal cracking changed consistently on Northeastern Ontario asphalt roads with up to six years of service life gained with scenarios #10, #13 and #15 as per **Table 3**. Minimal differences were noted on gravel roads. This is not surprising though, as gravel road performance is difficult to model. Reflective cracking did not change regardless of the amount of load restrictions, or schedule. The duration of load restrictions was made to vary between one and five months in the analysis, which revealed the following:

- The greatest gain in pavement service life (based on IRI, rutting or longitudinal cracking) is obtained with either four or five month load restrictions. Therefore, the five-month SLR duration appears to have no benefit.

- For a four-month load restriction duration (scenarios # 9 and #13 as per **Table 3**), the March to June schedule is slightly more efficient than the February to May schedule.

- The three-month duration (scenarios #8, #12 and #15 as per **Table 3**) is roughly one percent less efficient than the four-month duration, and the March to May and April to June schedules are equivalent.

- The two-month duration (scenarios #7, #11, #14 and #16 as per **Table 3**) can be up to three percent less effective than the three-month duration in increasing the pavement service life, and the March to April and April to May schedule are the most significant contributors.

- The one-month SLR provides limited benefit. However, the analysis showed that load restrictions should imperatively be in place during April, as this month appears to be a major contributor to pavement preservation.

THE FROST DEPTH MODEL

The second part of this paper describes the results of the second phase of a two-year on-going study in Northern Ontario. It involved the installation and instrumentation of two experimental sites in Northeastern Ontario (New Liskeard, Highway 569) and in Northwestern Ontario (Thunder Bay, Highway 527). The purpose was to develop and calibrate a model that relates frost depth in the pavement of a low volume road located in Northern Ontario to the air temperature and pavement temperature on this site **[3]**. The calculation of the Freezing and Thawing Index developed in the preliminary study mentioned earlier is summarized in **Equations 1** and **2**. These indices are being used in the frost depth prediction models described later. Air and pavement temperature were retrieved from the online database of the Road Weather Information System (RWIS), which is a network of climatic stations that enable maintenance personnel to make maintenance decisions based on real time road data **[3]**. Environment Canada forecasts will be also used to predict pavement condition up to five days in advance, based on the five-day air and pavement temperature forecasts.

The Freezing Index (FI) is defined as follows **[3]**:

$$\begin{cases} FI_1 = -T_1 \\ FI_{i+1} = FI_i - T_{i+1} \\ FI_i < 0 \Rightarrow FI_i = 0 \end{cases} \tag{1}$$

Where

Where	i	Number of days after the first day of below 0°C air temperatures
	T_i	Noon air temperature on day number i (in °C)
	FI_i	Freezing Index on day number i.

The Thawing Index (TI) is defined as follows **[3]**:

$$\begin{cases} TI_1 = T_1 - T_{ref} \\ TI_{i+1} = TI_i + (T_{i+1} - T_{ref}) \\ TI_i < 0 \Rightarrow TI_i = 0 \end{cases} \tag{2}$$

Where	i	Number of days after the first day of below 0°C air temperatures
	T_i	Noon air temperature on day number i (in °C)
	TI_i	Thawing Index on day number i.
	T_{ref}	Calibration parameter

The reference temperature (T_{ref}) was obtained by relating daily air temperatures with the corresponding pavement surface temperatures **[3]**. It was found to be equal to minus 5.5923°C on the New Liskeard experimental site, and to minus 2.7073°C on the Thunder Bay experimental site. Based on the frost thickness model introduced during the preliminary study in 2005/2006, predictors for the lower and the upper fringe of frost were developed this year and are presented herein. So far, they have only been calibrated for the Northeastern Ontario region using the frost data collected on the New Liskeard experimental site from November 2005 to May 2006. In this section, the main calculation steps are summarized. No results will be presented concerning the Northwestern region, as no consistent amount of data could be collected this year. Instrumentation and hardware issues on the Highway 527 experimental site are being currently investigated.

In order to use the frost depth model, two major dates were identified. It should be noted that they are site-specific and that they are likely to change from one year to the other. The first period starts on the first day on which the average air temperature falls below zero degrees Celsius. It will be indexed as day i_0 and will trigger all the calculations (Freezing Index (FI), Thawing Index (TI), frost depths). In the year 2005/ 2006, on the Northeastern experimental site, this day corresponded to the 10th of November 2005. The transition from period A to period B (defined below) allows the thawing phenomenon to gradually overcome the freezing process. After day i_0, the calculation of frost depth changes from **Equation 3** (period A) to **Equation 4** (period B) and from **Equation 5** (period A) to **Equation 6** (period B). On **Figure 7** below, periods A and B are identified.

