MECHANISTIC-EMPIRICAL EVALUATION OF THE IMPACT OF SPRING LOAD RESTRICTIONS

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ABSTRACT

The majority of Canadian geography is in a wet-freeze environment. In winter, pavements and the underlying subgrade freezes. During the spring thaw, water in the pavement structure and subgrade reduces the stiffness (resilient modulus) of some of the pavement layers and in particular the subgrade. This reduces the overall structural capacity of the pavement. In order to "protect" the pavement from excessive damage, most agencies institute a spring load restriction. During this period, the axle loads are restricted to half or three quarter the loads permitted during other periods of the year. While this practice is intended to mitigate pavement damage the application and removal of load restrictions is not typically based on a technical analysis of pavement capacity but rather on "historical dates" and it is very disruptive to the trucking industry.

Over the past 10 years, Canadian highway and municipal agencies have been working on the implementation of mechanistic-empirical (M-E) designs for their roadway infrastructure. Many agencies are working on aspects of M-E design, focusing on particular aspects that have the most impact on their pavement design procedures working towards calibration of the M-E models and adoption M-E design procedures. Until recently, most Canadian roadway agencies have utilized the pavement design procedures established by the American Association of State Highway and Transportation Officials (AASHTO). The AASHTO design procedure is limited to only a few key parameters such as resilient modulus, equivalent single axle loads (ESALs), etc. The M-E design procedure is a much more robust in that it is capable of a more rigorous pavement design.

This paper uses an M-E analysis to determine the impact of load restrictions on pavement damage for typical municipal roadway pavement sections from Ontario. The cost of future pavement repairs as a result of the damage is compared to the cost of the trucking industry in terms of additional trips, reduced loads, etc. Recommendations are made for an M-E analysis methodology to assist roadway agencies to mitigate pavement damage while permitting efficiencies for the trucking industry.

INTRODUCTION

The premise behind spring load restrictions is that spring environmental conditions can cause softening of the roadway subgrade, reducing its resilient modulus and therefore its overall load carrying capacity. For flexible pavements, the reduction in subgrade strength can increase the amount of bending of the asphalt concrete layer resulting in an increase in fatigue type cracking. Choices to prevent damage include building the pavement thicker to be able to resist pavement damage during the spring or to post load restrictions to reduce the impact of vehicle loading during spring conditions. The posting and removal of load restrictions are typically set by date or in more sophisticated situations, by determining the condition state of the pavement layers and subgrade, i.e. frozen/unfrozen and degree of moisture saturation. The selection of the magnitude of load reduction is typically more conservative and not modified, i.e. half load restrictions. Other methods have been developed such as those that measure the potential impact and risk of opening a road after it has been flooded, e.g. Florida DOT or to determine the potential for pavement damage and reduction of remaining life due to shale gas extraction, e.g. Pennsylvania DOT.

The purpose of this paper is to assess the potential damage to municipal road pavements in Ontario for the currently required load restriction axle weight limits as well as the anticipated increase in pavement damage that would be experienced if the load limits were increased during the traditional spring load restriction timeframe. Finally, an alternative is presented which determines the reduction in road damage that would occur if the tire pressures were reduced using technology such as central tire inflation.

In order to make the assessment outlined above, the following steps were necessary:

1. Identify the appropriate heavy vehicle (truck) characteristics.
2. Evaluate the anticipated traffic levels.
3. Select a representative flexible pavement sections typical of a roadway that would be subject to load restrictions in Ontario including layer thicknesses, material types and characteristics and two subgrade soil types, i.e. low and high strength.
4. Analyze the impact of the load restricted and non-load restricted conditions on pavement damage over a 25-year design life.
5. Determine the impact on maintenance and future rehabilitation activities and costs for each scenario.

MECHANISTIC EMPIRICAL PAVEMENT DESIGN

The MEPDG is the pavement design guide developed for AASHTO under the U.S. National Cooperative Highway Research Program (NCHRP) Project 1-37A. The MEPDG uses mechanistic-empirical principles to predict the deterioration of pavements and their expected service lives. The design procedure is very comprehensive. It includes procedures for the analysis and design of new and rehabilitated rigid and flexible pavements, procedures for evaluating existing pavements, procedures for subdrainage design, recommendations on rehabilitation treatments and foundation improvements, and procedures for life cycle cost analysis.

