Using LTPP Data to Develop Spring Load Restrictions: A Pilot Study

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ABSTRACT
In northern parts of North America, the road network is weakened and extensively damaged by the seasonal loading. The yearly cycle of above and below freezing temperatures causes cycles of freezing and thawing of the groundwater underneath the pavement. As the groundwater freezes, the pavement undergoes uplift, while as the temperature rises to above freezing, the frozen ground thaws. As the pavement thaws from the surface down, the soil eventually becomes saturated as the water becomes trapped between the pavement surface and the frozen soil. The pavement is in a weakened state during this saturated period, which can last up to several weeks every year. Most authorities have opted to impose load restrictions on vehicles during this thawing period. Yet, since the pavement temperature tends to lag behind the air temperature, it is difficult to determine the exact time duration that the pavement is in this weakened state. An accurate time for imposing the load restriction is required since delayed restrictions will cause pavement damage, whereas premature load restrictions will cause undue economic hardship on industries that require transportation of their goods. A promising and convenient method is the thawing index method developed by the Minnesota Road Research Section. This paper will investigate ways to improve the determination of the start of load restrictions based on weather information, and the possibility of adopting it for use in Ontario.

INTRODUCTION
In Canada and northern parts of the United States, temperatures typically reach the high twenties in the summer, and drop to the negative twenties or thirties in the winter, which can last up to three or four months. During this yearly seasonal change, the pavements in these regions also undergo a cyclic change in the form of freeze-thaw of the sub-surface soils. When the soil freezes, it occurs from the surface down, while in the spring time, as the temperature rises, the soil thaws from the surface down. As thawing takes place on the surface, the water gets trapped between the road surface and the frozen soil, resulting in a weakened base. Therefore, these pavements are susceptible to damage by heavily-loaded vehicles. It has been found that the pavement maintenance cost alone due to this freeze-thaw cycle and the subsequent heavy loading has been estimated to be in excess of 2 billion dollars per year (*1*). The solution that most authorities have come up with is to impose load restrictions during the spring time. The beginning date and duration of these load restrictions are based either on historical weather data, where the air temperature is used to predict when the pavement is weakest. However, these predictions may not accurately predict the exact time that the pavement is in a weakened state, and prolonged restrictions will cause undue

economic hardship on the industries that need to transport their products on the road system.

FROST HEAVE THEORY

As the temperature drops to below freezing, the water within the soil freezes and expands by as much as nine percent in volume (*2*). As the soil freezes on the surface, capillary forces draw more moisture from the soil underneath the frozen soil, and the additional moisture also freezes and expands. This movement of moisture from the unfrozen zone to the frozen zone and the resulting volumetric expansion is called *frost heave*. As the temperature increases in spring, thawing begins from the top, and the water is trapped between the pavement surface and the frozen soil. The result is that the soil becomes saturated, which decreases the bearing capacity of the soil. It has been found that spring thaw can reduce the bearing capacity of paved roads on top of frost susceptible soil by 50% or more, or for gravel-surfaced roads on frost susceptible soil, a reduction of more than 70% is possible (*3*).

The type of soil within the pavement structure is an important factor that will determine the amount of frost that is possible. Due to the small diameter and plate-like shape of the particles, clays have a large surface area to mass ratio, which provides a greater opportunity for water molecules to attach to the clay particles. As a result, clays are capable of absorbing quantities of water that several times their dry weight, and as the moisture content rises the engineering properties will change. Generally, as the moisture content of clays rises, the strength of the clay will decrease. Although clays are capable of absorbing and drawing water through capillary action, it has a low hydraulic conductivity, which makes it difficult for clays to transport large amounts of water. As a result, clays are only capable of a limited amount of frost heave. On the other extreme, clean sands and gravel have a much lower surface to mass ratio, thereby making any changes in the moisture content to cause only a very small effect on the engineering properties. Also, only a very limited amount of capillary rise is possible for clean sands and gravel, therefore frost heave will not be a problem for these materials. However, frost heave will be a concern for intermediate soils such as silts and fine sands as these materials are capable of substantial capillary rise and have a high hydraulic conductivity (*4*).

Temperature is another important factor affecting the amount of frost formation underneath the pavement structure. However, the air temperature is different from the temperature beneath the ground due to conductive and convective heat transfer. It has been found that the air temperature follows a sinusoidal function with the following equation (*2*):

$$T = T_{avg} - A_T \sin 2\pi ft \quad (1)$$

where T is the temperature, T_{avg} is the mean annual temperature, A_T is the sinusoidal amplitude, f is the frequency (1/365 cycles per day), and t is time (*2*). Figure 1 (*5*) is a plot of the daily average temperature, and the sinusoidal curve fit, for North Bay, Ontario, Canada from 2001 to 2002.

The temperature changes in the ground will lag behind changes in the air temperature, and the surface temperature is usually warmer than the air in the summer and colder in the winter for pavements in cold regions (*2*). There have been numerous methods formulated to predict the rate of freeze and thaw and the temperature change beneath the pavement structure. These range from relatively simple analytical methods such as the Berggren formula, to more sophisticated numerical methods using thermal conduction theories, to even more sophisticated procedures using finite element analysis. All these methods have inherent assumptions and, therefore, limitations to their use.

