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AIRPORT ENGINEERING

ATR-029

Development of SUPERPAVE PG Asphalt Selection Guidelines for Canadian Airport Pavements

R&D PROJECT

The use of
SHRP SUPERPAVE PG Binders
on Airport Pavements
Phase 2

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Subject: **Consultant Report: "Development of SUPERPAVE PG Asphalt Selection Guidelines for Canadian Airport Pavements"**

The attached Airport engineering technical report is the result of an R&D project conducted in 1997/98 by EBA Engineering Consultants Ltd. on behalf of the Airport Engineering Division of Public Works and Government Services Canada (PWGSC).

The goal of this research was to evaluate the new SUPERPAVE Performance Graded (PG) asphalt binder specifications and associated test methods, that were developed by the U.S. Strategic Highway Research Program, to verify whether they are applicable for the unique technical requirements of Canadian airport pavements.

Your feedback, questions or comments related to this report would be appreciated and should be sent directly to me at PWGSC.

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Sincerely,

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DEVELOPMENT OF SUPERPAVE PG ASPHALT SELECTION GUIDELINES FOR CANADIAN AIRPORT PAVEMENTS

submitted to:

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

prepared by:

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EDMONTON, ALBERTA

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1.0 INTRODUCTION

The Strategic Highway Research Program (SHRP) has produced new asphalt specifications and protocols for asphalt binders and a new mix design methodology, which together, are referred to as Superpave. An initial study undertaken for Public Works and Government Services Canada [PWGSC, 1997] provides background information on Superpave specific to Canadian Airport Pavements.

The selection of Superpave asphalt binder grades is based primarily on estimated in-service pavement temperatures. Site specific summer (maximum) and winter (minimum) air temperatures are used to estimate the temperature of the pavement and the asphalt grade is then selected based on these design temperatures and the desired degree of reliability for both high and low temperatures.

A secondary criteria for Superpave high temperature asphalt binder grades selection, intended for highway pavement applications, is based on traffic volumes and traffic speeds: (1) > 10 million ESALs - increase 1 grade higher; (2) > 30 million ESALs - increase 2 grades higher; (3) slow moving traffic - increase 1 grade higher; (4) stopped traffic - increase 2 grades higher.

The Superpave selection process is intended to address pavement performance issues most significantly impacted by the asphalt binder. This includes performance at low temperatures as manifested as thermal cracking, performance at moderate temperatures relative to fatigue cracking, and performance at high temperature conditions relative to instability rutting within the asphalt concrete mix. The development of a final Superpave binder specification is still many years and many debates away; however, it is felt that future changes will not significantly impact the basic principles of the current specifications.

The study reported herein was built upon available Superpave technology and utilized a more practical engineering approach to allow specific criteria to be developed for the selection of Superpave PG asphalts for Canadian airport pavements without introducing unreasonable risks.

Significant reliance on knowledge about asphalt grades that are known to have performed historically was utilized in the development of the guidelines presented in this report. This includes the significant amount of work and knowledge associated with the CGSB asphalt specifications and the many years of experience of PWGSC.

1.1 Objectives

The main objectives of this project were to develop the selection criteria for performance graded (PG) asphalts specifically for Canadian airport pavements. This includes consideration of the unique loadings on airports, and the significance that overlays versus new construction has in the asphalt selection process. A further objective was to provide criteria for validating the proposed process and guidelines for constructing trial sections.

1.2 Background

EBA Engineering Consultants Ltd. (EBA) completed a study for PWGSC in 1997 that examined the Superpave binder specifications and testing protocols, and compared them to the current CGSB asphalt specifications [PWGSC 1997].

From this 1997 report, the following recommendations identified a basis for the development work undertaken for the project documented in this report:

For high temperature loadings, it is recommended that the high temperature grade be increased based on the speed and size of aircraft. As was demonstrated with the relationship between loading frequency and stiffness (Complex modulus), standing loads greatly reduces the asphalt modulus. SHRP currently recommends an adjustment of one grade for slow traffic and two grades for standing traffic.

For airport loadings, based on the CGSB grades currently used, an increase of two grades is recommended as an interim measure, for airport pavements when the airport is utilized by large jet aircraft.

When applying the SUPERPAVE specification a degree of conservatism in the selection of the minimum design temperature is recommended when new pavement construction is undertaken. A reliability of 98% is considered warranted because low temperature cracking can occur with a single occurrence of the low temperature.

When overlaying cracked asphalt or PCC pavements, the cracking will generally be controlled more by the underlying pavement and conservatism in the selection of the low pavement temperature is not warranted. For overlays, the low temperature selection should include consideration of the overlay thickness as a major factor in reflective cracking. The low temperature reliability should then be selected on the basis of the binders potential in contributing to thermal cracking severity. This recommendation is made recognizing that the binder selection alone will not prevent reflective cracking but needs to provide some resistance to significant deterioration of reflected cracks.

2.0 SUPERPAVE DESIGN TEMPERATURE SELECTION PROCESS

The Superpave protocol for selecting a Superpave PG binder grade is the determination of the pavement design temperatures for the proposed construction site. The procedure is well documented in Asphalt Institute SP-1.

SHRP has developed a temperature database which is based on over 7500 weather stations in Canada and the United States (over 1800 in Canada). The SHRP weather database will calculate the high pavement design temperature at a depth 20 mm below the pavement surface for any given project location based on the following relationship:

$$T_{20mm} = (T_{air} - 0.00618\ Lat^2 + 0.2289\ Lat + 42.2)(0.9545) - 17.78$$

where

T_{20mm} = high pavement design temperature at a depth of 20 mm
T_{air} = seven-day average high air temperature
Lat = the project's location in degrees latitude

Reliability concepts are introduced by adding nσ to the equation where n is related to the degree of reliability and σ is the standard deviation of the seven-day average high temperatures (T_{air} is replaced by ($T_{air} + n\sigma$)).

The design low pavement temperature is currently a matter of debate within the pavements community. Three algorithms of significance currently exist.

The Asphalt Institute's SP-1 manual includes a low temperature algorithm originally developed by Deme based on data from the St. Anne test road and was restated by Robertson [Robertson, 1989]. The algorithm, as included in the SP-1 manual is:

$$T_{surf} = 0.859T_{air} + 1.7 \text{ where } T_{air} = \text{1-day minimum air temperature}$$

Recent work by EBA [TAC 1996] evaluated the available Canadian models and recommended that models utilizing reliability be used. This is accomplished by replacing the T_{air} term in the T_{surf} equation with the term ($T_{air} - n\sigma$) where σ is the standard deviation and *n* is dependent on the desired reliability.

Substituting the reliability term provides the following form of the equation:

$$T_{surf} = 0.859(T_{air} - n\sigma_{air}) + 1.7 \text{ where } T_{air} = \text{1-day minimum air temperature}$$

Robertson recently completed work for TAC [TAC, 1997] who have published an empirical algorithm developed for the purpose of predicting appropriate low design pavement temperatures for use within the Superpave system. The TAC algorithm for the low design temperature is:

$$T_{surface} = 0.749\,(T_{air} - n\sigma_{air}) - n\sigma_{surf}$$

where:

σ_{surf} = 1.5°C
n = multiplier associated with the desired reliability.
(where n is determined by $(1-\Phi(n)) = (1-R)^{0.5}$ where R is the desired reliability and $\Phi(n)$ is the standard normal probability corresponding to $n*\sigma$ for a normal distribution).

The FHWA's Long Term Pavement Performance (LTPP) office has also developed algorithms for predicting low pavement temperatures [Mohseni, 1996] [FHWA, 1997] based on instrumented LTPP sites. The LTPP algorithm is as follows:

$$T_{surf} = -1.56+0.72\,T_{air} - 0.004(\text{latitude})^2 + 6.26\,\text{Log}\,(H+25) - z(4.4+0.52\sigma_{air}{}^2)^{0.5}$$

where:

z is from standard normal probability tables = 2 for 98% reliability
H = depth to surface = 0 for surface temperature

These models are discussed further in Section 5.0.

3.0 ISSUES

During the background work undertaken for this project numerous issues were raised. Issues which were considered of significance for either the implementation or the development of the Superpave PG asphalt selection criteria have been documented in this section. Therefore, this section provides some background to the development of the selection criteria and highlights issues which may impact the implementation of the use of PG asphalts for Canadian airport pavements.

- Issue: The highway sector tends to drive asphalt specifications and hence supply.

  This issue relates to the relative size of the airport "market" compared to the roadway "market" and as a result the implementation and continuous refinement of the PG binder specification is currently driven by roadway users and may not recognize unique airport requirements and needs related to:
  - loadings (traffic)

- pavement design (structural design and mix design)
- risk tolerance (including FOD)
- maintenance and rehabilitation practices
- pavement temperature algorithms

Further, because there is currently a movement throughout Canada and the United States among the large transportation agencies (i.e. Provincial and Municipal) to adopt PG specifications sooner rather than later, the available asphalt supply in the future may be exclusively Superpave performance graded asphalts.

- Issue: PG asphalts allow for larger variations within a given grade than is currently the case for CGSB asphalts.

  The stiffness of an asphalt is a measure of the binder's fundamental engineering property. The stiffness of asphalt is a function of the temperature at which the stiffness is determined. For CGSB asphalts the difference in stiffness from one grade to the next is typically equivalent to about 3°C [TAC 1996]; for Superpave PG asphalts the grades are defined by the temperature at which specific stiffness requirements are met and are specified in 6°C increments. The significance of this observation is that the use of PG asphalts essentially eliminates the ability to differentiate between current CGSB 150-200 and 120-150 asphalt grades and can result in "over-specifying" in order to assure the desired stiffness is achieved with the PG asphalt.

- Issue: Although the criteria developed for this study provides a rationale means of selecting an asphalt which will perform for Canadian airport pavements, such grades may be unavailable.

  The availability of asphalt grades on a regional basis may be dictated by user demand. As a result, PG asphalts selected for airport pavements may not be available or be available only at a significant cost.

- Issue: Many PG asphalts are only possible by modifying the asphalt cement.

  As PG asphalts address both high and low temperature regimes, it is often not possible to meet the specification requirements with a "straight run" asphalt. Polymers have been used to modify the properties of asphalt cements to address performance over the range of pavement temperatures expected. However, polymer modified asphalts are not reliably graded using the existing Superpave testing protocols and as such introduce an unknown to the question of performance while at the same time demanding a significant premium in cost.

- Issue: Pavement performance is governed by the overall characteristics of the mixture.

  The performance of asphalt pavements is very much dependent on the asphalt binder/aggregate/asphalt mix system which is additionally influenced by the quality of construction.

  This issue was found to be significant throughout the development of the asphalt selection criteria when issues of performance were to be related to the asphalt characteristics.

- Issue: Superpave low temperature characteristics are determined on the basis of PAV aged asphalts.

  The pressure aging vessel (PAV) developed by SHRP ages an asphalt a similar amount as some number of years in-service (5 to 10 years). This suggests the asphalt is being designed to resist cracking only for this time period (5 to 10 years). When designing an asphalt pavement on the basis of life cycle costs, such issues introduce further unknowns into the analysis.

4.0 HIGH TEMPERATURE ASPHALT GRADE FOR CANADIAN AIRPORTS

The selection of the high temperature grade for Canadian airport pavements has been evaluated on the basis of fatigue and instability rutting of the asphalt concrete layers. The work undertaken by EBA to develop these guidelines has been carried out under the premise that neither fatigue nor instability rutting is currently a predominant distress mode for airport pavements. This information is seen as significant in the development of guidelines for asphalt grade selection as it provides a high level of confidence in the existing practices of PWGSC.

The selection of an asphalt binder typically requires the designer to optimize the performance of the pavement for high and low temperature considerations. Straight run asphalts have a relatively constant temperature susceptibility that is dependent on the source of the asphalt. This temperature susceptibility defines how the binder will perform at varying temperatures. The use of polymers to modify binders has been shown to reduce the temperature susceptibility of the asphalt; however, the characterization of polymer modified asphalts (PMA) is still not resolved. While the existing Superpave testing protocols may define the characteristics of a modified binder in a superior manner to what was possible with conventional testing protocols previously, the non-linear behaviour of PMAs can still result in misleading characterization of the modified binder. The FHWA has an ongoing study (NCHRP 9-10) to evaluate testing protocols for modified asphalts.

4.1 Fatigue of Asphalt Concrete Pavements

Fatigue of asphalt pavement is generally believed to be a function the tensile strain experienced at the bottom of the pavement layer, and the stiffness of the asphalt concrete.

G*Sin(δ) was originally touted as the asphalt parameter to help guard against fatigue. As discussed in the PWGSC 1997 study, this parameter has since been reported to correlate poorly to fatigue life of pavements. The rheological index 'R' is currently being considered as the parameter which will provide a measure for fatigue performance. At this time, the FHWA and their Expert Task Groups are examining the potential of the rheological index as a specification measure [D'Angelo, 1998].

The rheological index, R, is defined as the difference between the glassy modulus (i.e. the limiting modulus that is obtained at very low temperatures or very short loading times - which tends to $G^9 = 1 \times 10^9$ Pa for all asphalts) and the modulus measured at a frequency at which the phase angle δ is equal to 45° (the cross-over frequency). R provides a measure of how quickly the modulus of the asphalt changes with loading time [Christensen et al, 1992] [Anderson et al, 1991].

Additionally, the 'm' value, determined during the BBR testing at low temperatures, is considered important in low temperature fatigue.

The impact the stiffness plays on the fatigue life, including the role of seasonal variation (i.e. G*sin(δ) and G*/Sin(δ) are tested at a specified temperature), and the significance relative to typical or expected values is difficult to quantify. There are conflicting discussions in the literature on the ability to relate binder properties to actual fatigue performance. For the purposes of this study, conventional relationships between asphalt and mix stiffness have been used to examine fatigue.

A common fatigue model as presented by the Asphalt Institute [Asphalt Institute, 1982] is given by the following relationship:

$$N_f = f_0 * (10^M) * (f_1 * e_t^{-f_2}) * (E^{-f_3})$$

where:

N_f = Number of repetitions until failure,

f_o = Laboratory to field shift factor = 18.4

$$M = f_4 * [\frac{V_b}{V_v + V_b}) - f_5]$$

E = Stiffness of mix

$f_1 = 0.004325$	$f_4 = 4.84$
$f_2 = 3.291$	$f_5 = 0.69$
$f_3 = 0.854$	V_v and V_b = Volume of asphalt and voids in mix

As can be seen from Figure 1, the fatigue resistance is a function of the tensile strain in the asphalt concrete layer and the stiffness of the asphalt concrete. Within the form of the model, the voids in the mix and the volume of asphalt cement are used to adjust the resulting fatigue life, relative to the characteristics of the mixtures utilized in the laboratory, to develop the relationships. While Figure 1 would suggest that 'softer' binders will result in longer fatigue life for a given level of strain, it must be noted that the resultant mix stiffness will in fact impact the overall structure strength and, therefore, the strain of the hot mixed asphalt concrete (HMAC).