The MEPDG uses state-of-the-practice mechanistic models to predict the accumulation of pavement distresses based on the traffic loads and the material properties. This process is repeated hundreds of thousands of times to account for all of the possible traffic load combinations and the changes in materials due to age and climatic conditions.
To ensure that the models closely represent the distress conditions of in-service pavements, the process was calibrated to match known performance information from the Long Term Pavement Performance study and other test tracks across North America. These comprehensive data sources have been used to perform an empirical calibration to the field conditions documented from over 20 years of detailed performance observations. The design procedures used in the Guide are based on mechanistic-empirical concepts, which are a quantum leap from the old AASHO Road Test empirical designs that are used by many Canadian transportation agencies.

Mechanistic-empirical design focuses on pavement performance and accounts for many factors that have not been well addressed previously. All of these new design inputs that directly affect pavement performance such as materials, climate, traffic loads and construction procedures are used to estimate the distress condition of the pavement over time (Figure 1). For flexible pavement, the MEPDG uses transfer functions to relate accumulated damage to the following pavement performance parameters: roughness (IRI), fatigue cracking, thermal cracking, and rutting. For rigid pavement, the MEPDG uses transfer functions to relate accumulated damage to the following pavement performance parameters: roughness (IRI), slab cracking, and faulting.

One of the other major advancements of the MEPDG and the accompanying software is the ability to establish local calibration of the models. Since there are many differences in both the climate and materials used by different agencies, there are many factors that are expected to contribute to the variability in the analysis. As a part of the implementation of the MEPDG by Canadian transportation agencies, local calibration efforts are being completed to both develop the appropriate inputs as well as to monitor the performance of their pavements. The list of design inputs and applicable values developed by the Ministry of Transportation of Ontario (MTO) for use in Ontario are discussed in this paper [1].

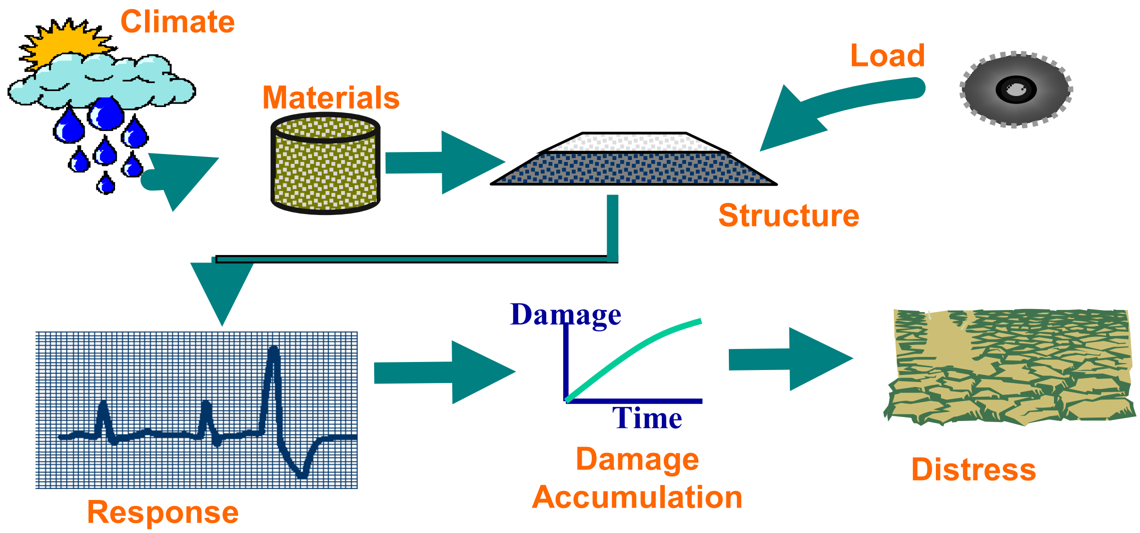


Figure 1. General Pavement Design Procedure and Analysis

The design inputs have been subdivided into categories for ease of implementation. The following inputs are used by the MEPDG to model the pavement performance:

- General Inputs
- General Information
- Site/Project Identification
- Analysis Parameters
- Traffic
- Traffic Volume Adjustment Factors
- Axle Load Distribution Factors
- General Traffic Inputs
- Climate
- Structure
- Drainage and Surface Properties
- Pavement Structural Layers
- Asphalt Concrete Layers
- Granular Layers
- Foundation/Subgrade
- Thermal Cracking
- Distress Potential

Traffic Information

The volume and composition of traffic has always been a major focus of pavement design due to the impact it has on determining the thickness of the pavement. Traffic has been traditionally described as the number of vehicles using the road in terms of the Average Annual Daily Traffic (AADT). In the 1993 AASHTO Design Guide [2], the traffic was described in terms of Equivalent Single Axle Loads (ESALs), which described the total damage caused by different vehicles in terms of the damage caused by 80 kN single axles.