Frost heave is a complicated process, but simply stated, frost heave is caused by in-situ pore water being drawn from the unfrozen soil to the freezing front where ice crystals are formed. Frost heave then occurs as these ice crystals are formed and expands in volume. The rate of frost heaving is dependent on the rate of temperature drop in the soil, the rate of water flow towards the frozen area, and the compressibility of the unfrozen soil (*2*). These factors are themselves dependent on temperature of the air, the degree of saturation, and the effective stress or overburden. Numerous theories have been proposed to address the mechanics of frost heave, and these theories can be divided into three categories: capillary rise theory; secondary heave theory; and segregation potential theory (*6, 7*). Although several methods of predicting the rate of frost heaving have been proposed, there are many simplifying assumptions behind them, thus making some of these theories unrealistic, or unpractical to use in the real world.

LOAD RESTRICTION PRACTICES

In Northern climates, the amount of environmental load such as temperature-induced concrete expansion and contraction, frost action, and the amount of precipitation, that a pavement will experience needs to be considered during pavement the design phase. Some of the factors that should be considered when a section is designed for freeze-thaw include: the depth of frost line; amount of frost heave, and the resulting damage; and deformation and consolidation due to thaw. It has been found that by using coarser grained soils, moisture migration, which causes frost heaving and the resulting thaw weakening, can be eliminated (*8*). Other methods, such as installing drains and the use of geotextiles, have been proven to be effective means of protecting the soil against freezing or strengthening the soil (*8*). However, designing the pavement so that it is safe to use by all types of traffic all year round is extremely expensive and unrealistic. Therefore, another measure that authorities have implemented in conjunction with designing non-frost susceptible pavement is to impose load restrictions on certain roads. In the United States, more than 20 states have implemented spring load restrictions, while all the provinces in Canada are subject to spring load restrictions (Table 1). Both countries limit the weight that each axle can apply to the pavement, while for certain countries such as France and Finland, the restriction is based on the total weight of the vehicle.

As can be seen from Table 1, the decision to impose or lift the load restriction is mainly based on field measurements or from historical data. One of the measuring devices, the frost tubes, uses thin transparent tubes filled with a blue water-methelyne solution, or other types of fluid, to measure the depth of frost underneath the pavement. These frost probes are usually installed at the center of the lane, and for the methelyne solution, it turns clear when it freezes, thus indicating the frost depth. The Falling Weight Deflectometer, Dynaflect, and Benkelman Beam are also used in certain provinces to measure the strength of the pavement during spring thaw. Models have also been generated to predict the period when the pavement's strength is weakest. These models are created from the historical data for the road conditions and weather patterns.

The methods used to predict the commencement of thaw as summarized in Table 1 lack a convenient method which uses readily available data, such as weather data collected by Environment Canada or local airports.

Some authorities in the United States have implemented the use of the concepts "freeze index" and "thaw index", which are measures of the duration of below and above-freezing temperatures. Studies performed at the Washington DOT have resulted in the following findings: a relationship between the duration of thaw and the freeze index; and that the duration of the thaw period could be estimated based on the date when a particular level of thaw index is surpassed, which is also based on the freeze index (*9*).

The Minnesota DOT also derived relationships to predict the duration of thaw. Specifically, a relationship was determined to relate the duration of thaw with the freeze index and frost depth. It could be reasonably assumed that the depth of frost is a function of the temperature or the freeze index, therefore a relationship was derived to predict the frost depth using the freeze index (*10*), thereby simplifying the frost depth relationship to a function of freeze index only.

The South Dakota DOT utilizes the thaw index and freeze index in an alternate method to calculate the commencement and duration of spring load restrictions. Instead of varying the thaw index equation, as is the case for Minnesota, the South Dakota DOT varies the threshold, or critical, thaw index. A relationship was determined between the threshold thaw index and the amount of precipitation from August to November of the previous year. Load restrictions are then lifted when the thaw index has reached a certain percentage of the maximum freeze index, where the percentage is once again based on the amount of precipitation from August to November of the previous year. Table 1 (*11*) is a summary of the trigger values for the thaw index and for the removal of load restrictions based on the amount of precipitation.

Although the South Dakota DOT and the Minnesota DOT might seem to use different methods to predict the onset of thaw, the methods used by these two agencies are actually quite similar. The amount of precipitation is an indirect method of measuring the degree of saturation of the soil, which will have an effect on the frost depth. Therefore, the method used by the South Dakota DOT and the relationship between the duration of thaw and freeze index as developed by the Minnesota DOT is based on the same criteria, which is the degree of saturation of the soil.

The work in this paper will focus on ways to improve the current spring load restriction practices in Ontario, Canada by using LTPP and temperature data and the method involving the thaw index.