- Period (A): The moisture located in the pavement is freezing; the TI rises constantly. But as a result of a high number of freeze-thaw cycles in that region, designated as a low-freeze area, warmer periods cause the surface ice to thaw and the TI to display positive values. The combination of those two phenomenon illustrates **Equation 3** and **Equation 5** below. It can be noted that from Feb.8th, 2006 to March 8th, 2006, the pavement was freezing very rapidly and no warm days occurred after that; the TI stayed equal to zero.

- Period (B), starting from the day indexed as i_0: Beginning of the thawing season. The frozen layers of the pavement are thawing from the top-down but also from the bottom-up, what illustrates **Equation 4** and **Equation 6** below.

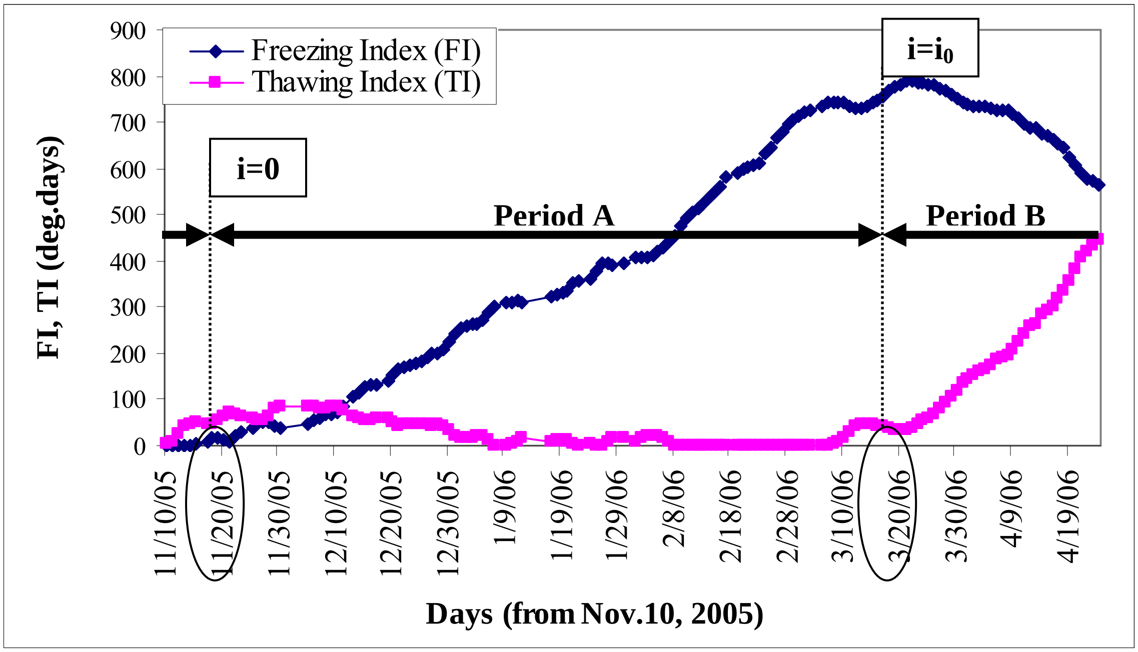

Figure 7 **Freezing and Thawing indices on the Northeastern experimental site (Highway 569), year 2005/2006.**

The calculation steps for the lower and upper depths of frost are summarized below:

Lower fringe of frost

During period (A) $LFFD_i = -5.537 * \sqrt{FI_i}$ **(3)**

During period (B) $LFFD_i = LFFD_{i_o} + 5.537 * \frac{1}{2}\sqrt{TI_i}$ **(4)**

Where	LFFDi	Lower Frost Fringe Depth for day i
	LFFDi$_0$	Lower Frost Fringe Depth for day i$_0$
	FI$_i$	Freezing Index for day i
	TI$_i$	Thawing Index for day i
	i	Number of days after day i$_0$
	i$_0$	First day after which the TI rises consistently above zero

Upper Fringe of Frost

During period (A) $UFFD_i = -5.537 * (\frac{1}{2}\sqrt{FI_i} - \sqrt{TI_i})$ **(5)**