The MEPDG takes a different approach to more accurately evaluate the damage caused by each axle load on a specific cross-section over the range of conditions it is expected to endure, commonly known as axle load spectra. To accomplish this, the MEPDG uses a large range of traffic parameters. This level of traffic detail is not commonly available for municipal roadways and some assumptions or regional defaults are necessary.

Traffic Volume

The most common traffic input is the number of vehicles expected to pass over a roadway during its design life. As the load applied by passenger vehicles is very low, the MEPDG does not consider them in the analysis. The number of load applications from trucks and buses is summarized using the Average Annual Daily Truck Traffic (AADTT). For the purpose of providing equivalent designs a range of AADTT values are used ranging from 250 to 10,000 trucks per day. These traffic levels represent collector, minor arterial and major arterial roadways.

For the purpose of analysis, it is assumed that half of the traffic travels are in each direction. For all the traffic levels, it is assumed that the traffic distributions is similar to collector roadways and are assumed to have only one lane in each direction. For traffic level 2500 to 10,000 AADTT, it is assumed to have two lanes in each direction, with 80 percent of the commercial vehicle traffic in the design lane. A compound growth rate of 2 percent was used to account for increases in vehicle volume over time.

Truck Type Distribution

The MEPDG uses a rigorous process to estimate the traffic loads on a roadway. To complete this part of the process, the traffic volume for each month, is divided into the 13 vehicle classes as established by the US Federal Highway Administration (FHWA). Light vehicles, class 1 through 3 (motorcycles and light passenger vehicles), are ignored with the remaining vehicle classes being the focus of the pavement structural design.

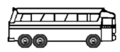
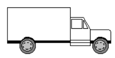
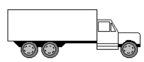
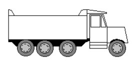
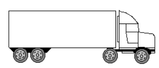
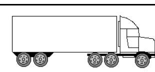
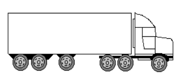
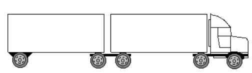
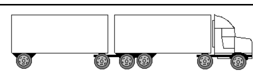
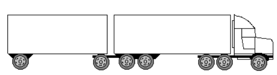
Truck traffic classification (TTC) 1 was used for the entire analysis for this paper. While conditions may vary locally, typical distributions being modelled in this paper are shown in Table 1.

The commercial vehicle distributions are used in conjunction with axle type and load distributions for Ontario. The default values for the following list of parameters were used to represent commercial vehicle characterization:

- Hourly vehicle distribution
- Monthly vehicle distribution
- Vehicle length and axle spacing

For the purpose of this analysis, March and April are considered to be spring months and the axle loads were conservatively estimated to be limited to 5,000 kg and 7,000 kg separately for the analysis.

Table 1. Commercial Vehicle Distribution

FHWA Class	Commercial Vehicle		Distribution of commercial Vehicles
4		Two or Three Axle Buses	1.3
5		Two-Axle, Six-Tire, Single Unit Trucks	8.5
6		Three-Axle Single Unit Trucks	2.8
7		Four or More Axle Single Unit Trucks	0.3
8		Four or Less Axle Single Trailer Trucks	7.6
9		Five-Axle Single Trailer Trucks	74
10		Six or More Axle Single Trailer Trucks	1.2
11		Five or Less Axle Multi-Trailer Trucks	3.4
12		Six-Axle Multi-Trailer Trucks	0.6
13		Seven or More Axle Multi-Trailer Trucks	0.3

Climate Conditions

A significant factor influencing the performance of pavements is climate. The climate conditions as represented by data from the Lester B. Pearson Airport in Toronto were selected for the analysis. Extreme temperatures located in other locations are often accounted for by adjusting materials such as the asphalt binder type, base and subbase. The annual climate statistics for Toronto are shown in
Table 2.

Table 2. Annual Climate Statistics of a Major Climate Region of Ontario - Toronto

Parameters	Toronto
Mean annual air temperature (°C)	9.4
Mean annual precipitation (mm)	735.6
Freezing index (°C - days)	774
Average annual number of freeze/thaw cycles	61.4

Pavement Materials

The other major advancement in using mechanistic pavement models is the ability to better describe the pavement materials and any changes in their behaviour throughout the year, and over their expected service life. With the climate data available, the effects of temperature on pavement materials can be accounted for, as well as the effects of drainage and freezing.