THAW INDEX

Thaw weakening is a complex process, and the factors that must be considered in order to quantify the amount of damage, other than using direct measurements, include: the amount of frost heave occurring per unit thickness in the layer; the thawing rate of the layer; and the consolidation rate of the layer (*8*). A thaw-weakening index (TWin) has been developed that can be related to the ratio of the difference in deflection measurements between summer and spring, thus giving an indication of the loss in bearing capacity (*12*). The TWin takes into account the amount of frost heave, the thickness of the frozen soil layer, the thawing rate, and the settlement rate.

The TWin can be used as a characterization procedure to measure the susceptibility of a soil to frost damage. Generally speaking, the greater the content of fine particles in the soil, the higher the TWin value, which means the soil is more susceptible to frost damage (*12*). Although the TWin is a good measure of frost damage of a certain pavement section based on the soil type and the climatic conditions, it is only a measure of the total loss of strength of the pavement during the weakest moment, and is unable to approximate the loss at specific time periods.

The freeze index (FI) is an indication of the combination of freezing temperatures and the duration of freeze. The freeze index is the area below the 0 ^{o}C line and the temperature curve in Figure 1. The thawing index (TI) is used by the state of Minnesota to set their spring load restriction, and it indicates the progression of thaw in the pavement and the beginning of weakening and the eventual damage. The thawing index is the area above the 0 ^{o}C line and the temperature curve in Figure 1. The freeze and thaw indices can also be calculated using the cumulative degree-day plot similar to the one on Figure 2.

The freeze index can be calculated using the following equation:

$$FI = \Sigma\ (0\ ^{o}C - \text{Average Daily Temperature}) \quad (2)$$

The freeze index begins to accumulate on the first day when the average daily temperature drops below 0 ^{o}C. The freeze index will increase whenever the average daily temperature is below zero, and will decrease when it is above zero. However, the freeze index itself is not permitted to drop below zero.

The thawing index adopted by the state of Minnesota uses a reference temperature and is calculated using the following equation:

$$TI = \Sigma\ (\text{Average Daily Temperature} - \text{Reference Temperature}) \quad (3)$$

The Minnesota Road Research Facility (Mn/Road) used falling weight deflectometer (FWD) measurements and found that deflections increased dramatically when the thawing index reached 15 to 30 ^{o}C-days (*13*), which indicated the start of thaw season. This critical period generally occurred in late February or early March, where temperatures were generally between -1.6 and -1.1 ^{o}C. Therefore, the reference temperature as used by the state of Minnesota was -1.7 ^{o}C and restrictions are placed once the thawing index reaches 15 ^{o}C-days, and lasts for 8 weeks. However, further research indicated a more accurate way of determining the beginning of thaw with a revised reference temperature and threshold thaw index. The beginning of thaw was determined to occur when the thaw index reached 12 ^{o}C-days (*9*), and the reference temperature was determined to vary linearly from -1.7 ^{o}C on February 1 to -4.4 ^{o}C on March 15 (*3*). The freeze and thaw indices will begin to accumulate when the average temperature falls below the reference temperature.

Numerous methods have been proposed to describe the freeze-thaw cycle. Figure 3 is a summary of the different theories and indexes mentioned in the previous sections, and how they are interrelated.

Adoption of the Thaw Index for Ontario

The thaw index is a very simple and straight forward method of predicting the onset of spring thaw using air temperature, and can be adopted for use in Ontario determining the reference temperature and the critical cumulative degree-days. Air temperature data and the asphalt temperature data was obtained from the Long Term Pavement Performance (LTPP) program for six pavement sections in Ontario: 87-1620, 87-1622, 87-1680, 87-1806, 87-2811, 87-2812. Section 87-1622 is in Northern Ontario and is located on Highway 11 near Bracebridge, Ontario. Section 87-1620 is on Highway 400 west of Orillia, Ontario, while 87-1680 and 87-1806 are on Highway 404 in Stouffville, Ontario, and 87-2811 and 87-2812 are on Highway 402 west of London. The location for the latter five sections can be considered to be located in southern Ontario. To determine a thaw index equation suitable for Ontario, the first step would be to determine the reference temperature by the asphalt and air temperature database. When the reference temperature has been established, the thaw index can be calculated throughout the year, and the threshold thaw index can be determined.

Pavement performance data from the LTPP program, namely pavement and air temperatures, were used in this analysis. It is noteworthy that the frequency of data collection in the LTPP database is dependent on the type of data. For example, the FWD data for the sections that were used in this paper were collected once or twice every two years. The data that were used in this paper has been collected since 1990, and comes from the General Pavement Study (GPS) sections located in Ontario, Canada. In addition to the deflection data that was selected, air temperature data and pavement temperature data were needed to find a correlation between the different variables. As a result, air temperature data and pavement temperature data were also obtained for the GPS in Ontario. The air temperature data were collected daily, and for some locations, data were available for as far back as 1978. Although the pavement temperature data was not collected as frequently as the air temperature data, the dates suggest that the pavement temperature data were collected along with the FWD data, and that there were enough information to perform the analysis (*5*).