During period (B) $UFFD_i = UFFD_{i0} - 5.537 * \frac{1}{2}\sqrt{TI_i}$ **(6)**

Where	UFFDi	Upper Frost Fringe Depth for day i
	UFFDi$_0$	Upper Frost Fringe Depth for day i$_0$
	FI$_i$	Freezing Index for day i
	TI$_i$	Thawing Index for day i
	i	Number of days after day i$_0$
	i$_0$	First day after which the TI rises consistently above zero

The depths of the upper or the lower frost fringe are negative numbers and their unit is the centimetre. If one depth value happens to be positive, it will be replaced by zero. Moreover, as soon as the lower depth of frost and the upper depth of frost meet (which means that there are no frozen layers within the pavement anymore) they will be equalled and they will remain constant. At the end of this paper, **Figure 8** shows that the upper and lower depths of frost calculated with this model are close to the values measured on the New Liskeard (Highway 569) experimental site. In general, the amount of frost predicted is less than the amount observed on-site, which is suitable since it will translate into more conservative loading recommendations.

The second season of data collection is being currently prepared. Experimental data will be used to determine the coefficients of calibration denoted “a” and “b” in **Equation 7** below and further validate the frost predictors for both Northeastern and Northwestern

Ontario sites. Therefore, future focus is to ensure that sensing, acquisition and logging of the subsurface pavement temperatures will be achieved properly and with as little disruption as possible.

$$FFD_i = -5.537 * (a\sqrt{FI_i} - b\sqrt{TI_i}) \quad \textbf{(7)}$$

Where FFD$_i$ is the Upper or the Lower Frost Fringe Depth for day i

SUMMARY AND CONCLUSIONS

The MEPDG analysis was directed at quantifying how pavement distresses were impacted by various loading scenarios. The findings are encouraging and indicate that the appropriate timings can result in up to six years additional life for the pavement. The proper selection of the PG binder is also very important. Although the MEPDG does need to undergo extensive calibration for Canadian conditions, the results presented do seem reasonable and provide valuable insight into the impact of traffic loading on a pavement structure weakened by environmental constraints.

To fulfill the ultimate objective of this project, which is to assist the Ministry of Transportation of Ontario in making effective real time Spring Load Restrictions and Winter Weight Premiums decisions using RWIS and Environment Canada data, pavement performance will have to be related as consistently as possible to the key climatic variables provided by neighboring weather stations. Ultimately, both RWIS and Environment Canada data will be used to estimate frost depths on Northern Ontario's low volume roads.

FUTURE STEPS

Based on the economic and structural performance criteria of the transportation agencies, frost depths thresholds will be developed and used to trigger the implementation of load restrictions or surpluses. For this purpose, historical deflection data will be supplemented by actual testing using a portable version of the Falling Weight Deflectometer (FWD) device (Dynatest Prima 100 Portable FWD). Deflection data will be collected throughout the upcoming thawing season, from the beginning of March 2007 to end of April 2007, and it will be used to correlate the pavement bearing capacity to the depth of frost in the soil. Critical frost depth thresholds with the associated pavement strength will be identified: The least acceptable strength threshold will trigger load restrictions; the least strength recovery threshold will allow the removal of weight restrictions and even the placement of load surpluses. Moreover, a life cycle cost analysis will be performed in order to find a consistent balance between the reduction of maintenance expenses and the increase of vehicle payload.

In the long term, this methodology could provide Northern Ontario's highway offices with an accurate means of predicting when to enforce or remove load restrictions on their roads. For each particular location, air and pavement temperatures will be determined by extrapolating from the nearest RWIS and Environment Canada stations and then used in the frost depth model to calculate and/or predict the on-site depths of the upper and lower fringes of frost. Safety margins will be determined based on an analysis of variance of the predicted data with actual conditions. The research team will continue to collect data to ensure the models can be calibrated and further validated in the future.

REFERENCES

[1] http://www.mto.gov.on.ca/english/trucks/loadnotice.pdf
Last accessed 03/12/2007.

[2] Reduced Load Periods. Highway Traffic Act, R.S.O. 1990, Chapter H.8, Section 122.

[3] Tighe et. al. Development of Tools for Improved Spring Load Restriction Policies in Ontario. University of Waterloo, Civil Engineering, 2006 Annual Conference of the Transportation Association of Canada, Charlottetown, Prince Edward Island, May 2006.