Hot Mix Asphalt

The Hot Mix Asphalt (HMA) used for municipal roadways in Ontario is primarily based on the MTO's Default Parameters for AASHTOWare Pavement ME Design. In this analysis, Superpave 12.5 mix is used as a surface course for collector and arterial roadways and Superpave 19 is used for the base course asphalt. The properties of the HMA materials used in the analysis are shown in Table 3

Table 3. Hot Mix Asphalt Properties

Property	**Superpave 12.5 (Surface Course)**	**Superpave 12.5 FC1 (Surface Course)**	**Superpave 12.5 FC2 (Surface Course)**	**Superpave 19 (Base Course)**
Asphalt Cement Type	PG 64-28	PG 64-28	PG 64-28	PG 58-28
Unit Weight	2,530 kg/m^3	2,530 kg/m^3	2,530 kg/m^3	2460 kg/m^3
Effective Binder Content (Percent by Volume)	11.8	11.8	11.8	11.2
Air Voids	4.0 %	4.0 %	4.0 %	4.0 %
Gradation passing 19 mm	100 %	100 %	100 %	96.9 %
Gradation passing 9.5 mm	83.2 %	83.2 %	83.2 %	72.5 %
Gradation passing 4.75 mm	54 %	54 %	54 %	52.8 %
Gradation Passing 75 µm	4 %	4 %	4 %	3.9 %

Granular Base and Subbase

The most commonly available aggregates used in pavement construction in Ontario consist of Granular A base and Granular B Type 1 subbase. Table 4 shows the typical properties for granular material in Ontario.

Table 4. Granular Base and Subbase Properties

Property	**Sieve Size**	**Granular A**	**Granular B-I**
Aggregate Gradation (percent passing)	75 µm	5	4
	300 mm	13.5	33.5
	1.18 mm	27.5	55
	4.75 mm	45	60
	9.5 mm	61.5	-
	13.2 mm	77.5	-
	19.0 mm	92.5	-

	25 mm	100	75
Liquid Limit		6	11
Plasticity Index		0	0
Modulus		250 MPa	150 MPa

Subgrade Materials

For all detailed pavement designs, geotechnical investigations are required to determine specific conditions for the purposes of providing support to the roadway as well as information on the constructability of the pavement. For this project, a more generic pavement design process was used to develop the pavement designs based on typical subgrade materials for Ontario. To characterize the sensitivity of this parameter and to describe the range of potential conditions across the province, the subgrade parameters shown in Table 5 were used in the analysis.

Table 5. Subgrade Properties

Soil Properties	**Low Plasticity Clay**	**Sandy Silt**
Subgrade Strength Category	Low	High
Representative Resilient Modulus (annual average)	30 MPa	50 MPa
Equivalent CBR	3	5
Soil Classification	CL	SM
Liquid Limit	26	18
Plasticity Index	12	4

Recommended Terminal Service Level

When designing a pavement, the performance criteria of terminal serviceability represents the lowest acceptable condition that will be tolerated before rehabilitation is required. The limits selected represent those typical for a municipality for an arterial roadway and are shown in Table 6. Traditionally, the performance parameters are set based on the importance of the roadway and other factors such as the design speed. The level of reliability is higher for higher trafficked roadways to reflect the importance of preventing premature failures.

Table 6. Design Performance Parameters

General Pavement Limits	
Initial Design Life	25 years
Design Reliability	80%
Flexible Pavement Terminal Serviceability Limits	
Fatigue (Alligator) Cracking	20 %
Thermal (Transverse) Cracking	190 m/km
Rutting	6 mm
International Roughness Index (IRI)	2.7 m/km

DEVELOPMENT OF PAVEMENT DESIGNS

In order to develop pavement designs, a defined process was used to assess the structural capacity of various trial cross-sections. Since the pavement designs were established for municipal pavements in the province of Ontario, the materials chosen as well as many of the design features were established based on current Ontario design standards and common practice [3].

The thickness of the granular and bound surface layers was the primary factor used to satisfy the design requirements. An initial design was selected based on typical municipal cross-sections and then evaluated within the MEPDG. For each trial section, the MEPDG analysis was completed and results were examined to determine when and how the pavement was expected to fail. The results were then used to modify the trial design to either address premature failure due to one or more of the distresses, or to prevent the over-design of a pavement. The cycle was repeated as necessary to obtain appropriate pavement cross-sections for all traffic and subgrade combinations.

The resulting pavement designs are shown in Table 7. These designs are considered to be typical for municipal pavements across the province of Ontario.