The average daily temperature was plotted against the asphalt temperature underneath the asphalt surface, and a horizontal intercept of -3.4 ^{o}C was found using linear regression analysis (Figure 4). This intercept indicates that, on average, the temperature underneath the asphalt layer is 0 ^{o}C when the air temperature is -3.4 ^{o}C, which is very similar to the -4 ^{o}C that was calculated by Mn/Road for the state of Minnesota (*9*). Since thawing begins when the temperature reaches 0 ^{o}C, the thawing of the layers beneath the asphalt actually begins when the air temperature is -3.4 ^{o}C, which will also be used as the reference temperature for the thaw index equation.

The asphalt temperatures were then plotted against the cumulated thawing index, relative to -3.4 ^{o}C (Figure 5). The thaw index is calculated at the beginning of the freezing season, which begins when the freeze index remains above 0 for the rest of the winter. Therefore, the index will grow when the temperature is greater than the reference temperature of -3.4 ^{o}C, and will fall when it is lower. Although the thaw index is allowed to fall, it is not permitted to fall below 0 ^{o}C. The data indicates a parabolic curve fit, with a negative horizontal intercept, meaning that the asphalt will reach 0 ^{o}C and start to thaw even before the accumulation TI, or when it is still in the freezing season. This result is counterintuitive since it would be expected that thaw will begin only after the air temperature has reached above zero for a period of time.

Although the threshold thaw index given by Figure 5 appears to be incorrect, the general fit of the data is expected, since the thaw index begins every year at the start of freeze season, which is generally in mid to late November. Therefore, the asphalt will have a similar temperature in April and October, and hence the parabolic curve. Since studies at the Minnesota DOT indicates that the threshold thaw index will occur within the first 20 ^{o}C-days, the data for Ontario was re-analyzed for the first 100 ^{o}C-days, which will generally occur in late March to early April. The plot is shown in Figure 6.

Figure 6 shows that the asphalt will reach a temperature of 0 ^{o}C, and will begin to thaw at a thaw index of 12.7 ^{o}C-days. Therefore, the threshold thaw index of 13 ^{o}C-days can be used to calculate the start of the thawing season and load restrictions. The calculated threshold temperature of 13 ^{o}C-days is also very similar to the threshold temperature of 12 ^{o}C-days that is currently being used by the state of Minnesota (*9*).

However, it should be noted that the asphalt temperature data in the LTPP database is not measured on a continuous basis, and at most, only several measurements were made in any given month. The data plotted in Figures 4 and 5 are taken from 1990 until 1996, and only mainly for locations in southern Ontario. All of the pavement temperature data taken from southern Ontario are in the months between April to September, therefore, it does not include any pavement temperature data in the freezing season. As a result, the data points in Figure 6 include only the temperature data for the site location 1622 in northern Ontario.

IMPLEMENTATION

The thaw index method of the state of Minnesota for determining the beginning of the thaw season can be adopted for use in Ontario using a reference temperature of -3.4 ^{o}C. The equation for the thaw index then becomes:

$$TI = \Sigma \text{ (Average Daily Temperature + 3.4)} \qquad (4)$$

Load restrictions should be placed when the thaw index reaches 13 ^{o}C-days.

The calculation of the thaw index has a variable start date, which is the first day in fall or winter when the temperature drops below 0 ^{o}C. This start date was set so that the freeze and thaw indices would begin on the same day. In reality, the thaw index does not start to accumulate until the average daily temperature rises to above -3.4 ^{o}C. As a result, a more realistic start date could be set to reflect when the thaw index truly starts to accumulate. However, a single start date for the entire province of Ontario would be misleading since Ontario experiences such a wide spectrum and range of climatic conditions and temperatures. Figure 7 is a plot of the average daily temperatures for Toronto and North Bay, Ontario from January to April, 1996 (*14*). There is an obvious difference in the temperature for the two cities. North Bay, which can be considered to be located in the northern part Ontario, is approximately 350 km north of Toronto, which is in the southern part of Ontario. Figure 7 shows that on any given day, the temperature difference between the two cities can be between three to seven degrees celcius, while the lag in the degree day can be as high as 15 to 30 days. Clearly, a distinction in the start dates for the northern and southern parts of Ontario is required.

The LTPP air temperature data for the six sites in Ontario were separated into northern and southern regions and analyzed to determine the beginning dates for thaw index calculation based on the reference temperature of -3.4 ^{o}C. Specifically, section 1622 is in northern Ontario, while sections 1620, 1680, 1806, 2811, and 2812 are in southern Ontario. However, since the LTPP air temperature data for section 1622 contained only ten years of data, more data points are warranted. Therefore, temperature data obtained from Environment Canada for North Bay and Timmins, Ontario were used to supplement the data for northern Ontario (*14*). Figure 8 is a frequency plot of the beginning thaw dates for northern and southern Ontario.

The frequency plots show that historically, based on a reference temperature of -3.4 ^{o}C, there is a clear difference in the dates when thaw-index calculation could began. For southern Ontario, the earliest date was February 2, while for northern Ontario, the earliest was March 11. Although the frequency plot for southern Ontario would show that the historical start date peaked at February 14, a start date of February 1 would be more convenient and suitable as there is a relatively good chance that it would begin before February 14. For northern Ontario, a thaw index calculation start date of March 15 is recommended. The frequency plot for northern Ontario contained temperature data from 1961 to 2003, and in that span of 42 years, there was one occurrence of a March 11 start date. Clearly, there is a chance that the start date would occur before the recommended March 15 start date, but the chance is fairly slim. Therefore, the calculation of the thaw index for northern Ontario could begin on March 15, while for southern Ontario, the calculation could begin on February 1.