[4] www.ontariohighways.com
Last accessed 02/10/2007.

[5] G.J.Chong, G.A.Wrong, SP-025- Manual for Condition Rating of Gravel Surface Roads, Research Development Brand, Ontario Ministry of Transportation, August 1989.

[6] Applied Research Associates, Inc., ERES Consultants Division. Guide for Mechanistic Empirical Design of New and Rehabilitated Pavement Structures. NCRHP Project 1-37A. Washington, D.C., 2004.

[7] http://www.trb.org/mepdg/home.htm
Last accessed 03/28/2007.

[8] Research Result Digest 308. Changes to the Mechanistic-Empirical Pavement Design Guide Software through Version 0.900, July 2006. NCHRP, September 2006.

[9] Pavement Preservation with Thin Overlays. Better Roads, June 2003.

[10] http://www.raqsa.mto.gov.on.ca/techpubs/TrafficVolumes.nsf/tvweb
Last accessed 02/13/2007.

[11] Design of New and Reconstructed Flexible Pavements. Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Chapter 3. NCHRP 1-37A, March 2004.

[12] Low Volume Roads Design. Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Part 4, Chapter 4. NCHRP 1-37A, March 2004.

[13] Design Reliability. Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Appendix BB. NCHRP 1-37A, August 2002.

[14] http://www.fhwa.dot.gov/pavement/ltpp/pubs/06109/paper4.cfm
Last accessed 03/04/2007.

[15] http://www.fs.fed.us/eng/pubs/html/99771201/99771201.htm
Last accessed 03/04/2007.

[16] http://rwis.na.amec.com/rwisweb/
Last accessed 04/21/2007.

TABLES

Table 1 Baseline scenarios.

Typical Region	Northwestern		Northeastern	
Latitude	48°10’		49°20’	
Longitude	-80°00’		-89°00’	
Elevation	317 m		140 m	
Pavement type	Asphalt road	Gravel road	Asphalt road	Gravel road
Upper layer nature and thickness	Superpave PG 64-22	Crushed Gravel	Superpave PG 64-22	Crushed Gravel
	2.5 cm	2.5 cm	2.5 cm	2.5 cm
Base nature and thickness	Granular A-3	Crushed Gravel	Granular A-3	Crushed Gravel
	15.2 cm	15.2 cm	15.2 cm	15.2 cm
Subbase nature and thickness	Granular A-7-5	Granular A-7-5	Granular A-7-5	Granular A-7-5
	50.8 cm	50.8 cm	50.8 cm	50.8 cm
Subgrade nature and thickness	Clay	Clay	Clay	Clay
	Semi-infinite	Semi-infinite	Semi-infinite	Semi-infinite
Section ID	Highway 527, Tertiary Road 811		Highway 569, S JCT Highway 11	
2-way traffic **[10]**	200 AADTT		500 AADTT	
% Trucks	100			
Operational Speed	56.3 km/h			

Table 2 Analysis parameters used in MEPDG application (20-year design life).

Performance Criteria	Limit	**Reliability
*Terminal IRI (in m/km)	2.15	75%
Asphalt longitudinal cracking (in m/km)	189.4	75%
Asphalt reflective cracking (in %)	45	75%
Asphalt thermal cracking (in m/km)	18.94	75%
Total Rutting (permanent deformation) (in mm)	8.90	75%

* The initial IRI was set at 1.578 m/km.

** The reliability level of a given performance criteria is defined as the probability that this criteria is less than the critical level over the design life **[13]**.

Table 3 Spring Load Restriction (SLR) scenarios.

	No SLR	SLR in February	SLR in March	SLR in April	SLR in May	SLR in June
Scenario #1	√					
Scenario #2		√				
Scenario #3			√			
Scenario #4				√		
Scenario #5					√	
Scenario #6						√
Scenario #7		√	√			
Scenario #8		√	√	√		
Scenario #9		√	√	√	√	
Scenario #10		√	√	√	√	√
Scenario #11			√	√		
Scenario #12			√	√	√	
Scenario #13			√	√	√	√
Scenario #14				√	√	
Scenario #15				√	√	√
Scenario #16					√	√

Table 4 Years to reach performance limit for the four baseline sites.