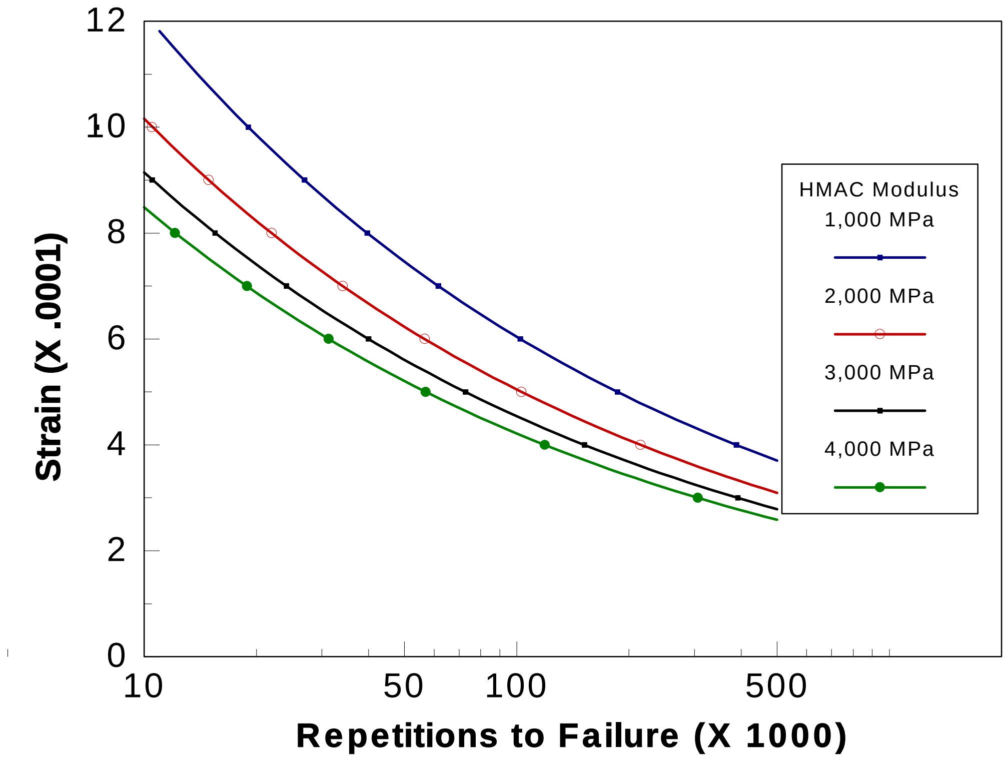

Figure 1 Asphalt Institute Fatigue Model

Example calculations were undertaken using a B737-300 aircraft loading on two 'equivalent' structures. These calculations indicate that, for large number of repetitions, the fatigue life is greatly affected by the HMAC modulus value and also by the thickness of the HMAC in the structure, as illustrated in Figure 2.

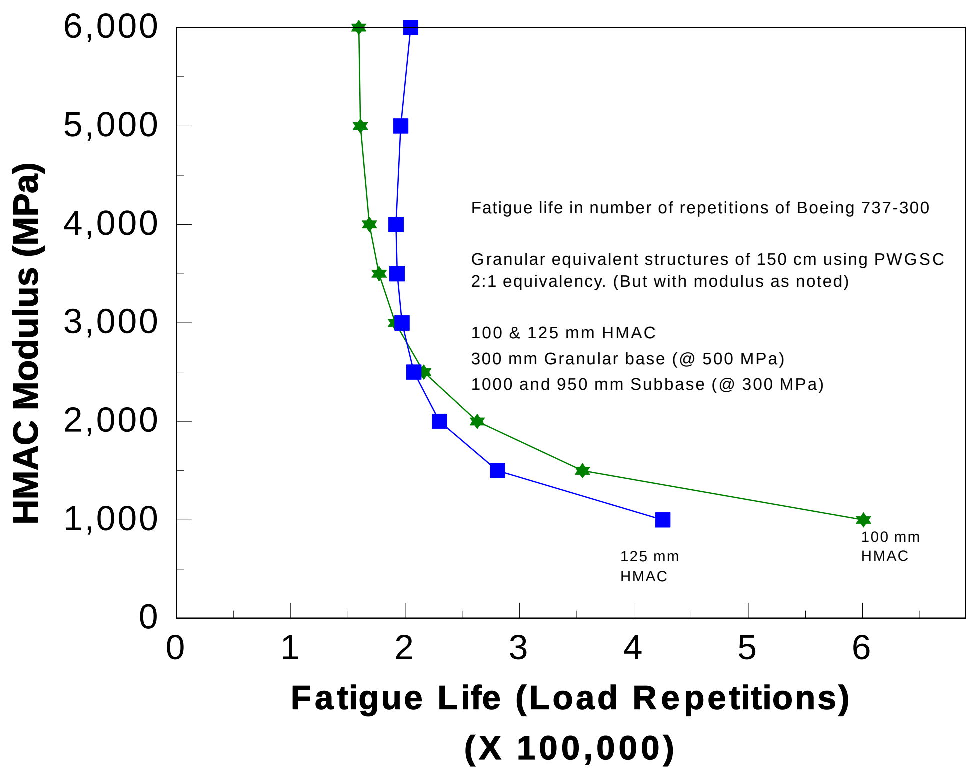

Figure 2 Fatigue Life for Different Structures for Varying Asphalt Modulus

Additional examples were examined for lighter loading conditions. For lighter loads (and appropriately lighter structures), fatigues lives are very much higher and exhibit the maximum fatigue resistance at a given HMAC modulus which changes significantly with ACP thickness. Generally, the fatigue life calculated far exceeds the expected number of load repetitions.

The void characteristics which are used in the fatigue model are also discussed in the next section and are illustrated relative to the mix stiffness and rutting.

Based on the review conducted for this project fatigue is not seen to be a concern and the selection of PG binders based on the criteria developed is not seen to impact the current fatigue performance. This conclusion is based on the observations that the fatigue lives calculated for various modulus values exceed the number of repetitions expected at Canadian airports.

4.2 Permanent Deformation (Rutting) of Asphalt Concrete Pavements

Permanent deformation, or rutting, of asphalt concrete pavements is a common distress mode on streets and highways. However, as for fatigue, it is not a typical problem for Canadian airport pavements. Throughout this project, this knowledge has been used as a focal point. It is considered a crucial observation as it provides the necessary confidence in the performance of asphalt concrete pavements on Canadian airports. Because rutting is not considered a performance issue with Canadian airport pavements, the characteristics of the mixtures used across the country can be assumed to be more than satisfactory. (The fact that rutting is not a significant problem indicates a margin of safety in the current practice).

While the asphalt binder plays a role in the resistance to rutting of the asphalt pavement, its contribution is considered to be in the order of 40% [TAC 1996]. The binder influence on the mix stiffness characteristics can be greatly overshadowed by the aggregate characteristics [Leahy et al, 1995]. Relationships between the stiffness of the asphalt binder and the asphalt concrete mix have been reported in the literature [Asphalt Institute, 1982] [TAC, 1996] and include additional variables such as asphalt volume, air voids, and the percent passing the number 200 sieve size. The influence of the aggregate characteristics such as angularity, fractures and texture can be shown conceptually as shown in Figure 3. Figure 3 also illustrates that void characteristics of a given mixture has a significant affect on the resulting mix stiffness characteristics.

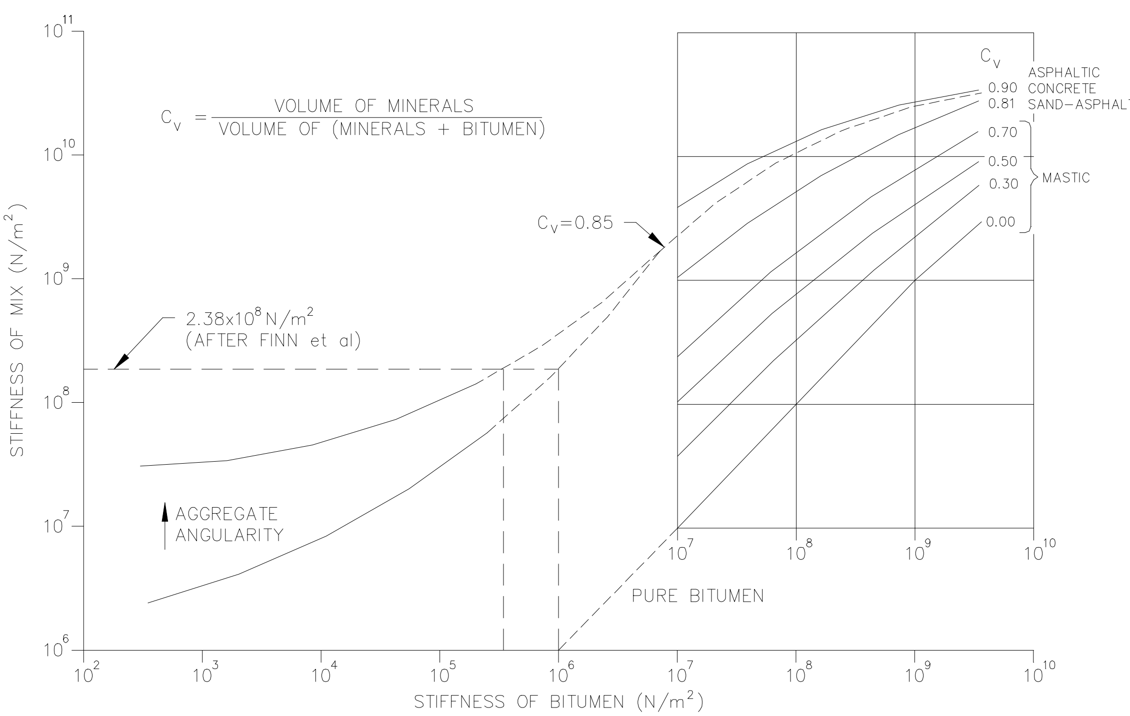

Figure 3 Relationship Between Stiffness of Asphalt and Mix Stiffness (reference TAC 1996)

While the published research findings and experience have long supported the relationship of binder stiffness to rutting, it is also apparent that the site-specific environment, mix characteristics, and loading conditions must all be defined in order to quantify the affect of any parameter.

Work conducted to evaluate the specific influence of the asphalt stiffness on the rutting performance has been reported in the literature [McMillan and Anderson 1988] [McMillan 1989] [Leahy et al, 1995]. Such work serves to help quantify the impact of the binder, and pavement temperature on the permanent deformation of the asphalt concrete mixture. For example, work conducted by McMillan [McMillan, 1989] suggests a significant change in rutting resistance between neighbouring CGSB asphalt grades, although the hardest grade used in the study was a 120-150A asphalt.

Work conducted for the Brampton Test Road [Morris et al 1974] used laboratory testing to define the mixture characteristics and predict rutting. The basic form of the rutting relationship given in this work was: $\epsilon_p = f(\sigma_1, \sigma_3, T, N)$, in which σ_1 and σ_3 are the vertical and horizontal stresses respectively, T is the temperature and N is the number of repetitions of the load.

Morris' work is significant in that the model developed directly references the loadings. Other models, such as that presented with the VESYS computer program, reference load less directly [Sherwood et al, 1998]. The VESYS rutting model is based on layer deflection which is a function of the HMAC modulus and the applied loading. (The model also considers permanent deformation in the base and subgrade layers).

A recent summary [Brown, 1997] highlighted the significance of laboratory loading conditions. Repeated load testing with and without confining pressures resulted in significantly different relative performance of a straight run asphalt compared to a PMA binder. This highlights issues related to applying laboratory based testing to field conditions and suggests that the application of theoretical laboratory studies must be tempered with good engineering judgement.

Part of the Superpave mixture protocols are intended to (eventually) utilize laboratory testing and models to allow the prediction of rutting. To date, the ability of the models to predict mixture performance, based on inputs from the Superpave Shear Tester (SST) has not been sufficient to allow for the adaptation of this part of Superpave [Zhang et al, 1996]. Work reported on FHWA accelerated load testing [Sherwood et al 1998] showed the SST determined mix modulus values correlated less than $G^*/\sin(\delta)$ of the binder to the measured rutting.

Full scale testing is currently ongoing to validate the existing Superpave binder stiffness requirements relative to pavement rutting. The FHWA [Sherwood et al, 1998] [Bonaquist, 1998] reported on work undertaken using accelerated loading, to, in part, “confirm that the binder properties identified by SHRP research as determinants of pavement performance are significant”.

The findings of this study relate G*/Sin(δ) to rutting and correlate the G*/Sin(δ) value to coefficients utilized in the VESYS rutting model. Figures 4 and 5 show the relationship determined by Sherwood for both the mix stiffness and binder G*/Sin(δ) to α (alpha) and μ (mu). The coefficients α and μ are used in the VESYS model to define the rutting characteristics of the layer. Values of μ and α reported for varying values of G*/Sin(δ) were subsequently used to calculate rut depths for 50,000 load repetitions and varying deflections of the HMAC layer.