POSSIBLE FUTURE WORK

It has been found that by varying the reference temperature, a more accurate prediction of the start of the thaw season and load restrictions can be obtained, and it will not be affected by the occurrence of erratic air temperature warming trends (*9*). A similar analysis can be performed, with the data broken down by month, to determine the required air temperature to obtain an asphalt temperature of 0 ^{o}C. Since Ontario covers a large area, the analysis can be further broken down into several regions to investigate the effect of location in determining the reference temperature and threshold thaw index. For convenience, Ontario can be divided in the same way that the MTO divides province into five regions.

This methodology could be adopted for each of the five regions, and as temperature data is collected by Environment Canada on a daily basis, only asphalt temperature data at certain representative sites are required. To further enhance the system, thermistors or thermocouples can be installed on certain highway sections to measure asphalt temperature on a daily basis, at least for the months from January to May, which will cover a portion of the freeze season up to when it is expected that thawing will begin.

The method used by the South Dakota DOT, and the recent research at the Minnesota DOT are promising methods of predicting the start and duration of thaw, since it takes into account the degree of saturation in the soil and the frost depth. Incorporating these methods in Ontario could improve the accuracy of predicting periods of thaw. Although measuring the frost depth is a more direct and accurate way of determining frost depth, using precipitation data would be more convenient. Frost probes and piezometers can be installed in several representative areas to develop a relationship between frost depth and precipitation. The onset and duration of thaw can then be related to the average daily temperature, and the amount of precipitation in the fall.

CONCLUSIONS and RECOMMENDATIONS

Several frost heave theories have been formulated by a number of authors, and it can be concluded that frost formation is a complex phenomenon. One of the main parameters that dictates soil freezing and thawing is temperature. However, since pavement engineers are mainly concerned with thaw underneath the pavement surface, it is the temperature in the pavement that is most important, and not the air temperature. Pavement temperature tends to lag behind air temperature, thus making the prediction of the commencement and duration of thaw even more difficult.

A thaw index method, similar to the one used by the Minnesota DOT, is proposed to be adopted for use by Ontario. The thaw index is the cumulative difference between the reference temperature and average daily temperature. Thaw is predicted to begin, and load restrictions are implemented, when the thaw index reaches a threshold value. Analysis of the data obtained from the LTPP program indicates a reference temperature of -3.4 ^{o}C and a threshold thaw index of 13 ^{o}C-days. The calculation of the thaw index could begin on February 1 for southern Ontario and on March 15 for Northern Ontario.

The thaw index method proposed in this paper should be viewed as a starting point for a more comprehensive study into the prediction of the commencement and duration of thaw. Further research should be performed to include other factors, other than air temperature, in predicting the thaw season. An additional factor that could potentially effect the thaw season would be the depth of frost that has accumulated in the freeze season. Thermistors, frost tubes, and piezometers are proposed to be installed in several sections of highways in each of the five regions in Ontario to study the relationship between the start and duration of thaw, the asphalt temperature, and the frost depth.

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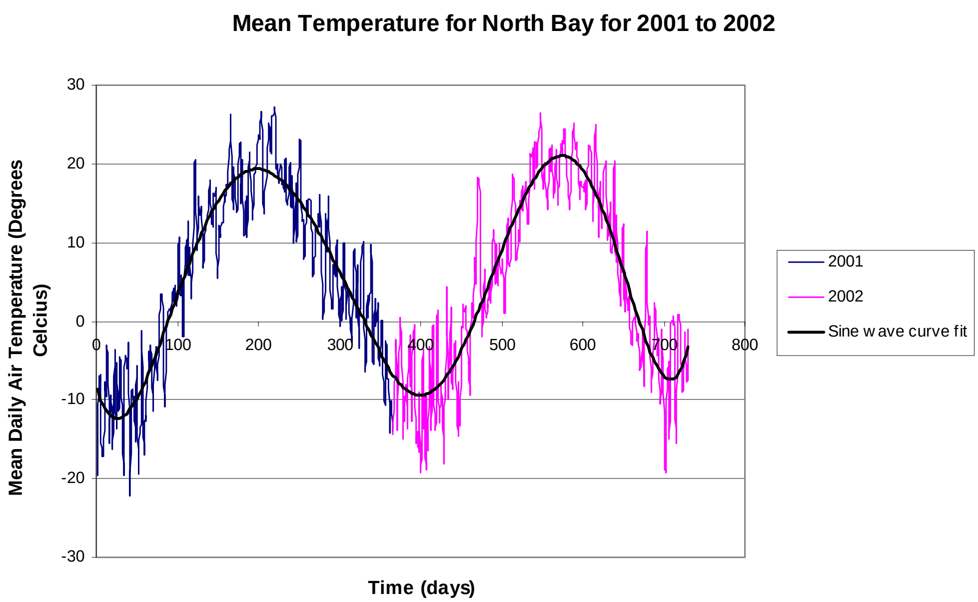

FIGURE 1 Average daily temperature for North Bay, Ontario.