Baseline sites	*NER AC road	*NWR AC road	*NER Gravel road	*NWR Gravel road
Years to reach the IRI performance limit	15.2	17.1	6.6	9.6
Years to reach the Longitudinal cracking performance limit	13.8	> 20	N/A	N/A
Years to reach the Reflective cracking performance limit	1.7	1.7	** Not Applicable	** Not Applicable
Years to reach the Transverse cracking performance limit	>20	>20	>20	>20
Years to reach the Total rutting performance limit	18.65	>20	0.62	0.83

* (as per **Table 1**) NER: Northeastern site; NWR: Northwestern site; AC: asphalt road.

** Reflective cracking is defined as cracking occurring in the Hot-Mix asphalt layer located below the asphalt overlay. Therefore, it is not defined on gravel roads, even if they have received an overlay.

FIGURES

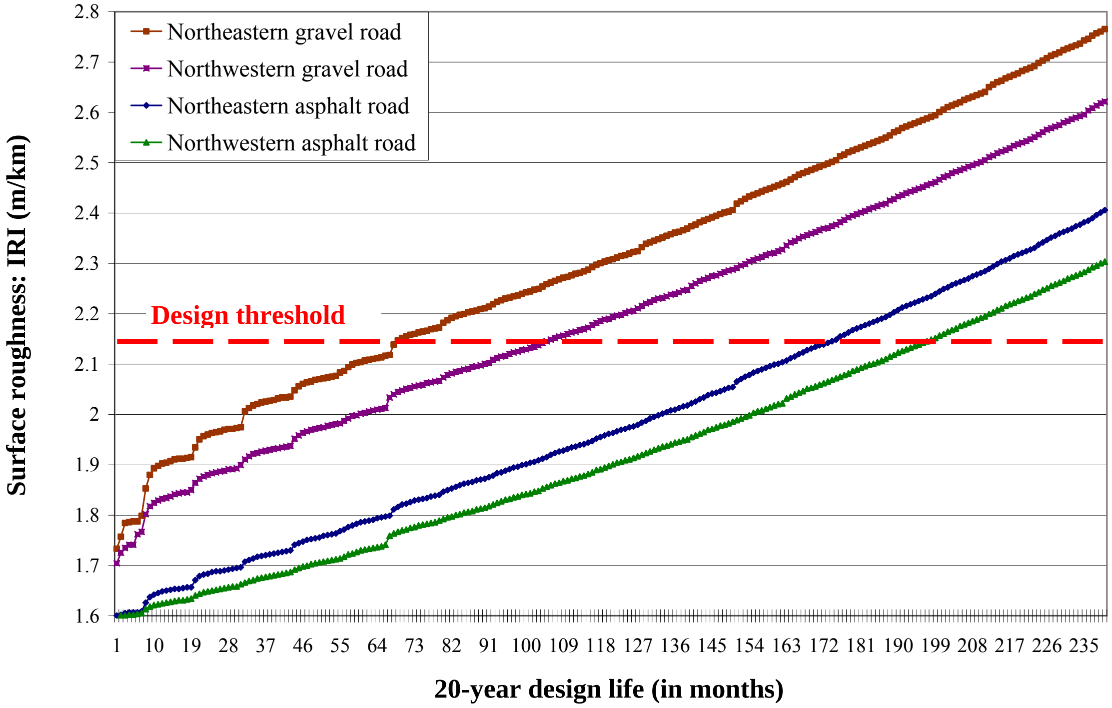

Figure 2 IRI changes over a 20-year design life ("no restrictions" scenario).