IMPACT OF SPRING LOAD RESTRICTIONS

The Ontario Highway Traffic Act states that:

> **116. (1)** *Subject to section 110, no vehicle or combination of vehicles shall be operated on a Class A Highway where the axle unit weight on an axle unit, whether or not part of any axle group, exceeds,*
> *(a) for a single axle with single tires, 9,000 kilograms;*
> *(b) for a single axle with dual tires, 10,000 kilograms;*

During reduced load periods, the maximum loads above are reduced as follows:

> *122. (1) Subject to section 110, during a reduced load period no commercial motor vehicle or trailer, other than a public vehicle or a vehicle referred to in subsection (2), shall be operated or drawn upon any designated highway where the weight upon an axle exceeds 5,000 kilograms. R.S.O. 1990, c. H.8, s. 122 (1).*

The enforcement of a 5,000 kg per axle limit during the spring months significantly reduces the load carrying capacity of trucks. Spring environmental conditions can cause softening of the roadway subgrade, reducing its resilient modulus and therefore its overall load carrying capacity. For flexible pavements, the reduction in subgrade strength can increase the amount of bending of the asphalt concrete layer resulting in an increase in fatigue type cracking.

Table 7. Pavement Designs Used for the Analysis

		Average Annual Daily Truck Traffic (AADTT) - 25 Year Pavement Design							
		250	500	1,000	1,500	2,500	5,000	7,500	10,000
Subgrade Strength	30 MPa (CBR=3)	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 90mm SP 19 150 mm Granular A 450mm Granular B	40 mm SP 12.5 100 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 110 mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 120 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 130 mm SP 19 150 mm Granular A 600 mm Granular B	40 mm SP 12.5 140 mm SP 19 150 mm Granular A 600 mm Granular B
Subgrade Strength	50 MPa (CBR=5)	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 80 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 90 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 100 mm SP 19 150 mm Granular A 300 mm Granular B	40 mm SP 12.5 110 mm SP 19 150 mm Granular A 350 mm Granular B	40 mm SP 12.5 120 mm SP 19 150 mm Granular A 400 mm Granular B	40 mm SP 12.5 130mm SP 19 150 mm Granular A 450 mm Granular B	40 mm SP 12.5 140 mm SP 19 150 mm Granular A 500 mm Granular B

Notes:

- All materials are based on current Ontario Specifications
    - Low Category (30 MPa) - Low Plasticity Clay Subgrade
    - High Category (50 MPa) – Sandy Silt Subgrade

While the complete removal of spring load restrictions is not considered reasonable, an analysis was completed to compare the damage in the pavement caused during spring by 5,000 kg and 7,000 kg axle loadings for low subgrade strength and high subgrade strength conditions. “Normal” axle loading was modeled for the months of January-February and May-December each year. Axle loads for all commercial vehicles traversing the roadway was limited to 5,000 kg for the months of March-April. While it is expected that not all axle loads would be as high as 5,000 kg, this assumption is considered to be conservative, i.e. over-predict the amount of fatigue cracking.

The fatigue cracking percentage expected at the end of the 25 year design life was calculated for each of the pavement structures and commercial vehicle loadings and subgrade strength values outlined in Table 7. The results of the analysis are provided in n Figure 2 for the low strength subgrade and Figure 3 for the high strength subgrade.

Table 8. Fatigue Cracking for Various AADTT

	Annual Average Daily Truck Traffic (AADTT)							
	Fatigue Cracking							
Traffic level	250	500	1000	1500	2500	5000	7500	10000
5000 kg (LS)	1.24	1.6	2.62	2.51	4.46	10.29	12.67	12.91
7000 kg (LS)	1.28	1.70	2.98	2.85	5.47	11.44	13.42	13.57
Delta (LS)	0.04	0.10	0.36	0.34	1.01	1.15	0.75	0.66
5000 kg (HS)	1.24	1.59	2.36	2.82	4.67	11.40	13.07	12.83
7000 kg (HS)	1.27	1.74	2.67	3.25	5.65	12.35	13.72	13.48
Delta (HS)	0.03	0.15	0.31	0.43	0.98	0.95	0.65	0.65
LS- Low subgrade strength								
HS- High subgrade strength								

The analysis shown is as expected for the difference in axle loads, traffic levels and subgrade conditions. The fatigue cracking percentage at the end of the 25 year pavement design life increases with traffic and axle loading. The rate of increase of fatigue cracking levels off or even reduces as the thickness of the asphalt concrete layer increases with increasing AADTT. This is due to the “beaming effect” of the thicker asphalt layers. As the thickness of the asphalt layer increases, the amount of horizontal tensile strain at the bottom of the asphalt layer (which causes fatigue cracking) decreases. This “inflection point” occurs at a lower traffic level for the higher strength subgrade. The percentages of fatigue cracking have slight differences between the low and high strength subgrade for the high traffic levels due to the rounding of the thickness of the granular subbase