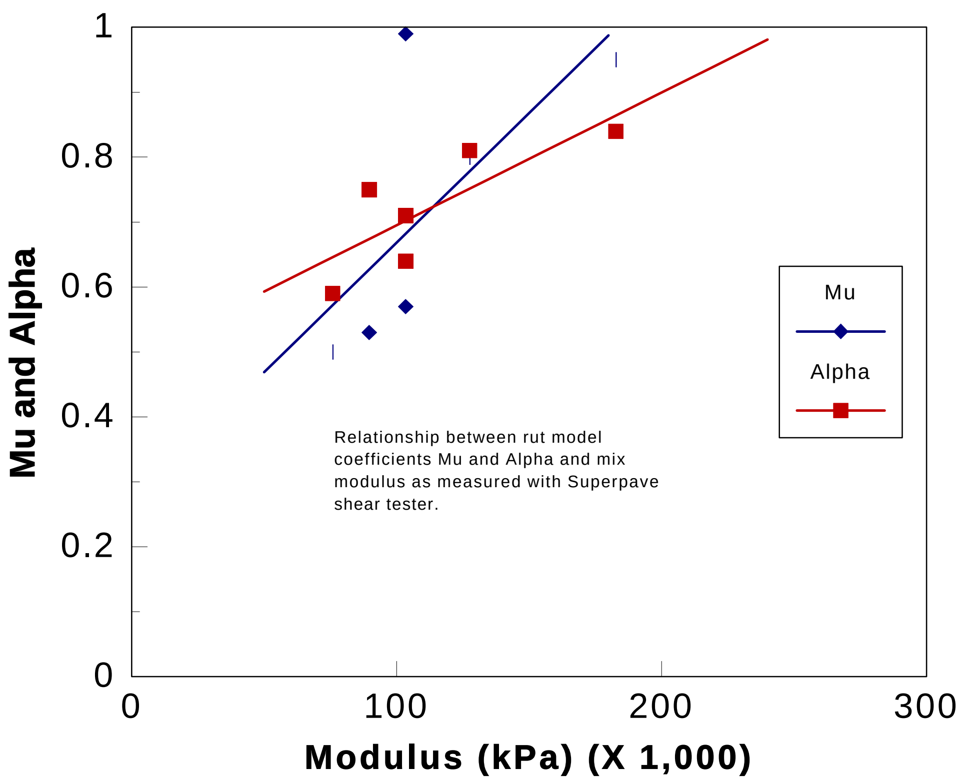

Figure 4 Relationship Between Asphalt Modulus and Rutting Parameters

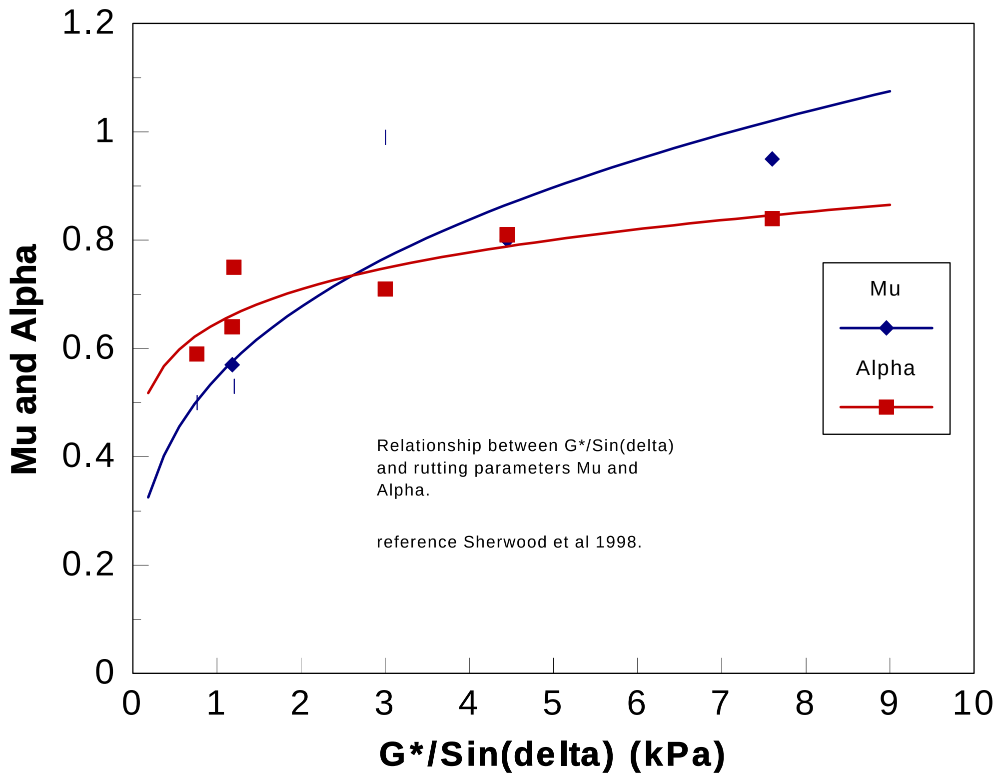

Figure 5 Relationship of Rutting Parameters to G*/Sin(δ)

While the correlation of the rut depths to G*/Sin(δ) is poor, it does provide a means of examining the potential impact of the asphalt characteristics to rutting.

The VESYS model is of the following form:

$$Rut\ Depth = H\epsilon_r \frac{\mu}{1-\alpha} N^{1-\alpha} = D\frac{\mu}{1-\alpha} N^{1-\alpha}$$

The rut depth determined for varying deflections (D) are shown in Figure 6. Similar data was plotted directly by Bonaquist [Bonaquist et al, 1998] and shows the same trends.

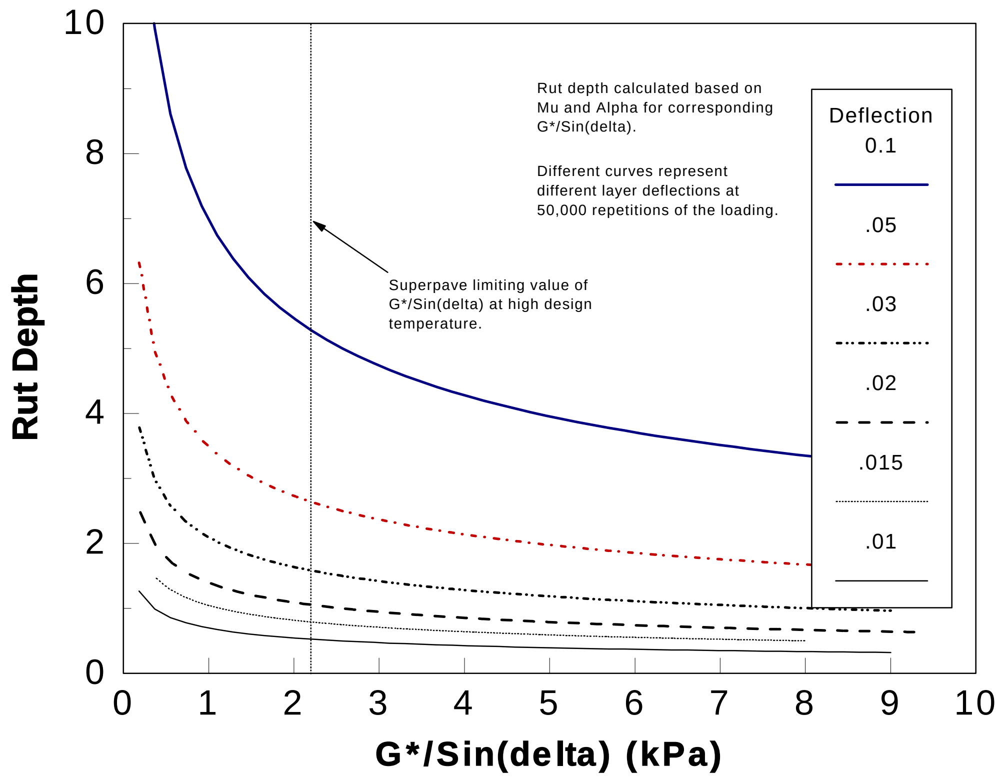

Figure 6 Approximate Relationship between Rutting and G*/Sin(δ)

Variations of asphalt 'stiffness', in terms of G*/Sin(δ), with temperature were examined based on the work reported by Sherwood. In addition, binder stiffnesses were determined on the basis of the Shell nomographs [Heukelom, 1973]. Both are shown in Figure 7. Note that the values are plotted to different scales and different measures (G*/Sin(δ) compared to stiffness). It can also be noted that stiffness can be expressed as a function of the complex modulus, S=2(1+μ)G*, where μ is Poissons ratio.

The rutting data was used to quantify the increase in stiffness required to maintain the same level of rutting with an increase in load. It was observed that for a given increase in deflection, the 'equivalent' stiffness required, (i.e. the increase in stiffness), reduced with increasing G*/Sin(δ). This was considered reasonable, and is consistent with results reported in the literature [McMillan, 1989].

This was summarized by Bonaquist [Bonaquist et al, 1998], as "... at low values of G*/Sin(δ) the rutting is very sensitive to small changes in binder properties ... high values of G*/Sin(δ), the rutting behaviour is relatively insensitive to changes in binder properties. The Superpave specification limit of 2.2 kPa appears to be in the transition area between these two zones".

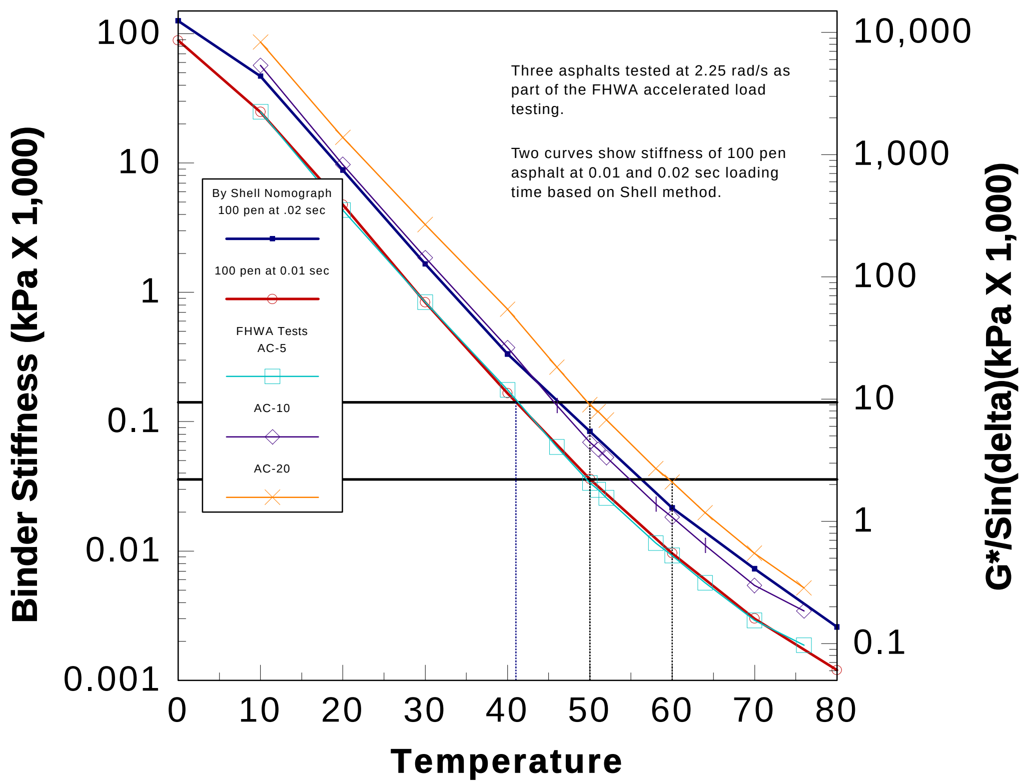

Figure 7 Variation of Asphalt Stiffness and Complex Modulus with Temperature

The FHWA accelerated loading project [Sherwood et al, 1998] stresses that the relationships determined are applicable to conventional binders. Similar findings were also reported by Australian researchers (Oliver et al, 1998] that is, a relatively good correlation was determined between conventional asphalts G*/Sin(δ) and wheel tracking results, however modified asphalts did not correlate well.

It is important to note that the deflections that would be expected in the HMAC layer will vary considerably under the same aircraft load depending on the stiffness of the mixture, which will vary with temperature. Figure 8 illustrates the change in layer deflection for typical and very thick HMAC layer thickness.

Irrespective of the uncertainties associated with the specific relationship of the binder (G*/Sin(δ)) to rutting, the data presented provides justification for a decreasing rate of change with respect to increasing the binder stiffness with increasing load.

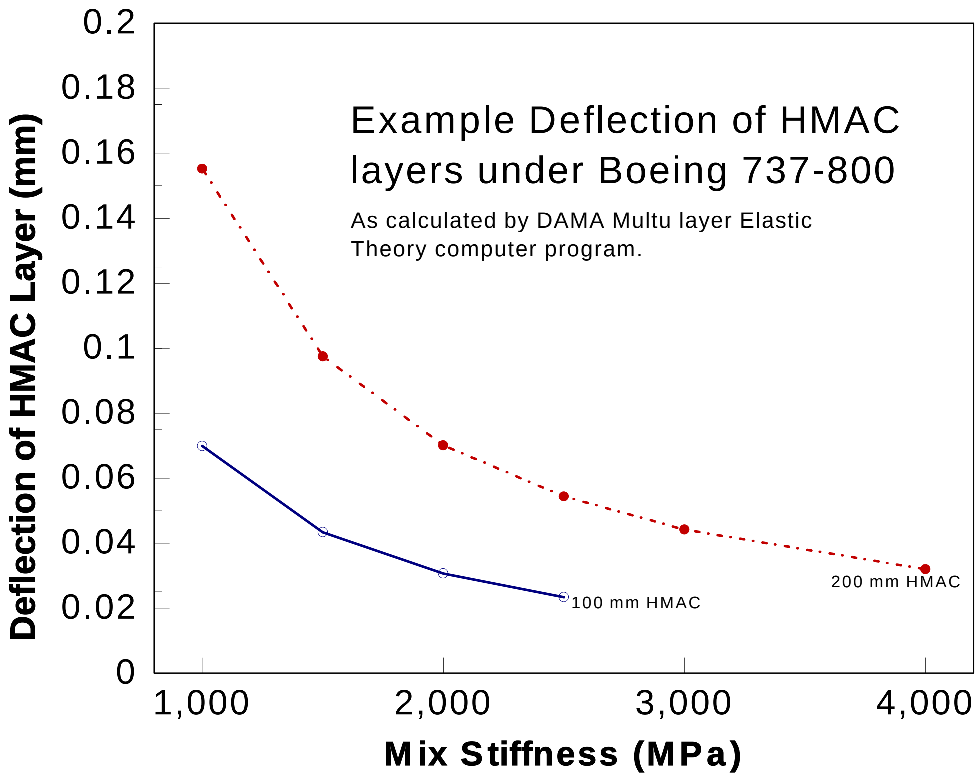

Figure 8 Example Deflections in HMAC layers

Therefore, the data presented in this section was used to select required changes in temperature grading to accommodate increasing loadings - this includes increasing gross loads, increasing tire pressures and increasing frequency of loadings.

4.3 Basis of Proposed Selection Criteria for High Temperature

4.3.1 Overview

As stated at the beginning of the Section 4.0, high temperature performance in the form of rutting or fatigue has not been a significant distress on airport pavements. As a result of this observation it can generally be assumed that it will not be necessary (nor desirable) to utilize stiffer asphalts than have historically have been utilized by PWGSC.

In Alberta, local airports were originally under the jurisdiction of the Provincial highway department (Alberta Transportation and Utilities (AT&U)). AT&U constructed many of these airports using 300-400A asphalt. These airports catered to local flying clubs and private pilots.

The performance of these types of airport pavements has been acceptable relative to high temperature related distress (distress has most typically been related to aging, raveling, cracking etc). These observations lend confidence to the use of softer asphalts for local – low loaded airports, than has previously been recommended by PWGSC.