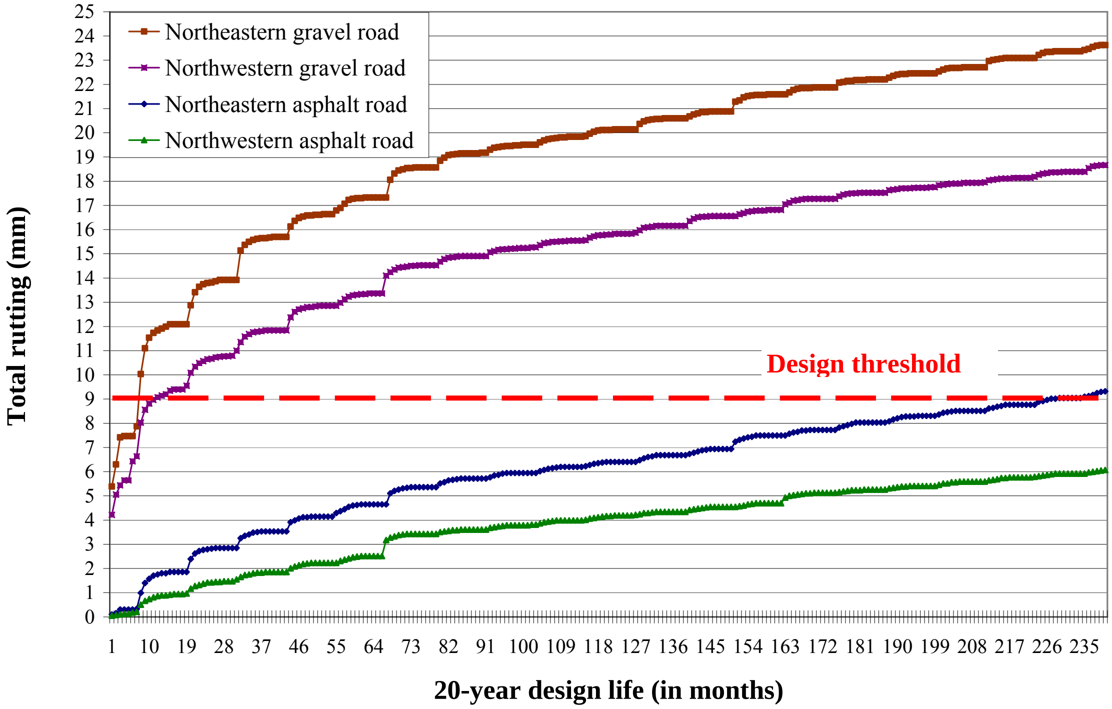

Figure 3 Rutting changes over a 20-year design life ("no restrictions" scenario).

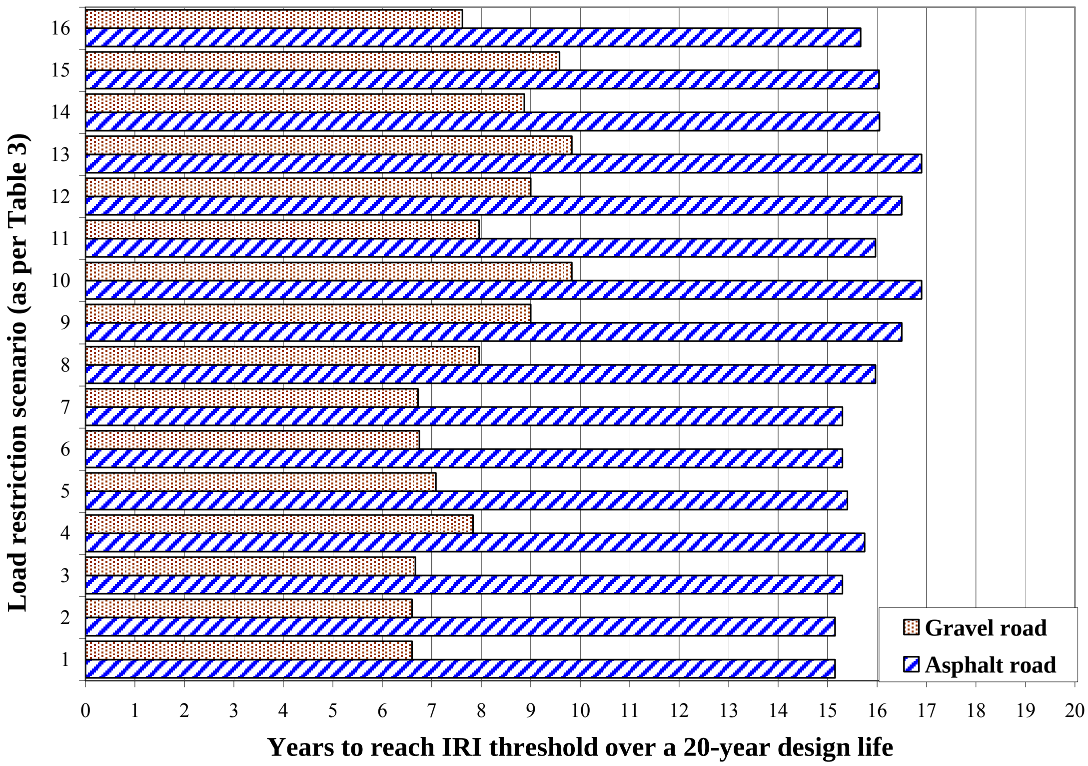

Figure 4 Lifetime (defined as the number of years to IRI failure) for the sixteen load restrictions scenarios (Northeastern region).