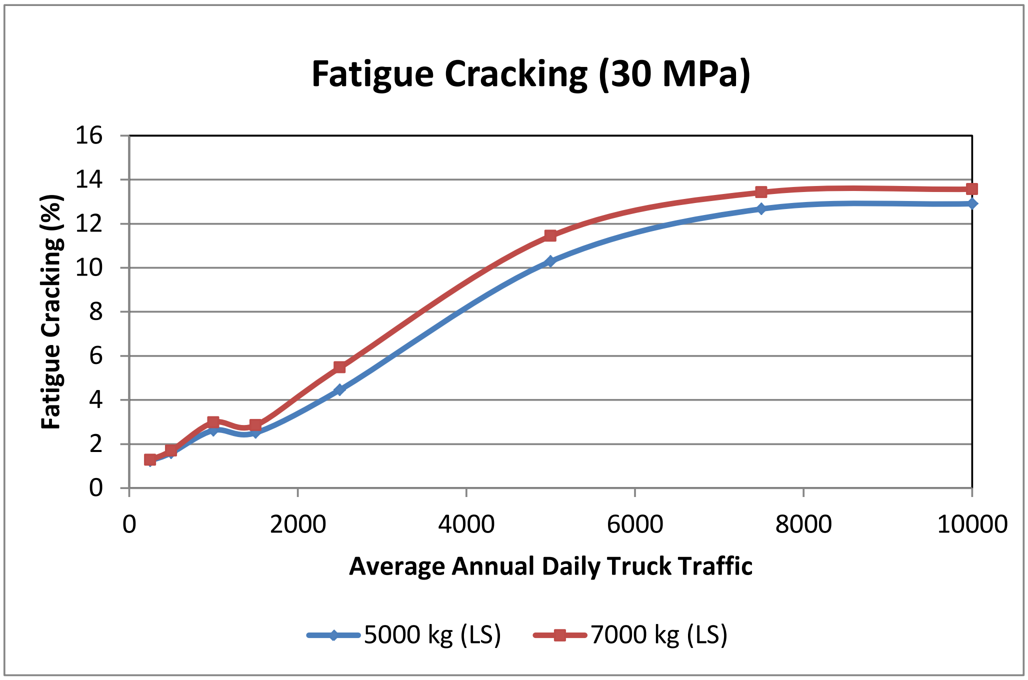


Figure 2. Predicted Fatigue Cracking for Low Strength Subgrade.

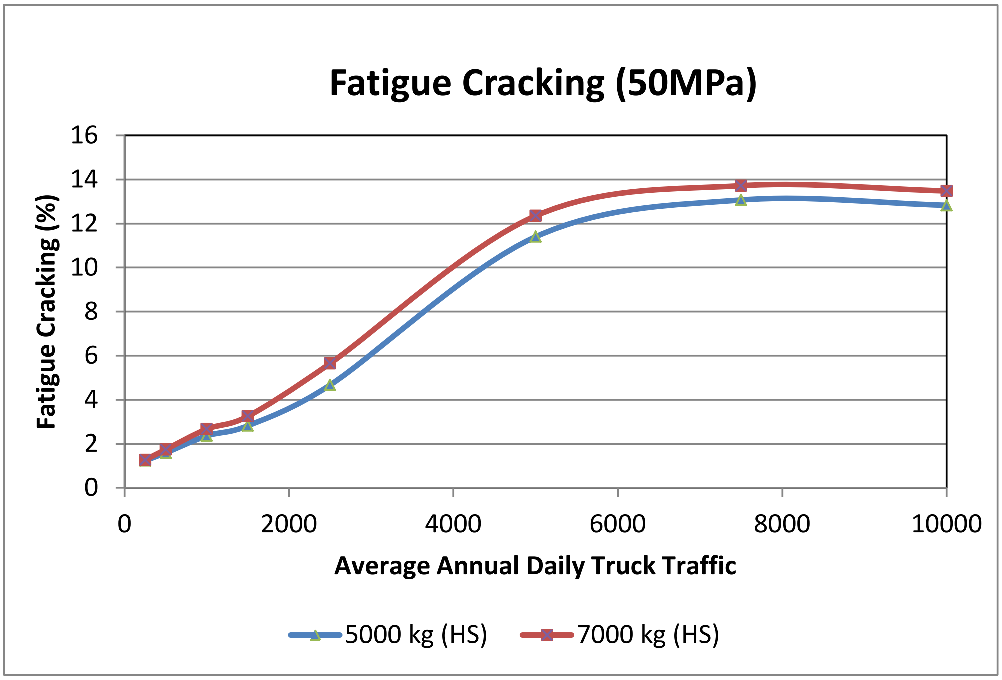


Figure 3. Predicted Fatigue Cracking for High Strength Subgrade.