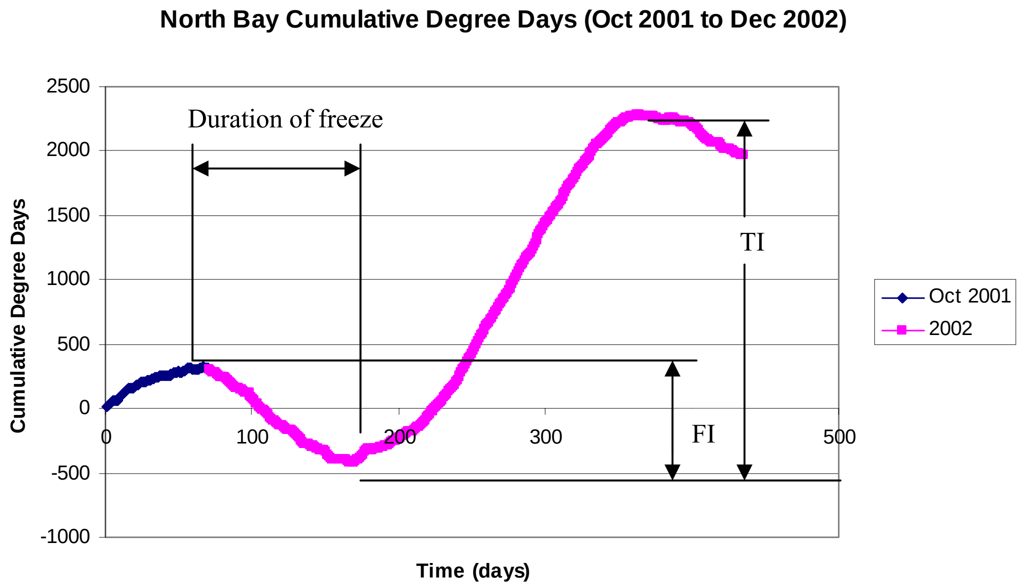

FIGURE 2 Cumulative degree days.

Figure 3 Summary of theories and methods from different authorities.

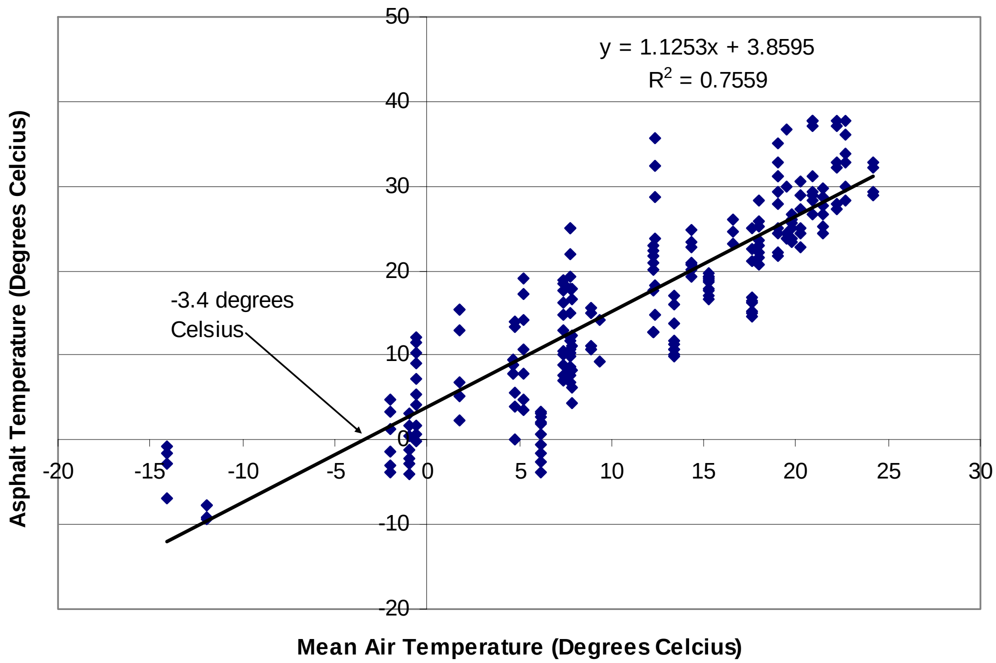

FIGURE 4 Temperature beneath the asphalt layer.