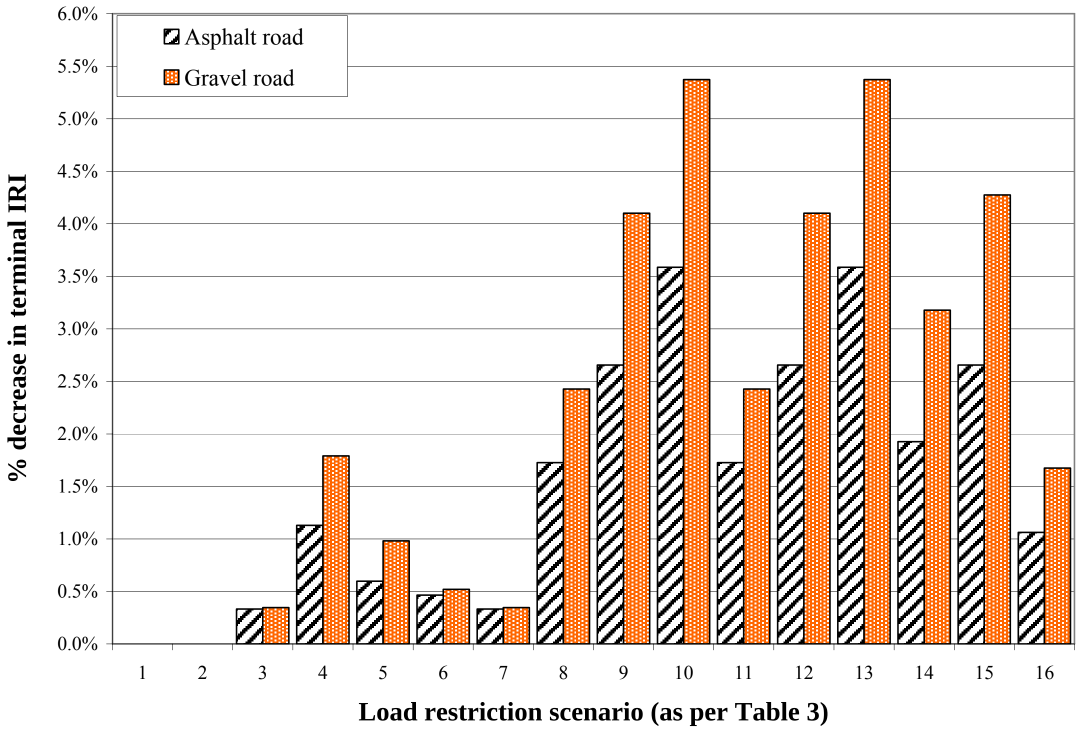

Figure 5 IRI changes over the sixteen scenarios (Northeastern region).