A survey completed by PWGSC (Scarlett et al, 1998) indicates that Canadian practice has generally followed PWGSC guidelines or, in some areas, used softer CGSB asphalt grades. However, it must also be noted that the softer asphalts (150-200A) have been used in regions which would not typically have significant numbers of the larger jet aircraft. The 150-200A grade was the softest asphalt reported by the PWGSC regional offices.

4.3.2 Loadings

PWGSC have developed a series of twelve standard gear loadings (SGL) which span the range of current aircraft loadings. The aircraft characteristics which determine the SGL includes gear configuration, gross loadings, and tire pressure.

A review of PWGSC Standard Gear Loadings was undertaken for the purpose of establishing logical load groups for the purpose of Performance Graded asphalt selection. It was recognized that the range in asphalt grades, that would be utilized for given pavement design temperatures, between the lightest loaded airport pavement and the heaviest loaded airport pavements, would not reasonably exceed three grades. Based on this reasoning, three "groupings" were considered desirable. SGL of 1 to 4; 5 to 8; and 9 to 12 were considered reasonable groupings in terms of impacting the selection of asphalt binders. Appendix E shows typical aircraft in each of the 12 Standard Gear Load (SGL) groups.

In the review, the loadings of typical aircraft in each of the SGL groups were examined. The loadings of SGLs 1 through 4 were considered to be of the same magnitude as might be achieved from highway truck traffic. (That is, tire pressures are within the realm of truck traffic, and gross loads, when considered in regards to the fourth power rule for truck loadings, resulted in a maximum of approximately seven equivalent single axle loads). The first grouping, because of the loose relationship to truck loadings, foreshadowed the potential of using the basic Superpave selection methodology for this grouping.

Similarly, the second and third levels defined for the SGLs attempted to distinguish logical groupings. It was noted it would probably be justified to define four groupings, however, recognizing that such further grouping would not result in different asphalt grade selections, two further groupings were selected.

A fourth level was also identified which is intended to address apron applications for high frequency or standing (i.e. apron) Level 3 loadings.

PWGSC Standard Gear Loadings (SGL)	Load Group
1 to 4	Level 1
5 to 8	Level 2
9 to 12	Level 3
High Frequency or Apron Applications	Level 4

4.3.3 Affect of Reliability

A review of available temperature data for Canadian weather stations, and particularly for Canadian airport weather stations was undertaken for the purpose of evaluating the grades that would be considered appropriate based on existing Superpave criteria. This review identified that the reliability selection made no difference in the high temperature grading in almost half the Canadian sites. There are two issues affecting this, firstly, the standard deviation is relatively low and as a result 2 times the standard deviation for 98% reliability typically does not result in more than about 2 to 4°C difference and secondly, as many sites are well below the 46°C minimum grade, the influence is not significant with respect to increasing the grade. When Canadian airport sites were examined exclusively and limited to sites with T_{20mm} at 50% reliability greater than 45°C, 42 of 84 sites did not require a change in asphalt high temperature grades for 50% versus 98% reliability; 41 sites changed 1 grade and 1 site changed 2 grades at 98% reliability compared to 50% reliability. The distributions of standard deviation for Canadian weather stations and Canadian airport sites are shown in Figures 9 and 10.

This insensitivity to reliability led to the use of the 50% reliability (i.e. 0 standard deviation) as the initial selection criteria for high design temperature. Superpave does not specifically recommend the reliability value to use when selecting the appropriate grade. The recommendation to use 50% reliability for Level 1 load groupings recognizes that all Canadian airport sites are subjected to much cooler temperatures for the majority of the year, and that the frequency of loading is low compared to highway applications. Concepts of reliability related to selection of the high design temperature grades are discussed in more detail later in this report.

4.3.4 Approaches to Select High Temperature Grade

The review of asphalt stiffness and G*/Sin(δ) relation with temperature, especially the work reported on the FHWA accelerated load testing [Sherwood 1998] [Bonaquist et al, 1998], was used to estimate reasonable increases in high design temperature (grade).

In developing specific selection criteria, the issue relating to the temperature spread within a

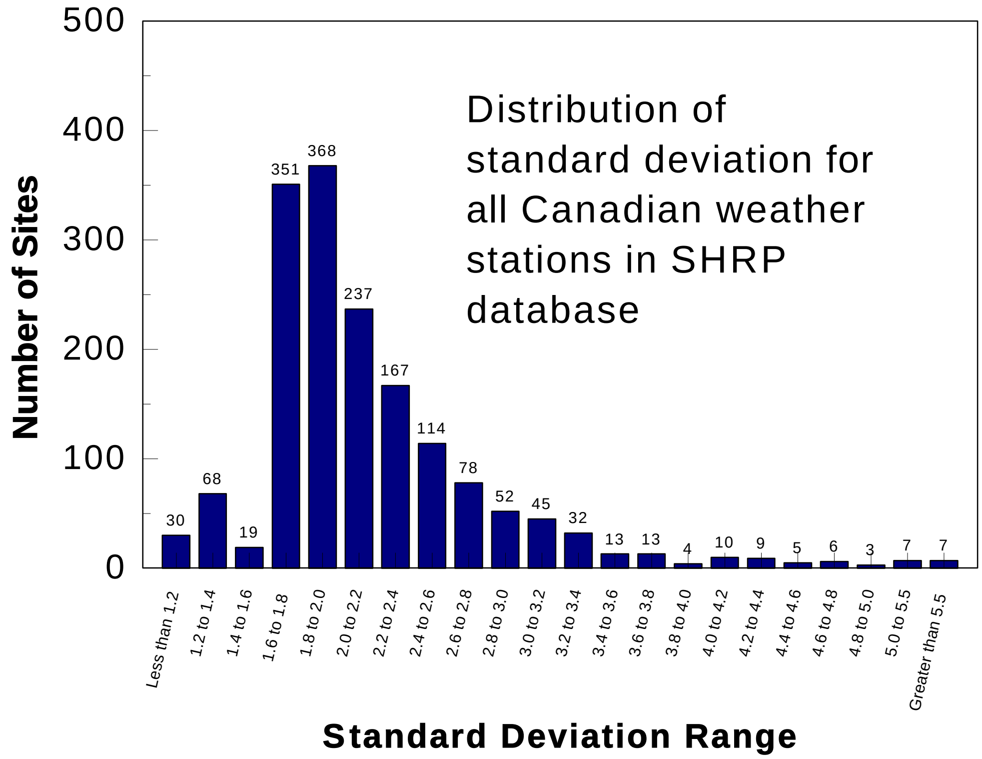

Figure 9 Standard Deviation of High Temperatures (7-day) in Canada)

particular PG grade (i.e. 6°C) was also considered. It was considered reasonable that suppliers will supply products that meet the G*/Sin(δ) requirements somewhere above the minimum specified temperature (i.e. the high design temperature grade). Recognizing that it is not economical to over-specify the asphalt requirements, a modification to the grade selection procedure was examined.

Two methods of developing specific selection protocols were examined. The first approach method would select the high temperature grade that is within 2°C of the high design temperature before requiring the next higher grade to be selected. (Example: If PG grades are 46, 52, 58, etc, a high design temperature determined to be 48 will utilize PG46- rather than

PG52 as the SHRP protocol would stipulate; a high design temperature of 48.1 would then utilize the next higher, e.g. PG52-XX grade).

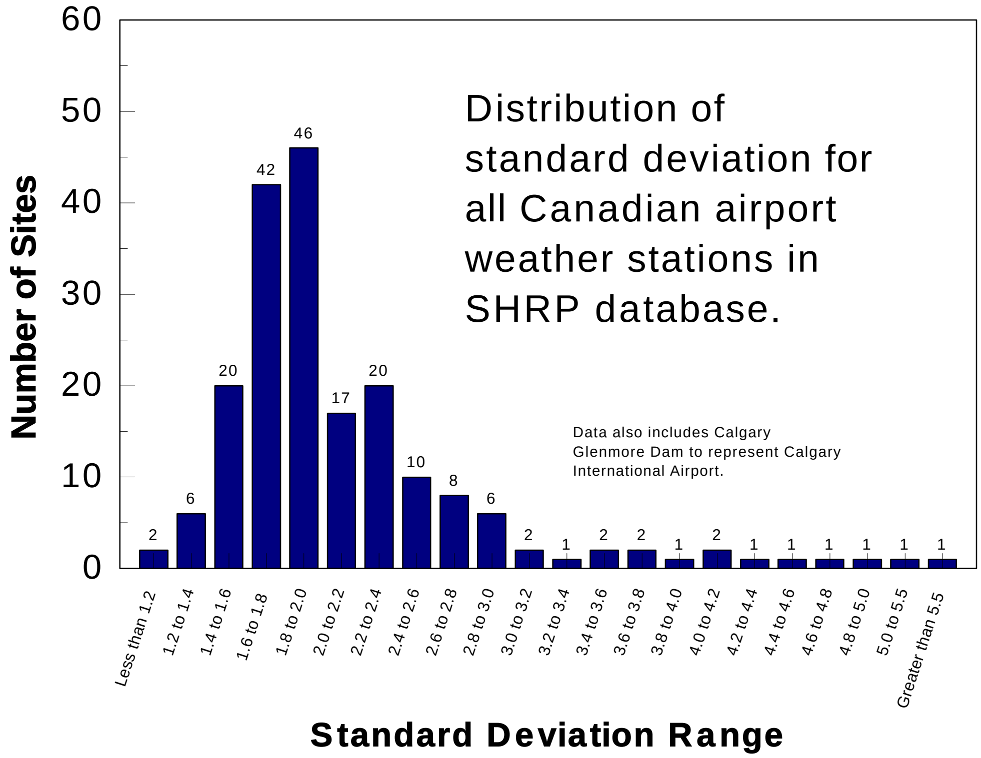

Figure 10 Standard Deviation of High Temperatures (7-day) at Canadian Airports

The second approach utilized the concept of reliability to provide a more rational approach to the high temperature grade selection.

The use of the 50% reliability was selected for the determination of the high design temperature for Level 1 applications using both approaches. The two approaches are discussed as Approach 1 and Approach 2 in the following discussions. For both approaches the rational discussed in Section 4.2 formed the basis for the proposed adjustments.

Approach 1

For Level 2 loadings, an increase of 8°C was selected to increase the binder stiffness when moving from very lightly loaded to moderately loaded airport pavements. The impact of this was reviewed and it was noted that the Canadian weather station information identified that there are numerous sites well below the minimum PG46- high temperature grade which the addition of 8°C will not result in a increase in PG grade. This was considered reasonable for these sites, which represent the northern part of the country. The 8°C was selected on the basis of two considerations. Firstly, it was selected based on the temperature change required to increase G*/Sin(δ) sufficiently to maintain an acceptable rutting level when low deflections were considered in Figure 6. Secondly, the 8°C was selected because it assumed an increase in grade when the design temperature was within 2° of a specific high temperature grade. This was considered important when moving from the softer asphalts which would be utilized for the Level 1 load grouping and is supported by the discussion in Section 4.2.

For Level 3 (heavily loaded airport pavements), it was not considered reasonable to utilize asphalts softer than the softest (150-200A) currently recommended by PWGSC. To address this, the temperature adjustment identified for Level 3 is based on the greater of the 50% high temperature value or 46°C. The temperature increase selected is 14°C which results in a minimum high temperature grade of PG58- for level 3 airport criteria (i.e. 46+14=60°C). The rationale for the 14°C increase followed the logic discussed for Level 2 grade selection. The 14°C was selected on the basis of a 6°C increase plus the 8°C increase determined for Level 2 (i.e. 6+8 = 14°C). The lessor change of 6°C recognizes the lessor sensitivity of rutting to changes in G*/Sin(δ) value for the design temperature, during cooler weather significantly higher stiffness will be realized.

The highest level, (Level 4) which is not identified in relation to SGL, incorporates an additional 4°C (4° + 14° = 18°C) increase from the Level 3 criteria. The increase of 4°C is based on the same reasoning as discussed for Level 3. Level 4 is seen to be applicable to very high loading conditions (i.e. aprons at a Level 3 airport) or high frequency of the same aircraft loadings (channelized loading).

Approach 2

The second approach evaluated examined the use of reliability as a more rational means of differentiating between Canadian Airport locations which represent a higher risk in terms of relative variations in the high design temperatures. That is, sites with high standard deviations have a higher risk of experiencing higher than average temperatures during any given year. The 2°C "gray zone" previously presented was not used in conjunction with this approach as it was envisioned that the use of varying levels of reliability, for the different airport loading levels, would achieve similar results.

For Approach 2, moving to Level 2 loading conditions from Level 1 requires the design temperature to increase by 1σ in the T_{20mm} determination. The design temperature is based on the greater of the calculated T_{20mm} (1σ) or 46°C plus an additional 5°C.

Moving to Level 3 loading conditions (heaviest gear loadings), a similar rationale was applied as for Approach 1 in that modifications to the high design temperature were made on the basis of the greater of the 98% (i.e. 2σ) reliability T_{20mm} temperature or 46°C. For Approach 2, a temperature increase of 9°C was applied to the T_{20mm} (98% reliability) high design temperature.

Level 4 high design temperature asphalt grade is determined on the basis of T_{20mm} 99.999% (i.e. 4σ) or 46° whichever is greater, plus 12°C.

The resultant grades selected with the two approaches are given in Appendix F for Canadian Airport locations. Section 4.4 summarizes the proposed selection criteria.

4.4 Summary of Proposed High Temperature Selection Protocol

The following table summarizes the proposed criteria for selecting the high design temperature grades for PG binders for Canadian airport pavements.

Level	**Standard Gear Loadings**	**High Design Temperature °C**	
		Approach 1	Approach 2
1	1-4	50% Reliability T_{20mm} Temp	50% Reliability T_{20mm} Temp
2	5-8	(50% T_{20mm} Temp)+8%C	Greater of {83% (1σ) Reliability T_{20mm} or (46°)}+5°C
3	9-12	(Greater of 46°C or 50% T_{20mm} Temp)+14°C	Greater of {98% (2σ) Reliability T_{20mm} or 46°C}+9°C
4	N/A	(Greater of 46°C or 50% T_{20mm} Temp)+18°C	Greater of {99.999% (4σ) Reliability T_{20mm} or 46°C}+12°C

The methodology which incorporates the reliability is considered the more rationale method for the various load levels identified.

Once these initial selection methodologies were developed it was considered desirable to simplify the selection of the high temperature grade. A simplified approach was examined based on constant 6°C changes (i.e. corresponding to 1 Superpave grade) between each load level. This approach duplicates the majority of the grades selected for the airport sites and load levels; however, for Level 4, the simplified approach often resulted in a different high temperature asphalt grade than rationalized with the reliability approach.

Therefore, the reliability approach is considered the more rationale method although a basic rule of thumb will be one grade increase between load levels.