COST ANALYSIS

In order to assess the impact of a potential change in the maximum allowable axle weights in the spring period from 5,000 to 7,000 kgs, an analysis of the difference in pavement maintenance cost for this change. From
Table 8, the increase in fatigue cracking for a pavement constructed to accommodate 5,000 AADTT is:

Fatigue for 7,000 kg axle load (11.44%) – Fatigue for 5,000 kg axle load (10.29%) = 1.2%

The typical maintenance action to address fatigue cracking varies from partial-depth removal (milling) and placement of new asphalt concrete layer(s) for low severity fatigue cracking to full-depth base repairs (removal of asphalt concrete and granular base/subbase) followed by placement of new materials. It is expected that an agency would prefer to complete the partial-depth repairs as they are less expensive and less intrusive in terms of traffic disruption. If we conservatively estimate the removal and replacement of all of the asphalt layers (160 mm) for the full-width of the paving lane (3.75 m) and a unit cost of $150/tonne of hot mix asphalt (including traffic control, sawcutting, tack coat, hot mix asphalt and placement), the increase in cost per lane kilometer due to the 7,000 kg axle loads versus 5,000 kg axle loads in the spring is:

0.012 (percent) x 0.160 m (asphalt thickness) x 3.75 m (lane width) x 1000 m (lane-km) x 2.450 tonnes/m^3 (unit weight of asphalt) x $150/tonne (unit cost) = $ 2,646/lane-km

This amounts to about $100 per lane-km per year. A similar analysis for a more moderate level of 1,000 AADTT (rural collector classification) would result in a per lane-km increase in maintenance cost of $645 or $26 per lane-km per year.

IMPACT OF REDUCED TIRE INFLATION PRESSURE

In order to determine if a reduction in tire pressure would reduce the amount of potential damage to the pavements, the analysis we repeated using a tire pressure of 550 kPa. The results of this analysis are presented in Table 9 and on Figures 4 and 5. From Table 9, it can be seen that the reduction in tire pressure can reduce the amount of predicted fatigue cracking from 8 to as high as 85 percent for the 2,500 AADTT pavement design over high strength subgrade. This would reduce the incremental damage of permitting a 7,000 kg axle load with 550 kPa tire pressure to only 7.09 percent which is less than the 10.29 percent that would have been expected under the restricted 5,000 kg axle load during the spring conditions, i.e. the reduced tire pressure as a greater impact on the reduction in pavement damage than the reduction in axle load.

Table 9. Fatigue Cracking Comparison for Reduced Tire Pressure

	Tire Pressure	Annual Average Daily Truck Traffic (AADTT)							
		Fatigue Cracking							
Traffic level		250	500	1000	1500	2500	5000	7500	10000
ESALs		1	2	5	7	12	23	35	47
5000 kg (LS)	825 kPa	1.24	1.60	2.62	2.51	4.46	10.29	12.67	12.91
5000 kg (LS)	550 kPa	1.15	1.38	1.70	1.89	2.61	5.84	8.85	9.55
% difference		-8	-16	-54	-33	-71	-76	-43	-35
7000 kg (LS)	825 kPa	1.28	1.70	2.98	2.85	5.47	11.44	13.42	13.57
7000 kg (LS)	550 kPa	1.17	1.43	1.79	2.02	2.99	7.09	10.22	10.74
% difference		-9	-19	-66	-41	-83	-61	-31	-26
5000 kg (HS)	825 kPa	1.24	1.59	2.36	2.82	4.67	11.40	13.07	12.83
5000 kg (HS)	550 kPa	1.15	1.40	1.78	2.00	2.68	7.02	9.56	9.49
% difference		-8	-14	-33	-41	-74	-62	-37	-35
7000 kg (HS)	825 kPa	1.27	1.74	2.67	3.25	5.65	12.35	13.72	13.48
7000 kg (HS)	550 kPa	1.17	1.45	1.90	2.16	3.06	8.26	10.75	10.58
% difference		-9	-20	-41	-50	-85	-50	-28	-27
LS- Low subgrade strength									
HS- High subgrade strength									