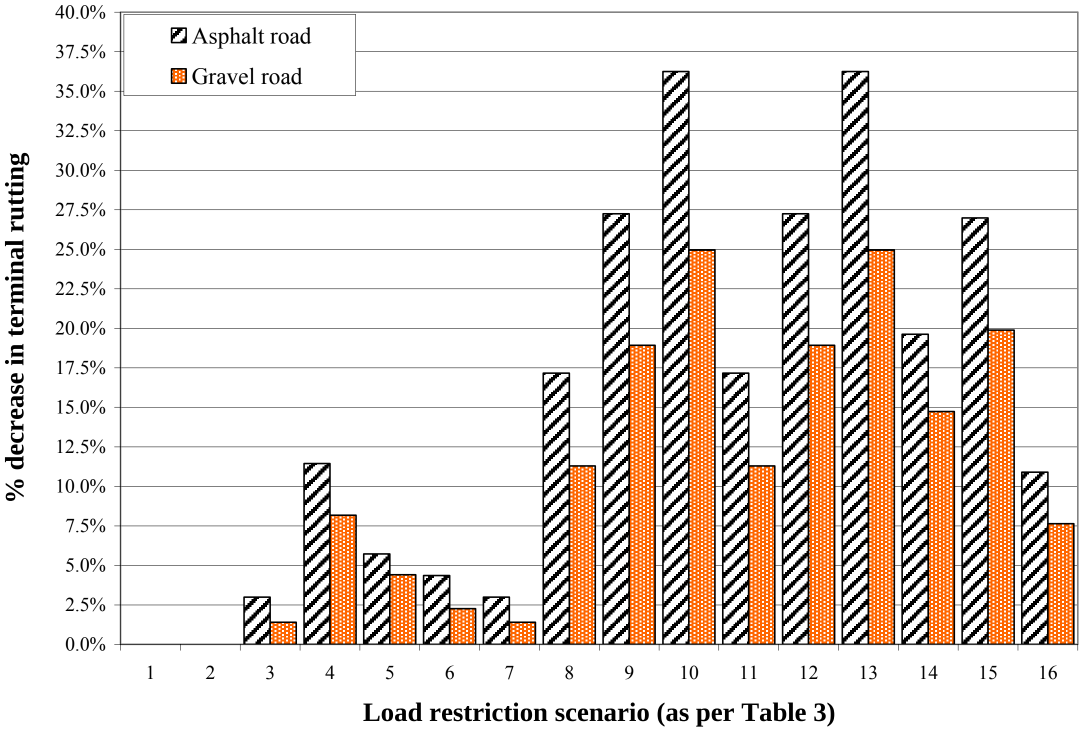

Figure 6 Total rutting changes over the sixteen scenarios (Northeastern region).

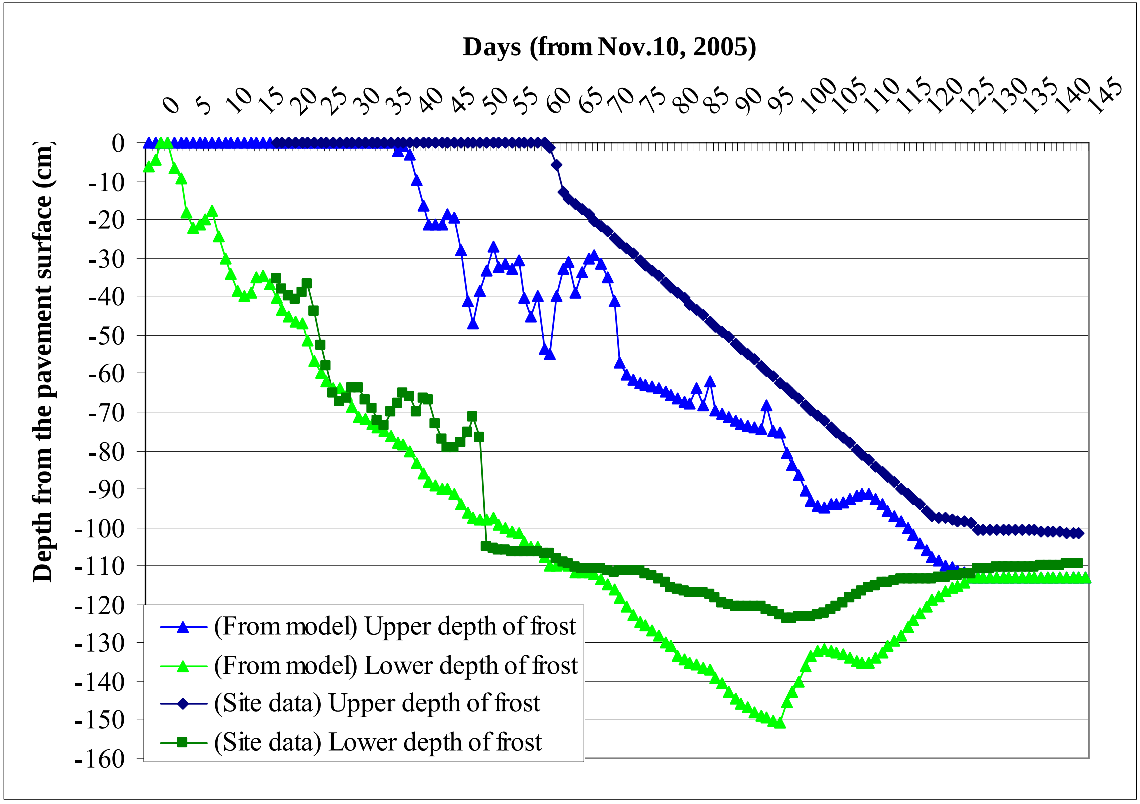

Figure 8 Comparison between the predicted and the on-site depths of frost (Northeastern Region, year 2005/2006).