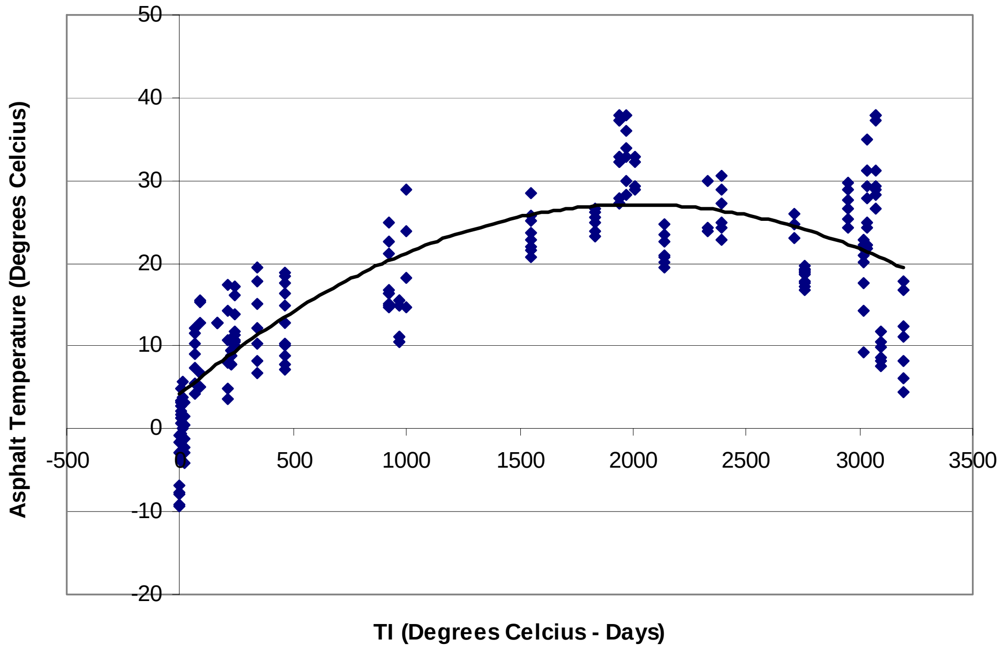

FIGURE 5 Determination of threshold TI.

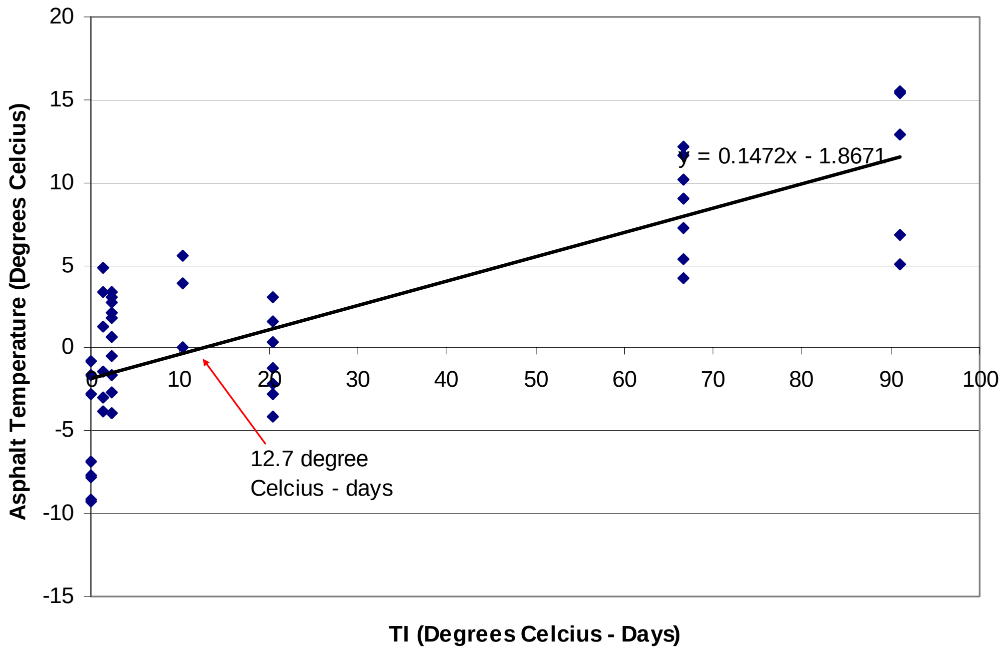

FIGURE 6 Determination of threshold TI using the first 100 ^{o}C-days.