5.0 PG BINDER SELECTION FOR LOW TEMPERATURE PERFORMANCE

5.1 Low Temperature Cracking

Thermal cracking of asphalt pavements is prevalent in most regions of Canada. Thermal cracking is influenced by the asphalt binder stiffness at low temperature more than any other factor. However, other factors that may influence the amount of cracking are the thickness of the asphalt concrete layer, the type of subgrade material (i.e. clay or sand subgrade), age of the asphalt concrete, and reflection of previously cracked pavement through an overlay.

In 1971 Hajek and Haas [Hajek et al, 1971] developed a method for predicting the frequency of cracking. Even though technology has advanced considerably since this paper was presented, the basic concerns are still valid. In their model the following factors were considered:

- Low design temperature
- Stiffness of asphalt cement
- Thickness of asphalt concrete layer
- Age of asphalt concrete
- Subgrade type

When designing a pavement, the parameters that can be controlled by the designer are the stiffness of the asphalt cement and the thickness of the asphalt concrete layer. The other factors are typically considered input to the design only.

More recent research [Haas et al, 1987] examined the thermal cracking at twenty-six selected airports in Canada. This study examined many factors that may influence the amount of thermal cracking and gathered field data to attempt to correlate the various factors with the amount of cracking observed. The data collected included information on climate (minimum temperature, freezing index, and maximum rainfall), asphalt properties (penetration, viscosity, and PVN number), mix properties (stiffness modulus at different temperatures, failure stress, bulk specific gravity, asphalt content, and thermal expansion coefficient), pavement design (thickness of asphalt concrete, base and subbase, spring reduction factor, and width) and pavement age.

The 1987 study concluded that thermal cracking is very dependent upon climatic factors, temperature susceptibility of the asphalt binder, the asphalt layer thickness and the coefficient of thermal contraction of the asphalt concrete. This list of dependent factors agrees very closely with the important factors in the 1971 study of Hajek and Haas.

Haas' 1987 paper selected some asphalt cements which should have been used for various airports based on the draft CGSB specifications of the day (very similar to current CGSB specifications). For most airports a 300-400 penetration grade or softer is the asphalt that would be selected to address low temperature cracking. In some cases a slightly harder 200-300A asphalt with a higher Penetration Index (i.e. less temperature susceptible) was identified as a possible alternate asphalt.

The Superpave PG Binder Selection procedures select the PG binder for cold conditions based on the low design temperature. While the binder specification considers the aging characteristics of the binder, no consideration for subgrade type or thickness of asphalt concrete layer are provided in the PG binder selection procedure.

More recent research [Hiltunen et al, 1994] has been completed on mechanistic-based prediction models for thermal cracking of asphaltic concrete pavements. This work had two goals: (1) to validate the effectiveness of the new SHRP binder and mixture specification tests to control thermal cracking performance of asphaltic pavements in the field, and (2) to develop a pavement performance prediction model to support the new SHRP mixture specifications and for use with the SHRP Superpave software. The model developed was based on fracture mechanics and has two parts, a mechanistic based model that calculates the progression of a vertical crack at one crack site having average material properties and a second part that calculates the global amount of thermal cracking visible on the pavement surface. The model was pavement information (layer types and thicknesses), materials properties (coefficient of thermal contraction, unit weight, thermal conductivity), and environmental data (ground temperature, maximum and minimum air temperature, latitude wind velocity). Once again these significant parameters are similar to the 1971 Hajek and Haas model.

The following sections discuss the above factors and utilize the concepts for developing criteria for the selection of the low design temperature asphalt grade for Canadian airport pavements.

5.2 Low Design Temperature

As discussed in Section 2, the determination of low design temperature to be used in selection of binder is one area that has been debated, especially in Canada, since the publication of the SHRP binder selection procedures. In the original selection criteria, the pavement temperature was assumed to be equal to the air temperature which resulted in the selection of cold temperature binder grades that were unreasonable based on Canadian experience. It was identified by Canadian researchers that pavement temperatures are generally much warmer than air temperatures at cold temperatures.

Three pavement temperature algorithms were presented in Section 2. The three models are as follows:

SP-1 $T_{surf} = 0.859\ (T_{air} - n\sigma_{air}) + 1.7$ (n = 2 for 98% reliability)
TAC $T_{surf} = 0.749\ (T_{air} - n\sigma_{air}) - 1.5\ n$ (n = 1.075 for 98% reliability)
LTPP $T_{surf} = -1.56 + 0.72\ T_{air} - 0.004\ (\text{Latitude})^2 + 8.75 - z(4.4+0.52\sigma_{air}{}^2)^{0.5}$
(z = 2 for 98% reliability)

(The depth term in the LTPP model was replaced with the constant 8.75 for 0 mm depth).

It can be seen that the algorithms will generally result in a much warmer predicted pavement temperature then would be obtained by considering the air temperature alone. A statistical approach is used in each of the models to result in a design temperature based on concepts of reliability. The LTPP model, however, does result in very minimal difference from air temperatures ($\bar{x} + 2\sigma$) at the more northern areas of Canada (and in some cases in the far north, calculates colder pavement than the average air temperature -2σ). The distribution of low temperature grades are shown in Figure 11. Calculated values are given in Appendix F.

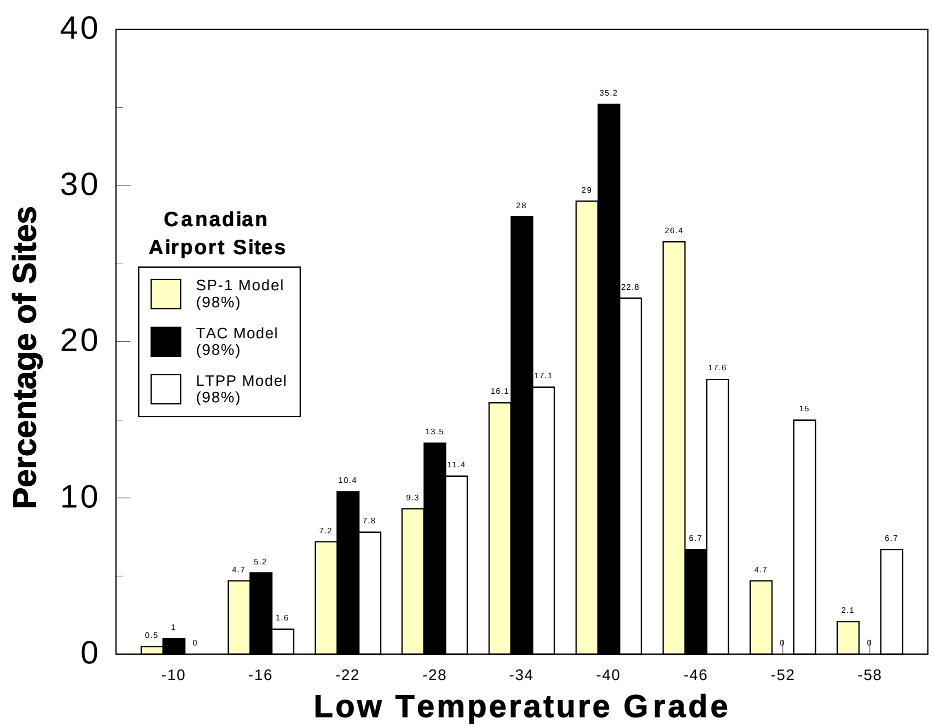

Figure 11 Distribution of Low Temperature Grades for Varying Pavement Design Temperature Algorithms

The TAC model represents further work by Canadian researchers and effectively replaces the SP-1 model. The methodology presented in the TAC model for reliability is based on the probabilities associated with variations in both the air temperature and the model's prediction of pavement temperature (i.e. the error of the estimate). Because the actual air temperature and the predicted pavement temperature are related, it is not clear that the combined probability as defined for the model will result in the actual reliability of the prediction. However, the model results in much more 'reasonable' low temperature grades and as such is seen to be the most practical model for initial use by PWGSC.

Ideally, the low design temperature should be the lowest temperature that the pavement is likely to experience during its design life. This is the lowest surface temperature associated with the lowest air temperature likely to be observed at the pavement location. Since pavement surface temperature is rarely available, it is necessary to estimate the lowest expected pavement surface temperature from available air temperature data.

As noted in the PWGSC study, the type of subgrade has a known affect on frequency of thermal cracking. It was suggested in the 1997 report that the relatively thick granular structures used for airport paving could influence the amount of cracking. For this reason it was recommended that specific information on the relationship of temperature with depth for airport pavements be obtained.

The SHRP temperature database was prepared for use in selection of PG binders and includes the information from over 7500 weather stations including over 1800 weather stations in Canada. This database or the actual temperature data from an airport site should be used as input to determine the winter design pavement temperature. The airport sites and the calculated low design temperatures are given in Appendix F.

5.3 Discussion on Low Temperature Grading

EBA's initial study [PWGSC, 1997] recommended that the design cold pavement temperature be determined for 98% reliability. This level of reliability is considered necessary to address low temperature cracking and is recommended as the initial method to select the PG grade for a given airport pavement. The TAC model is now recommended as the most practical model available.

PG grade asphalts are identified by the coding PGXX-YY where XX is the high temperature coding and YY is the low temperature coding. Since the PG grade testing identifies an asphalt cement in 6°C increments, there is some factor of safety in the grade selection when the design grade is close to the design temperature. For example if the product passes the test at -28°C but fails at -34°C the product designation becomes PGXX-28. Since the product passes at -28°C it is known that the product will not likely crack if pavement temperature reaches -28°C. However, it is uncertain what point cracking will develop between -28°C and -34°C.

Therefore, if the design cold pavement temperature falls between -28°C and -34°C a PGXX-34 grade would be selected. The factor of safety in this instance would be the difference between design cold temperature and -34°C plus the actual temperature at which the asphalt cement testing meets the stiffness criteria which could be an additional 0 to -5°C. (Note that cracking can develop with a single low temperature event and therefore it is not considered appropriate to reduce the grade as a standard practice).

5.4 Asphalt Layer Thickness

As noted previously, work performed by Hajek and Haas 1971 indicates that the thickness of the asphalt concrete layers influence the frequency of thermal cracking in pavements. Palsat (1996) conducted a study of Alberta highway pavements and concluded pavement thickness was a factor in cracking frequency. Palsat's model is shown in Figure 12.

While the reason for the reduced cracking in thick pavements has not been fully explained, Hajek postulated that a thick pavement has a temperature gradient through the asphalt concrete

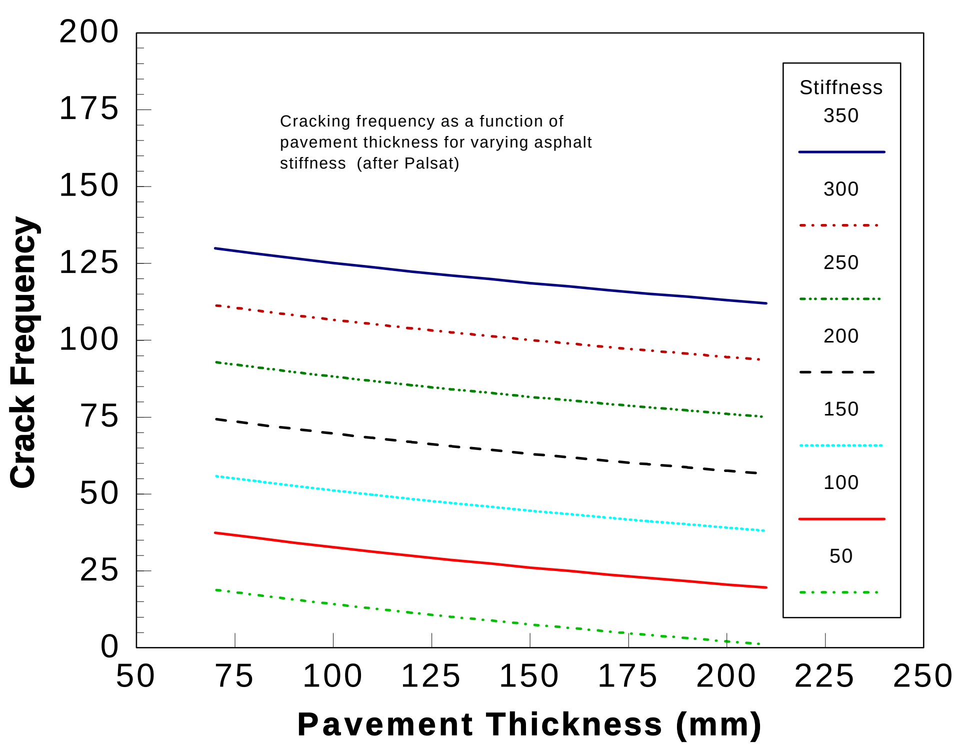

Figure 12 Example of the Influence of Pavment (HMAC) Thickness on Cracking Frequency

layer which may assist in preventing cracks from propagating through the layer. Thus, even if the surface of an asphalt concrete layer reaches the cracking temperature, if the base of the layer is warmer, the crack may not be able to propagate through the layer.

The algorithm for the pavement temperature presented in SP-1 has an expanded form [Robertson, 1997] that deals with the temperature with depth. This model, as shown below, illustrates the influence of pavement thickness on temperature.

$$T_D = 0.859\ T_{air} + (0.02 - 0.0007\ T_{air})D + 1.7°C$$

Where:

D is depth below surface and all other parameters have the same definitions as the previous formula.

In examining this formula it can be observed that the temperature differential with depth is a function of the air temperature and the colder the air temperature, the greater is the differential with depth. At an air temperature of -30°C there is a 3.7°C differential between the surface and 100 mm depth and a 7.8°C differential between the surface and 200 mm depth. The temperature with pavement depth is shown graphically in Figure 13.