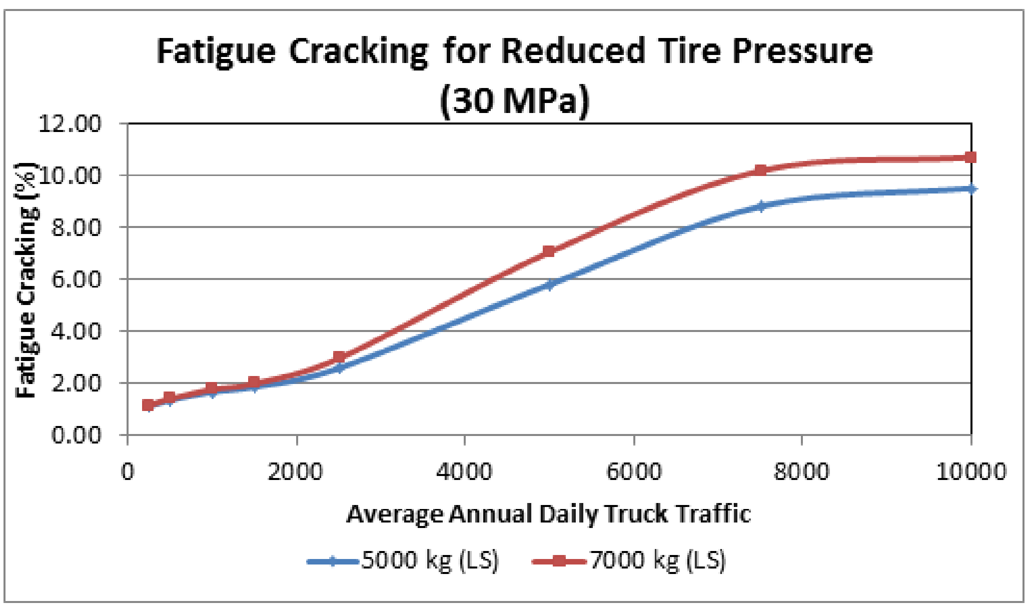


Figure 4. Predicted Fatigue Cracking for Low Strength Subgrade.

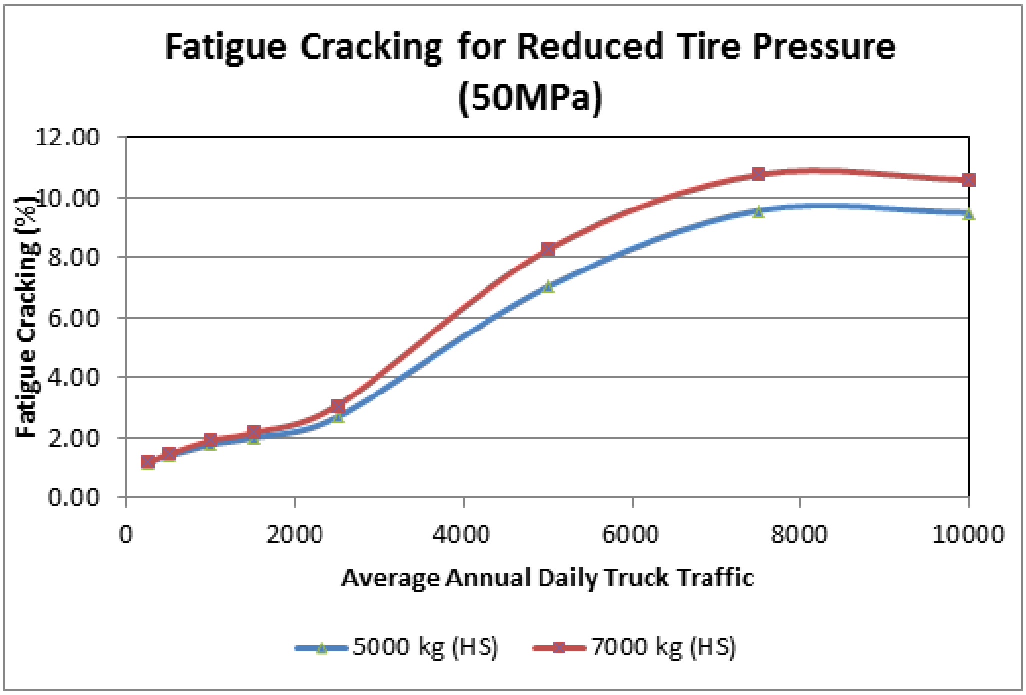


Figure 5. Predicted Fatigue Cracking for High Strength Subgrade.

CONCLUSIONS

The results of the analyses presented in this paper permits an agency to determine the impact of both reduced axle loads and tire pressure on the amount of fatigue cracking expected to occur for municipal pavements over a 25 year design period. The analysis shows that the incremental damage in permitting higher axle loads in the spring is relatively small for relatively low traffic levels as well as relatively high traffic levels. For higher traffic level pavements, the thickness of the asphalt concrete layer is fairly high which permits a beaming effect to distribute loads over the underlying pavement layers and subgrade resulting in less fatigue damage. The cost analysis permits the evaluation of future maintenance costs due to "relaxation" of spring load restrictions which may provide an alternative consideration to permit higher load limits in areas where spring load restrictions may provide significant economic hardship for the trucking industry.

1. References

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