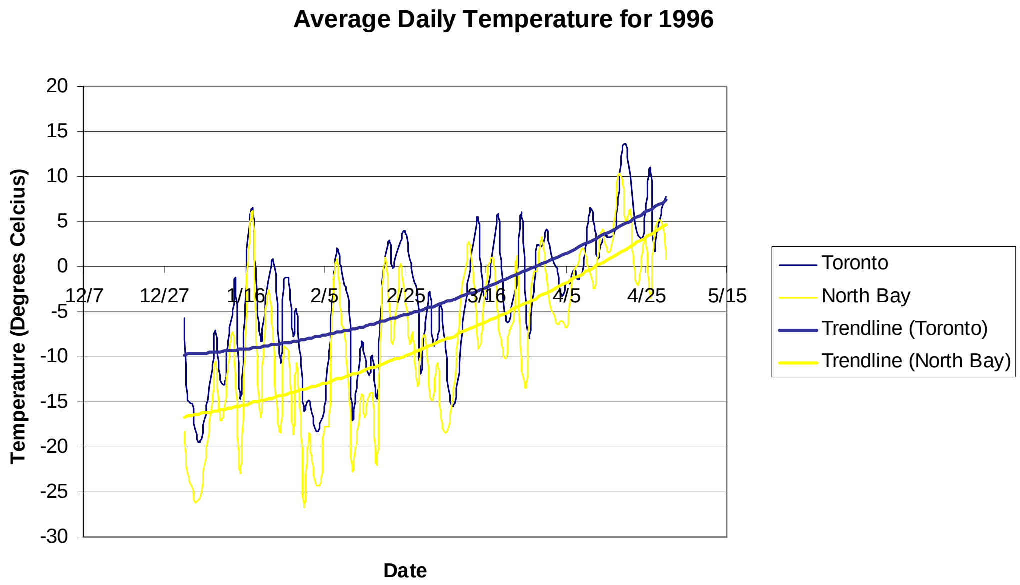

FIGURE 7 Average daily temperatures for Toronto and North Bay, Ontario from January 1 to April 30, 1996.

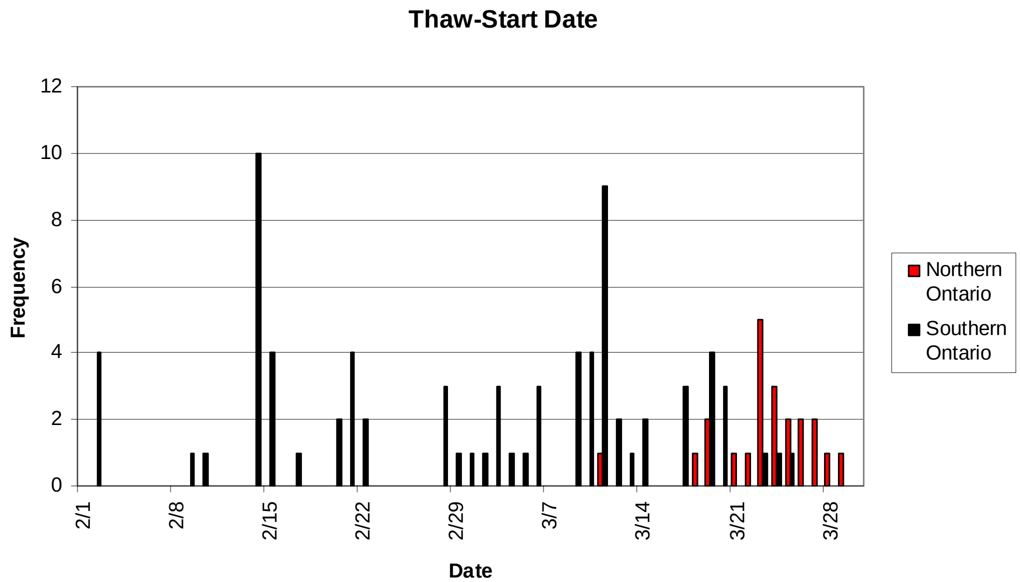

FIGURE 8 Thaw-start dates for northern and southern.

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TABLE 1: Spring Load Restriction Implementation in Canada

Province	Start/End Dates	Testing
British Columbia	**Mid-February to Mid-June**	Frost probes, weather synopsis, Benkelman Beam data for 20+ years, other historical data
Alberta	**Start Date:** 30 cm thaw and a heat flow model **End Date:** Determined with FWD testing	FWD
Saskatchewan	**Start Date:** Second or third week of March (weather dependent) **End Date:** Maximum six weeks after start date	Benkelman Beam
Manitoba	**Start Date:** Southern Zone: March 23 Northern Zone: April 15 **End Date:** May 31	Benkelman Beam
Ontario	Variable start and end dates. Typically first Monday in March to Mid May (Southern Region)	
Quebec	**North:** March 24 to May 25 **Central:** March 6 to May 12 **South:** March 21 to May 19 Timing can be advanced or delayed based on frost probe data. Start of restrictions at 300 mm thaw and ending at 5 weeks after 900 mm thaw below road surface	81 frost probes (1.5 m to 3.5 m depth) Measured weekly during freeze, daily during thaw, and then weekly at end of thaw.

New Brunswick	**Southern Zone:** Second week in March to mid-May **Northern Zone:** Third week in March to end of May Timing varied according to severity of winter and spring conditions.	Dynaflect testing on 40 affected control sections on weekly basis during restriction period.
Prince Edward Island	**March 1 to April 30** Timing varied according to severity of winter and spring conditions	Dynaflect testing on random sections throughout restriction period.
Nova Scotia	**Southern Region:** March 2 to April 24 **Central/Northern Regions:** March 2 to April 27	Dynaflect testing on random control sections (all classes) from mid-February to end of April.
Newfoundland	**February to April**	

TABLE 2: South Dakota Conditions for Commencement and Duration of Load Restrictions

Precipitation (Aug – Nov)	Critical Thaw Index	Removal of Restrictions (% of max freeze index)
7.75”	35	40
6.25”	40	35
5.50”	45	30
4.75”	50	25