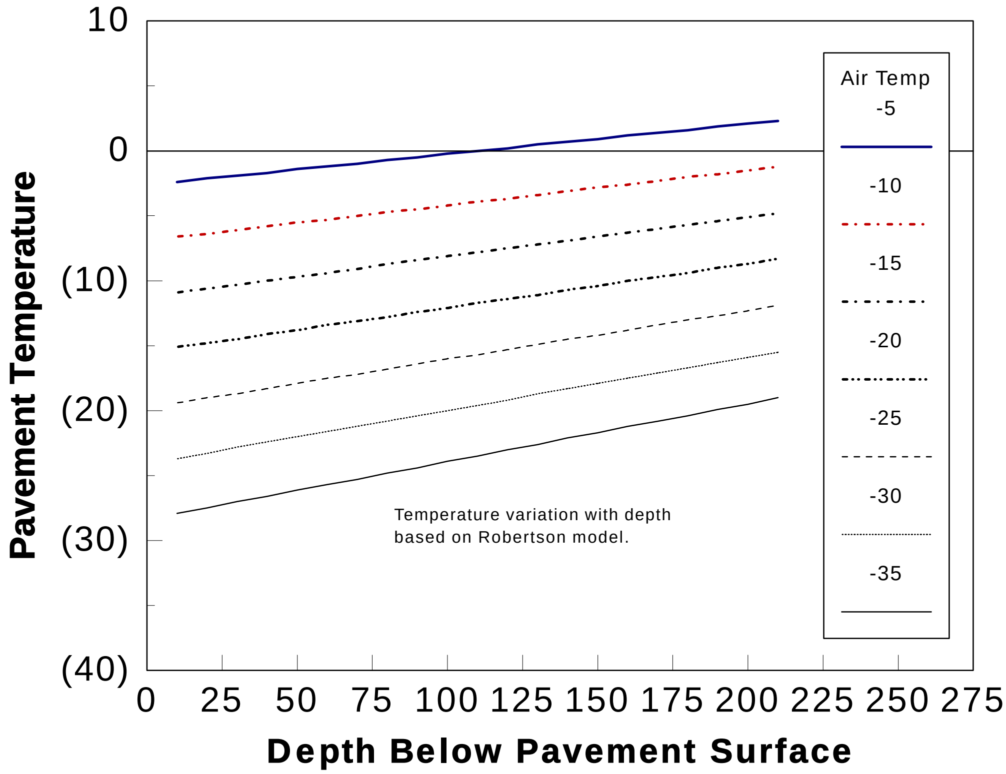

Figure 13 Pavement Temperature with Depth for Varying Air Temperature

Based on the calculated temperatures, and the theory postulated by Hajek, a PG grade may be selected for thick pavements (> 150 mm) that is one grade harder on the low temperature end than for a thin pavement, for those areas with very low design pavement temperatures (most of Canada). However, because the surface of the pavement will still experience the lowest temperatures and cracking may begin in the surficial layer, the selection of a harder grade should only be considered when the PG grade cannot be supplied by local asphalt cement producers without modification (i.e. if the 98% T_{surf} can be readily supplied it is still the desirable product). While it is recognized that thick pavements are not typical for airport pavements (and exceed PWGSC minimum requirements), the influence of pavement thickness on low temperature cracking must be understood by the designer.

5.5 Age of Asphalt Concrete

The asphalt concrete age affects the initiation and frequency of thermal cracking. As an asphalt age hardens the stiffness increases. As the binder increases in stiffness, the pavement will crack at a higher temperature in accordance with its limiting stiffness. For this reason a pavement will crack after several years performance even if the temperatures are more moderate than the initial winter temperatures. (Likewise, the frequency of cracking will increase as the pavement ages).

Superpave, to consider the age hardening process, uses two different testing methods [Asphalt Institute, SP-1]. The Rolling Thin Film Oven Test (RTFOT) and the Pressure Aging Vessel (PAV) both subject tank run asphalt cement to an aging process before testing the high and low temperature properties. This aging process is intended to represent several years (5 to 10 years) of field aging.

Using the two separate aging tests helps ensure that an asphalt cement performs over its design life. A properly selected PG graded asphalt should perform very well for several years after construction (i.e. thermal cracking should not occur until the asphalt age hardens to a point where it is stiffer than predicted by the PAV aging).

5.6 Pavement Overlays

It is expected that most asphalt concrete to be placed on Canadian airports in the future will be overlays over existing (cracked) asphalt concrete or Portland cement concrete pavements. In these cases the amount of cracking in the original surface will influence the cracking in the overlay regardless of the design temperature or the asphalt binder used in the overlay. In order to provide a cost effective approach to selection of asphalt binder for use in overlays, the degree of cracking of the existing surface should be considered. Section 7 discusses considerations in the actual grade selection.

6.0 IMPLEMENTATION OF PROPOSED BINDER SELECTION GUIDELINES

In order to manage and direct the successful implementation of PG graded asphalt binders on Canadian airports, it will be necessary to:

- validate key assumptions that formed the basis for the binder selection guidelines (i.e. that neither rutting nor fatigue are currently significant issues for Canadian Airport pavements (and that existing asphalt grades used are generally providing acceptable performance)).
- assess the impacts resulting from the implementation of the binder selection guidelines
- evaluate the performance of airport pavements constructed with PG binder grades selected following the guidelines

The following tasks have been identified which collectively provide an approach for implementing the proposed binder selection guidelines:

1. Determine the practicality and reasonableness of the selection criteria in terms of the availability of PG binder grades on a regional basis in Canada. (The reasonableness of the criteria has been reviewed on broad scale but specific regional market information must be reviewed by PWGSC or individual designers.)

2. Confirm that airport pavements constructed with asphalt binders selected using current PWGSC guidelines are providing acceptable performance in terms of rutting and fatigue.

3. Integrate the criteria used for binder grade selection, which are based on site specific aircraft loading and climatic conditions, with specification requirements for asphalt concrete aggregates and mix design.

4. Validate low temperature pavement algorithms that have been developed for roadway pavements.

5. Evaluate the field performance of trial sections constructed using PG binders selected following the proposed guidelines.

A detailed methodology for each of these tasks is provided in the following sections.

6.1 Reasonableness of Selected PG Binder Grades

A study should be carried out to assess the availability of PG binder grades on a regional basis as required by the guidelines to ensure the required grades are commercially available at a reasonable cost. Information on availability costs and user requirements should be accessed through suppliers, specifying agencies, and national and regional user - producer groups.

It is understood that PWGSC is currently collecting such information via a regional survey.

6.2 Historical Rutting and Fatigue Performance

The guidelines provided in this report related to high and intermediate temperature performance are based upon asphalt research reported in the literature and the past experience and observation of PWGSC and others which indicate that airport pavements, properly designed and constructed, historically have exhibited acceptable levels of rutting and fatigue cracking distresses. These performance observations should be confirmed through actual field measurements on representative airport taxiways and runways reflecting a range of climate and loading conditions.

There likely exist airport pavements constructed with asphalt cement grades (or modified asphalts) that, for a variety of reasons, do not conform to present PWGSC selection criteria. Attempts should be made to identify these pavements through PWGSC records and through past and present airport operators. Where sufficient information exists regarding pavement inventory and asphalt grades actually used, sites should be selected representing a range of facilities across Canada for detailed pavement condition assessments.

This information should then be analyzed to identify and confirm the influence of binder grades on rutting and fatigue performance.

6.3 Integration of Binder, Aggregate and Mix Design Specifications and Selection Criteria

It is recognized that the performance of an asphalt concrete pavement is a function of the characteristics of the asphalt binder, the asphalt concrete mix and the layer types and thicknesses. Specifically:

Pavement Distress	Influencing Factors
Low Temperature Transverse Cracking	asphalt binder characteristics (and aging affects) asphalt pavement thickness subgrade characteristics
Fatigue Cracking	pavement structural design mix characteristics asphalt binder characteristics loadings

Instability Rutting	asphalt mix design/mix characteristics aggregate characteristics asphalt binder characteristics loadings

It is necessary to assess aggregate and mix design requirements in conjunction with the implementation of PG binder specifications, e.g. coarse aggregate angularity, fine aggregate angularity, moisture sensitivity, Marshall vs Superpave Level 1 mix design, etc. Aggregate and mix design specifications should be reviewed in conjunction with the proposed PG binder implementation. Criteria should be established for the selection of aggregate and mix design specifications that are also based on site specific loading and climatic conditions.

6.4 Validation of Low Pavement Temperature Algorithms

The various low temperature algorithms used to select the PG low temperature grade should be validated for airport pavements. Airport pavements differ from highway pavements in that asphalt concrete thicknesses are generally less, and thicknesses of granular base and subbases are often substantially greater for frost protection purposes. These conditions may result in different temperature regimes within the pavement layers during the coldest parts of the winter. Validation is necessary to ensure that low pavement temperatures are not under-estimated and that the proper asphalt binder is selected for site conditions and deep granular structures. Air, asphalt pavement, granular base and subgrade temperatures should be collected at several airport sites across Canada representing a range of winter climatic conditions. This monitoring could be coordinated with the construction of test sections.

6.5 Evaluate Field Performance of PG Binders

The guidelines provided in this report may result in the selection of asphalt binder grades, including modified asphalts, that in the past would not have been used on many airport pavements. Construction of test sections, test projects or demonstration projects are required to validate, under field operating and environmental conditions, the acceptability of the longer term performance with the implementation of Superpave binder specifications.

Given that airport pavements have historically provided acceptable performance in terms of rutting and fatigue cracking, the initial primary focus on implementation of PG graded binders should be to evaluate the low temperature cracking performance of new construction flexible pavements and asphalt overlays of existing flexible pavement structures.

In general, a test section should utilize a PG grade as selected by the guidelines presented in this report, that is at least one grade different than what would have been selected following ASG-06 or what would be normal past local practice.

General guidelines for the design of trial sections to evaluate the low temperature field performance of PG binders are provided in Section 6.5.1. A detailed methodology using the Calgary International Airport as an example is provided in Section 6.5.2.

6.5.1 Guidelines for the Design of PG Asphalt Trial Sections

As previously discussed, the guidelines provided in this report will, in some cases, result in different binder grades being selected than the "equivalent" grade that would have been used in the past. For example, for Runways and Taxiways:

	Equivalent PG Grade and CGSB Grade as per present PWGSC Guidelines	Recommended PG Grade as per the Guidelines in this Report (Load Groups)
Vancouver International	64 -22 (80-100)	58-16 (Level 3)
Winnipeg International	58 -28 (150-200)	64-34 (Level 3)
Cooking Lake, AB	58 -28 (150-200)	46-40 (Level 1)
Toronto Pearson International	64 -22 (80-100)	64-28 (Level 3)
Montreal	58-22 (120-150)	64-28 (Level 3)
Yellowknife	58-28 (150-200)	58-40 (Level 3)
Thunder Bay	58-28 (150-200)	58-34 (Level 3)
Halifax	58-22 (120-150)	58-22 (Level 2)
Fredericton, NB	58 - 22 (120-150)	64-28 (Level 3)
Calgary International	58 -22 (120-150)	58 - 34 (Level 3)

Test sections are constructed to evaluate performance under field operating and environmental conditions. Often sections are included that are designed to fail at an early stage in order to provide validation of design limits or to assess the degree of conservatism within the design limits. In the case of airport pavements, it is recognized that the risk of a pavement failure may not be acceptable in terms of aircraft safety, aircraft damage (FOD) or the disruption of airport operations during maintenance, repair or reconstruction. This risk needs to be considered in the design and construction of test sections.

Further, the use of PG asphalt grades on roadway projects in Canada has progressed rapidly as an accepted design practice, at least on a minority of projects, and therefore the constructability of pavements incorporating these asphalt binders need not be an issue for evaluation. However, the performance history of modified asphalt binders on Canadian roadways is significantly shorter than for conventional paving grade asphalt cements and may be even more limited on airports. Therefore, the performance of modified asphalts in particular requires field validation.

The primary objective for the construction of test sections are to:

- allow the assessment of long term pavement performance,
- confirm the principles that form the basis of the guidelines, and
- validate the guideline selection criteria.

The following general guidelines for the construction of test sections are provided:

1. Type of Construction - Incorporation of a test section within a new construction project is the most desirable as the characteristics and conditions of the entire new pavement structure, including subgrade and subbase and base course layers, can be controlled or adequately monitored and documented. The incorporation of a test section within an asphalt overlay of an existing cracked pavement in order to evaluate low temperature performance would be ineffective as the low temperature cracking behaviour of the asphalt overlay is generally governed by existing crack conditions and/or the low temperature behaviour of the existing pavement structure or subgrade.

2. Airport Sites - Consideration should be given to locating test sections in several major geographical/climatic zones, with a range of loadings represented and that reflect the spectrum of potential PG grades (including modified asphalts) that could be used on Canadian airports.

3. Airport Facility - Risk of unsatisfactory performance of the test section must be considered. For a major airport, a tangent section of a taxiway where infrequent stopping is anticipated is most desirable. On minor airports, a portion of the runway would be acceptable.

4. Size and Location of Test Section - The size and location of a test section is a function of:

    - Location within the facility (taxiway or runway) - The performance of a test section can be influenced or affected by the performance of the adjoining pavement. Ideally the width of the test section should coincide with the width of the facility. For example, a test section located on a runway should extend the entire width of the runway.

Test sections constructed within a runway will result in transverse construction joints at each end which is considered undesirable. It is difficult from a construction point of view to change asphalt grades "on-the-run" and to coordinate supply of mix with the beginning and ending of the test section. Test section locations should be placed at the ends of runways to minimize the number of construction joints. Due to the reduced width of a taxiway, the location of a test section within a taxiway is less critical.

- Geometry of the Facility (taxiway or runway) - The low temperature cracking performance in terms of transverse crack spacing may be affected by the geometry, or the ratio of length to width, of the test section. A linear geometry is required to ensure that low temperature cracking parallel to the centreline of the taxiway or runway does not occur. Therefore, the desirable length of a test section should be about ten times the width of the facility. In the case of runway widths of 30 m, 45 m and 60 m, desirable test section lengths would be 300 m, 450 m and 600 m, respectively.

5. Control Section - A control section at least equivalent in size to the test section must be included. The control section should be identical to the rest of the construction in terms of pavement design thickness, mix design and asphalt binder. However, the purpose of the control section is to provide the identical monitoring program as the test section and will provide the basis for long term performance comparisons.

6. Pre-Construction Surveys - It is necessary to document pre-construction conditions of the locations of the test and control sections and to identify all conditions that may have an influence on their performance. In the case of new construction this may be as simple as an air photo review. The detailed pre-construction survey would also be used to set the actual limits of the sections.

7. Construction Monitoring, Testing, Sampling and Documentation - It is necessary to carry out a program to document the characteristics and properties of all materials incorporated into the sections. These results would be used to confirm that specification requirements, in particular properties of PG binders supplied, have been achieved and that actual properties of as-supplied binders are characterized. The results would also be used to confirm that aggregate and mix designs specifications for both the test and control sections have been achieved. This latter requirement is very important to ensure that conclusions reached at some time in the future based upon any observed differences in performance between the test sections and control sections reflect the influences of binder properties only.

This program would also document conditions at the time of construction, the sequence of construction activities, as-built pavement layer thicknesses, degree of compaction, in-place air voids, etc. and any other observations.

Sampling of binders, aggregates and asphalt mixtures incorporated into the work would be carried out for future testing or validation as required. Any core samples retrieved as part of the QC/QA testing program or follow-up monitoring should be located in transition areas outside of the crack monitoring area.

A construction report documenting as-built locations of all QC/QA test results must be prepared for future references.

8. Instrumentation Installation - To provide temperature data required to validate low pavement temperature algorithms, installation of thermistors within the asphalt concrete and underlying granular base course, granular subbase and subgrade to a depth of about 2 m are required in addition to site air temperature. These should be automatically and continuously monitored, along with air temperature. It is not considered necessary to install crack detection loops to determine actual pavement cracking temperatures as the purpose is not to determine the temperature of the pavement or air at the time of cracking. This has been established by other researchers. However, it would be important to carry out periodic inspections especially during and following cold spells in order to identify any crack occurrences.

   Temperature monitoring should continue for two to four winter seasons depending on the severity of winter weather conditions.

9. Post Construction Monitoring - A rigorous post construction monitoring program should be established to include:

   - periodic visual inspections in spring and fall - documentation of all surface distress, classification and mapping of all cracks, transverse profile measurements.
   - visual inspections during and following cold spells to identify the occurrence of the first and subsequent low temperature cracks.

   Depending upon observations, it may be required to carry out a field sampling and laboratory testing program in order to measure and evaluate changes in properties with time.

The key to a successful field validation program is to identify personnel responsible for documentation, monitoring and evaluation of results. It is not uncommon for enthusiasm to disappear after initial construction and, through staff changes or disinterest, for records and documentation to be lost and monitoring programs not achieved.

6.5.2 PG Asphalt Trial Section - Detailed Methodology-Calgary International Airport

The construction of Taxiway Juliet at the Calgary International Airport may provide an opportunity for the construction of a test section. A more detailed methodology for the establishment of a test section to evaluate the field performance of PG binders is provided in this section using the Calgary project as an example.

Project Description

Taxiway Juliet is to be new construction of a flexible pavement structure. The asphalt portion of the taxiway will be about 1000 m long and 23 m wide with 10.5 wide paved shoulders. The recommended structures are:

Main Taxiway	**Paved Shoulders**
200 mm Asphalt Concrete	80 mm Asphalt Concrete
300 mm Crushed Granular Base	250 mm (min) Crushed Granular Base
1050 mm Pit Run Aggregate Subbase	300 mm (min) Pit Run Aggregate Subbase

The project consultant's recommended asphalt cement grade is a 150-200A which, from Alberta sources, grades to a PG58-28. Based upon the guidelines presented in this report, the recommended PG grade is 58-34; it is understood that this binder supplied from local Alberta sources would not require polymer modification.

In order to provide validation of the low temperature PG grade selection as recommended in the guidelines of this report that would have application to airport pavements across Canada, it would be desirable to incorporate the following grades into the test sections:

150-200 A (PG58-28)	(as per project consultant recommendations)
PG58-34	(as per recommended guidelines)
120-150 A (PG58-28)	(as per current PWGSC ASG-06 guidelines)

These three grades would reflect relative low temperature cracking properties between -28°C and -34°C. It is interesting to note that 120-150A and 150-200A may both grade to a PG58-28. Based upon past experience in Alberta, 120-150A and 150-200A would be expected to provide different high and low temperature performance. It would be expected that all three grades may have similar high temperature properties. However, both high and low temperature properties would need to be confirmed based on the properties of the actual asphalt binders supplied. Depending on the severity of winter conditions and the in-place binder properties, a monitoring period of 3 to 5 years or more may be required before differences in low temperature performance are observed.

Objectives of the Test Section

The objectives of the construction of these test sections on Taxiway Juliet are:

1. To validate the proposed binder grade selection guidelines for low temperature grade selection,
2. To validate the SHRP low temperature algorithm currently being used to select low temperature PG grades.

These objectives will be accomplished by:

1. The assessment of the long term low temperature performance of the test sections and control section.
2. The installation of thermistors within the overall pavement structure and monitoring of temperatures over the winter months over several years. (There also may be a benefit of monitoring temperatures over the summer months as well.)

The cross-section of the taxiway, with a centre 23 m wide portion with a 200 mm thick asphalt layer, and two adjoining 10.5 m wide shoulders with a 80 mm thick asphalt layer, will, in effect, provide two subsections with each test section. It has been identified by others [Hajek et al, 1971], [Palsat, 1986], [Haas et al, 1987] that the frequency of low temperature cracking will be affected by a thickness of the asphalt concrete layer. All other factors being equal, it would be expected that shoulder sections would develop a higher crack frequency than the taxiway. It would be expected that a longitudinal crack would form out the interface between the taxiway and shoulder that would allow the two sections to perform independently.

It is considered that this project would be an adequate candidate to allow validation of the low temperature performance of the three asphalt binders identified.

Size of Test and Control Sections

As discussed, two test sections and one control section would be considered desirable to be incorporated into the construction:

Test Section 1	-	PG58-34
Test Section 2	-	120-150A (PG58-28)
Control Section	-	150-200A (PG58-28)

Each section should be about 200 m long by 44 m wide which corresponds to the total width of the taxiway plus paved shoulders. Each section would require about 2700 tonnes of mix and about 160 tonnes of binder.

The three sections should be constructed contiguously to minimize effects of variations in subgrade characteristics and should be located along a tangent section in an area where aircraft operations will be consistent (i.e. where aircraft are not expected to stop or slow down).

Even though the same binder grade would be used for both the main taxiway and for the adjoining paved shoulders, the low temperature cracking performance would not be expected to be the same. These conditions therefore would provide an opportunity to assess and quantify the effect of asphalt concrete pavement thickness on low temperature cracking frequency.

Pre-Construction Survey

The results of field drilling and laboratory testing program carried for the design of the taxiway should be reviewed along with available aerial photographs. Based upon this review and the design of the final alignment, actual test section locations can be determined. Test section locations must reflect sections which are as similar as possible.

Construction Monitoring, Testing, Sampling and Documentation

This program would include for both control and test sections:

- documentation of mix designs
- sampling and verification QA testing of asphalt binder as supplied to the project; the as-supplied binders should be tested to verify conformance to requirements for the specified grade and to measure actual properties and temperatures as per SHRP protocols and procedures (i.e. determine specific temperatures where stiffness and complex modulus requirements are achieved). Recovered asphalt should also be tested.
- sampling and verification QA testing of aggregate materials incorporated into subbase and granular base courses (gradation, moisture content, as-built density)
- sampling and verification QA testing of asphalt concrete mixes incorporated into the work (asphalt content, Marshall densities, voids analysis, gradation, mix temperatures, % compaction, surface smoothness, surface deficiencies, segregation, checking, tearing, etc.)
- documentation of sequence of construction, construction equipment, weather conditions
- retention of asphalt binder, aggregates and asphalt mixture samples for future testing if required.

A construction report documenting as-built locations of all QC/QA test results should be prepared for future references.

Instrumentation Installation

Thermistor strings should be installed in the pavement structure at four locations - two near the middle of the taxiway and two within the paved shoulder. This will provide information on low temperature profiles at two different offsets and also provide a factor of safety if one string becomes dysfunctional. Air temperature data from the existing airport facilities can be used if available; if not available (such as at the Calgary airport) provision must be made to collect ambient air temperatures. Thermistors should be located at the following depths within the pavement structure:

Taxiway Layer Thickness	Depth From Surface (mm)	Depth of Thermistor (mm)
200 ACP	0-200	near surface 200
300 GBC	200-500	500
1050 Pit Run	500-1550	1000 1500
Subgrade	> 1550	2000

Paved Shoulder Layer Thickness	Depth from Surface (mm)	Depth of Thermistor (mm)
80 ACP	0-80	near surface 80 mm
250 (min) GBC	80-330	330
300 (min) Pit Run	330-630	600
Subgrade		1000 1500 2000

It is considered necessary only to monitor the near surface and bottom surface of the asphalt concrete layer. The pavement temperature at the two depths, along with air temperature, is required to validate the SHRP low temperature algorithm. Temperatures at the bottom of the asphalt pavement layer for both the 80 mm thick shoulder and 200 mm thick taxiway are required to model the pavement temperature with depth which allows for the prediction of surface temperature.

Installation of thermistors within both the shoulder and the taxiway is required as a different temperature profile would be expected because the pavement structures are significantly different.

Installation of thermistor at depth within the granular base and underlying subgrade will allow the effects of different granular thicknesses on overall depth of frost penetration. This information could be considered optional but would also provide validation of PWGSC design practice with respect to frost protection.

The strings should be connected to a data logger along the taxiway and ideally linked using cellular phone technology to allow for continuous remote monitoring of temperatures during winter periods for several winter seasons depending on the severity of individual winter conditions.

Post Construction Monitoring

A rigorous post construction monitoring program should be established to include:

- periodic visual inspections in spring and fall - documentation of all surface distress, classification and mapping of all cracks, transverse profile measurements.
- visual inspections during and following cold spells to identify the occurrence of the first and subsequent low temperature cracks.

Depending upon observations, it would be desirable to carry out a field sampling and laboratory testing program in order to measure and evaluate changes in properties with time.

6.5.3 Summary

The primary objectives associated with the construction of test sections are:

1. the validation of proposed binder grade selection guidelines
2. the validation of low temperature algorithms

Key activities associated with the successful achievement of these objectives are:

1. Selection of test sections and control section locations and determine dimensions and quantities.
2. Coordination of development of specifications and special provisions.
3. Development, coordination and documentation of construction monitoring, QA testing and sampling programs.
4. Coordination and installation of instrumentation.
5. Analysis of construction QA testing programs and preparation of documents report.
6. Documentation and coordination of post construction laboratory testing programs.
7. Carry out and document semi-annual inspections. Carry out inspections following cold spells to document incidence first crack generations.
8. Monitor instrumentation.
9. Analyze data from instrumentation and validate low temperature algorithms.

10. Analyze the results of all testing programs and field performance observations and provide validation or alternatively, recommendations for modification to selection guidelines.
11. Provide documenting reports.

These activities should be assigned to an individual or organization that would clearly be responsible for their successful implementation and achievement.

7.0 SUMMARY OF RECOMMENDED BINDER SELECTION PROTOCOL

The recommended binder selection criteria for performance graded asphalts for Canada airport pavements are:

1. Select high design temperature grade on the basis of reliability and load level as described in Section 4. Appendix A contains the grades calculated for each Canadian airport in the LTPPBIND weather database.

    - for Apron applications select one load level higher
    - for high frequency usage by the same aircraft type (creating channelized loadings) an increase of one level is warranted. High frequency loading would be greater than about 0.25 million repetitions of the same aircraft type.

2. Select low design temperature grades on the basis of 98% reliability using the algorithm for low pavement temperature as presented by TAC.

    $T_{surf} = 0.749(T_{air} + n\sigma_{air}) + 1.5\ n$ where n = 1.075 for 98% reliability

    - for new construction, thick overlays or overlays over non-thermally cracked pavements consider this the desirable low temperature grade. Recognize that grades lower than -40°C are not current available.
    - for overlays over thermally cracked pavements, or PCC pavements, confirm the grade relative to the need for a modified asphalt. If the spread between the high and low temperature is greater than about 90°C, a modified asphalt is typically required (will vary somewhat by region).
      For overlays, the low temperature grade can be relaxed one grade "warmer" to eliminate the need for modification.

***Discussion on Modified Asphalts*.**

The use of modified asphalts to achieve the selected design grades will generally be required when the design temperature range (i.e. °C between the high and low grading) exceeds 90. For low temperatures colder than -40°C even modified asphalts are not commercially available.

At this time it is recommended that the use of polymer modified binders (at high premiums) be restricted to test projects until the economics can be proven. The use of life cycle analysis is recommended to support the use of such premium asphalts. Test projects should be monitored over a period of several years. Additionally, it is recommended that life cycle costing be utilized for justifying the use of all modified binders.

Practical Application of Guidelines

Figure 11 shows the distribution of the low temperature grades which would be selected for Canadian airport sites based on the LTPPBIND database and the three low temperature algorithms. In many cases it will not be practical to design airport pavements to perform at the low temperature extremes (for a large number of Canadian sites) with respect to thermal cracking. In this regard the designer is encouraged to utilize a common sense approach, in conjunction with a life cycle cost analysis, in arriving at the final recommended asphalt grade. This includes reviewing the actual T_{surf} temperature to evaluate the reliability of the selected grade; i.e. is the grade selected really 99.99% reliability to meet the 98% criteria?

8.0 CLOSURE

EBA appreciates the opportunity afforded by PWGSC to contribute to this leading edge development in the area of asphalt and airport engineering.

Yours truly,
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APPENDIX A

RECOMMENDED PG GRADES
FOR CANADIAN AIRPORT PAVEMENTS

Recommended Asphalt Grade Selection

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
CALGARY GLENMORE DAM	AB	46	52	58	64	-34
COLD LAKE A	AB	46	52	58	64	-40
CORONATION A	AB	46	58	58	64	-34
COWLEY A	AB	52	58	64	70	-34
EDMONTON INT'L A	AB	46	52	58	64	-40
EDMONTON MUNICIPAL A	AB	46	52	58	70	-34
EDMONTON NAMAO A	AB	46	52	58	64	-34
EDSON A	AB	46	52	58	64	-40
EMBARRAS A	AB	46	52	58	64	-40
FORT CHIPEWYAN A	AB	46	52	58	64	-40
FORT MCMURRAY A	AB	46	52	58	64	-40
GRANDE PRAIRIE A	AB	46	52	58	64	-40
HIGH LEVEL A	AB	46	52	64	76	-40
LETHBRIDGE A	AB	52	58	64	70	-34
PEACE RIVER A	AB	46	52	58	64	-40
RED DEER A	AB	46	52	58	64	-34
SLAVE LAKE A	AB	46	52	58	64	-34
SUFFIELD A	AB	52	58	64	70	-34
VERMILION A	AB	46	52	58	64	-40
ABBOTSFORD A	BC	46	58	64	70	-16
BEATTON RIVER A	BC	46	52	58	58	-40
BLUE RIVER A	BC	52	58	64	70	-34
CAMPBELL RIVER A	BC	52	58	64	70	-22
CASTLEGAR A	BC	52	64	70	76	-22
COMOX A	BC	46	52	58	70	-16
CRANBROOK A	BC	52	58	64	70	-34

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
CRANBROOK A	BC	52	58	64	70	-34
DAWSON CREEK A	BC	46	52	58	64	-40
FORT NELSON A	BC	46	52	58	64	-40
FORT ST JOHN A	BC	46	52	58	64	-34
HOPE A	BC	52	58	64	70	-16
KAMLOOPS A	BC	52	58	64	70	-28
KELOWNA A	BC	52	64	70	0	-28
KIMBERLEY A	BC	52	58	64	70	-34
NANAIMO A	BC	52	58	64	70	-16
PENTICTON A	BC	52	58	64	70	-22
PORT ALBERNI A	BC	52	58	64	76	-16
PORT HARDY A	BC	46	52	58	58	-10
POWELL RIVER A	BC	46	52	58	70	-16
PRINCE GEORGE A	BC	46	52	58	64	-40
PRINCE RUPERT A	BC	46	52	58	58	-22
PRINCETON A	BC	52	58	64	76	-34
QUESNEL A	BC	52	58	64	70	-34
REVELSTOKE A	BC	52	58	64	70	-28
SANDSPIT A	BC	46	52	58	58	-16
SMITH RIVER A	BC	46	52	58	58	-46
SMITHERS A	BC	46	52	58	64	-34
TERRACE A	BC	46	52	64	70	-22
TOFINO A	BC	46	52	58	64	-10
VANCOUVER INT'L A	BC	46	52	58	64	-16
VICTORIA INT'L A	BC	46	52	58	64	-16
WILLIAMS LAKE A	BC	46	52	58	70	-34
BRANDON A	MB	52	58	64	70	-34
BROCHET A	MB	46	52	58	64	-40
CHURCHILL A	MB	46	52	58	58	-40

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
DAUPHIN A	MB	52	58	64	70	-34
FLIN FLON A	MB	46	52	58	64	-40
GILLAM A	MB	46	52	58	64	-40
GIMLI A	MB	52	58	58	64	-34
ISLAND LAKE A	MB	46	52	58	64	-34
LYNN LAKE A	MB	46	52	58	64	-40
PORTAGE LA PRAIRIE A	MB	52	58	64	70	-34
RIVERS A	MB	52	58	64	70	-34
THE PAS A	MB	46	52	58	64	-40
THOMPSON A	MB	46	52	58	70	-40
WINNIPEG INT'L A	MB	52	58	64	70	-34
CHARLO A	NB	52	58	64	70	-28
CHATHAM A	NB	52	58	64	70	-28
FREDERICTON A	NB	52	58	64	70	-28
MONCTON A	NB	52	58	64	70	-28
SAINT JOHN A	NB	46	52	58	64	-28
ARGENTIA A	NF	46	52	58	58	-16
BUCHANS A	NF	46	52	58	64	-28
CHURCHILL FALLS A	NF	46	52	58	58	-34
DEER LAKE A	NF	46	52	58	64	-28
GANDER INT'L A	NF	46	52	58	64	-22
GOOSE A	NF	46	52	58	64	-34
NAIN A	NF	46	52	58	64	-34
ST JOHN'S A	NF	46	52	58	64	-22
STEPHENVILLE A	NF	46	52	58	58	-22
WABUSH LAKE A	NF	46	52	58	64	-40
GREENWOOD A	NS	52	58	64	70	-22
HALIFAX INT'L A	NS	52	58	58	64	-22
SHEARWATER A	NS	46	52	58	64	-22

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
SYDNEY A	NS	46	58	58	64	-22
YARMOUTH A	NS	46	52	58	64	-22
AKLAVIK A	NT	46	52	58	58	-40
BAKER LAKE A	NT	46	52	58	58	-40
BYRON BAY A	NT	46	52	58	58	-40
CAMBRIDGE BAY A	NT	46	52	58	58	-40
CAPE DORSET A	NT	46	52	58	58	-40
CAPE DYER A	NT	46	52	58	58	-40
CAPE PARRY A	NT	46	52	58	58	-40
CAPE YOUNG A	NT	46	52	58	58	-40
CLYDE A	NT	46	52	58	58	-40
CORAL HARBOUR A	NT	46	52	58	58	-40
FORT GOOD HOPE A	NT	46	52	58	58	-46
FORT NORMAN A	NT	46	52	58	58	-46
FORT RESOLUTION A	NT	46	52	58	64	-40
FORT SIMPSON A	NT	46	52	58	64	-40
FORT SMITH A	NT	46	52	58	64	-40
GLADMAN POINT A	NT	46	52	58	58	-40
HALL BEACH A	NT	46	52	58	58	-40
HAY RIVER A	NT	46	52	58	64	-40
INUVIK A	NT	46	52	58	58	-40
IQALUIT A	NT	46	52	58	58	-40
JENNY LIND ISLAND A	NT	46	52	58	58	-40
LADY FRANKLIN POINT A	NT	46	52	58	58	-40
MOULD BAY A	NT	46	52	58	58	-40
NORMAN WELLS A	NT	46	52	58	58	-40
RESOLUTE A	NT	46	52	58	58	-40
SACHS HARBOUR A	NT	46	52	58	58	-40
SHEPHERD BAY A	NT	46	52	58	58	-46

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
TUKTOYAKTUK A	NT	46	52	58	58	-40
WRIGLEY A	NT	46	52	58	64	-46
YELLOWKNIFE A	NT	46	52	58	58	-40
ARMSTRONG A	ON	46	52	58	64	-40
CENTRALIA A	ON	52	58	64	70	-22
DRYDEN A	ON	52	58	64	70	-34
EARLTON A	ON	52	58	64	70	-40
GORE BAY A	ON	52	58	64	70	-28
GRAHAM A	ON	46	58	64	70	-40
HAMILTON A	ON	52	58	64	70	-22
KAPUSKASING A	ON	46	58	58	70	-34
KENORA A	ON	46	58	58	70	-34
KINGSTON A	ON	52	58	64	70	-28
LONDON A	ON	52	58	64	70	-28
MUSKOKA A	ON	52	58	64	70	-34
NAKINA A	ON	46	52	58	64	-40
NORTH BAY A	ON	52	58	64	70	-34
OTTAWA INT'L A	ON	52	58	64	70	-28
OTTAWA ROCKCLIFFE A	ON	52	58	64	70	-28
PAGWA A	ON	46	58	64	70	-34
PETAWAWA A	ON	52	58	64	70	-34
PETERBOROUGH A	ON	52	58	64	70	-34
RED LAKE A	ON	46	58	64	70	-40
SARNIA A	ON	52	58	64	70	-22
SAULT STE MARIE A	ON	52	58	64	70	-34
SIOUX LOOKOUT A	ON	46	58	58	70	-34
SUDBURY A	ON	52	58	64	70	-34
THUNDER BAY A	ON	46	58	58	64	-34
TIMMINS A	ON	52	58	64	70	-34

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
TORONTO DOWNSVIEW A	ON	52	58	64	76	-28
TORONTO ISLAND A	ON	52	58	64	70	-22
TORONTO PEARSON INT'L A	ON	52	58	64	70	-28
TRENTON A	ON	52	58	64	70	-28
WATERLOO WELLINGTON A	ON	52	58	64	70	-28
WIARTON A	ON	52	58	64	70	-28
WINDSOR A	ON	52	64	64	76	-22
CHARLOTTETOWN A	PE	46	52	58	64	-22
SUMMERSIDE A	PE	46	58	58	64	-22
BAGOTVILLE A	PQ	52	58	64	70	-34
BAIE COMEAU A	PQ	46	52	58	64	-34
GAGNON A	PQ	46	52	58	70	-40
GASPE A	PQ	46	52	58	64	-28
KUUJJUAQ A	PQ	46	52	58	58	-40
KUUJJUARAPIK A	PQ	46	52	58	64	-40
LA MACAZA A	PQ	52	58	64	70	-40
MEGANTIC A	PQ	46	58	64	70	-34
MONT JOLI A	PQ	46	52	58	64	-28
MONTREAL/DORVAL INT'L A	PQ	52	58	64	70	-28
NATASHQUAN A	PQ	46	52	58	58	-28
QUEBEC A	PQ	52	58	64	70	-28
ROBERVAL A	PQ	46	58	64	70	-34
SCHEFFERVILLE A	PQ	46	52	58	64	-40
SEPT-ILES A	PQ	46	52	58	58	-34
SHERBROOKE A	PQ	52	58	64	70	-34
ST HUBERT A	PQ	52	58	64	70	-28
VAL D'OR A	PQ	52	58	64	70	-34
BROADVIEW A	SK	52	58	64	70	-34
DAFOE A	SK	46	58	64	70	-40

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
ESTEVAN A	SK	52	58	64	70	-34
LA RONGE A	SK	46	52	58	64	-40
MOOSE JAW A	SK	52	58	64	70	-34
NORTH BATTLEFORD A	SK	46	52	58	64	-34
PRINCE ALBERT A	SK	46	52	58	64	-40
REGINA A	SK	52	58	64	70	-40
SASKATOON A	SK	52	58	64	70	-40
SWIFT CURRENT A	SK	52	58	64	70	-34
URANIUM CITY A	SK	46	52	58	64	-40
YORKTON A	SK	52	58	64	70	-34
AISHIHIK A	YT	46	52	58	58	-46
BEAVER CREEK A	YT	46	52	58	58	-46
BURWASH A	YT	46	52	58	64	-46
KOMAKUK BEACH A	YT	46	52	58	58	-40
MAYO A	YT	46	52	58	64	-46
OLD CROW A	YT	46	52	58	70	-46
ROSS RIVER A	YT	46	52	58	64	-46
SHINGLE POINT A	YT	46	52	58	58	-40
SNAG A	YT	46	52	58	64	-46
TESLIN A	YT	46	52	58	70	-40
WATSON LAKE A	YT	46	52	58	64	-46
WHITEHORSE A	YT	46	52	58	64	-40

APPENDIX B

COMPARISON OF SIMPLIFIED GRADE SELECTION

Comparison of Simplified Grade Selection

STATION	Province	Level 1	Level 2	Level 3	Level 4
CALGARY GLENMORE DAM	AB	46 (46)	52 (52)	58 (58)	64 (64)
COLD LAKE A	AB	46 (46)	52 (52)	58 (58)	64 (64)
CORONATION A	AB	46 (46)	58 (52)	58 (58)	64 (64)
COWLEY A	AB	52 (52)	58 (58)	64 (64)	70 (70)
EDMONTON INT'L A	AB	46 (46)	52 (52)	58 (58)	64 (64)
EDMONTON MUNICIPAL A	AB	46 (46)	52 (52)	58 (58)	70 (64)
EDMONTON NAMAO A	AB	46 (46)	52 (52)	58 (58)	64 (64)
EDSON A	AB	46 (46)	52 (52)	58 (58)	64 (64)
EMBARRAS A	AB	46 (46)	52 (52)	58 (58)	64 (64)
FORT CHIPEWYAN A	AB	46 (46)	52 (52)	58 (58)	64 (64)
FORT MCMURRAY A	AB	46 (46)	52 (52)	58 (58)	64 (64)
GRANDE PRAIRIE A	AB	46 (46)	52 (52)	58 (58)	64 (64)
HIGH LEVEL A	AB	46 (46)	52 (52)	64 (58)	76 (64)
LETHBRIDGE A	AB	52 (52)	58 (58)	64 (64)	70 (70)
PEACE RIVER A	AB	46 (46)	52 (52)	58 (58)	64 (64)
RED DEER A	AB	46 (46)	52 (52)	58 (58)	64 (64)
SLAVE LAKE A	AB	46 (46)	52 (52)	58 (58)	64 (64)
SUFFIELD A	AB	52 (52)	58 (58)	64 (64)	70 (70)
VERMILION A	AB	46 (46)	52 (52)	58 (58)	64 (64)
ABBOTSFORD A	BC	46 (46)	58 (52)	64 (58)	70 (64)
BEATTON RIVER A	BC	46 (46)	52 (52)	58 (58)	58 (64)
BLUE RIVER A	BC	52 (52)	58 (58)	64 (64)	70 (70)
CAMPBELL RIVER A	BC	52 (52)	58 (58)	64 (64)	70 (70)
CASTLEGAR A	BC	52 (52)	64 (58)	70 (64)	76 (70)
COMOX A	BC	46 (46)	52 (52)	58 (58)	70 (64)
CRANBROOK A	BC	52 (52)	58 (58)	64 (64)	70 (70)
CRANBROOK A	BC	52 (52)	58 (58)	64 (64)	70 (70)
CRANBROOK A	BC	52 (52)	58 (58)	64 (64)	70 (70)
CRANBROOK A	BC	52 (52)	58 (58)	64 (64)	70 (70)
DAWSON CREEK A	BC	46 (46)	52 (52)	58 (58)	64 (64)

Bracketed values based on the simplified selection approach described in Section 4

STATION	Province	Level 1	Level 2	Level 3	Level 4
FORT NELSON A	BC	46 (46)	52 (52)	58 (58)	64 (64)
FORT ST JOHN A	BC	46 (46)	52 (52)	58 (58)	64 (64)
HOPE A	BC	52 (52)	58 (58)	64 (64)	70 (70)
KAMLOOPS A	BC	52 (52)	58 (58)	64 (64)	70 (70)
KELOWNA A	BC	52 (52)	64 (58)	70 (64)	0 (70)
KIMBERLEY A	BC	52 (52)	58 (58)	64 (64)	70 (70)
NANAIMO A	BC	52 (52)	58 (58)	64 (64)	70 (70)
PENTICTON A	BC	52 (52)	58 (58)	64 (64)	70 (70)
PORT ALBERNI A	BC	52 (52)	58 (58)	64 (64)	76 (70)
PORT HARDY A	BC	46 (46)	52 (52)	58 (58)	58 (64)
POWELL RIVER A	BC	46 (46)	52 (52)	58 (58)	70 (64)
PRINCE GEORGE A	BC	46 (46)	52 (52)	58 (58)	64 (64)
PRINCE RUPERT A	BC	46 (46)	52 (52)	58 (58)	58 (64)
PRINCETON A	BC	52 (52)	58 (58)	64 (64)	76 (70)
QUESNEL A	BC	52 (52)	58 (58)	64 (64)	70 (70)
REVELSTOKE A	BC	52 (52)	58 (58)	64 (64)	70 (70)
SANDSPIT A	BC	46 (46)	52 (52)	58 (58)	58 (64)
SMITH RIVER A	BC	46 (46)	52 (52)	58 (58)	58 (64)
SMITHERS A	BC	46 (46)	52 (52)	58 (58)	64 (64)
TERRACE A	BC	46 (46)	52 (52)	64 (58)	70 (64)
TOFINO A	BC	46 (46)	52 (52)	58 (58)	64 (64)
VANCOUVER INT'L A	BC	46 (46)	52 (52)	58 (58)	64 (64)
VICTORIA INT'L A	BC	46 (46)	52 (52)	58 (58)	64 (64)
WILLIAMS LAKE A	BC	46 (46)	52 (52)	58 (58)	70 (64)
BRANDON A	MB	52 (52)	58 (58)	64 (64)	70 (70)
BROCHET A	MB	46 (46)	52 (52)	58 (58)	64 (64)
CHURCHILL A	MB	46 (46)	52 (52)	58 (58)	58 (64)
DAUPHIN A	MB	52 (52)	58 (58)	64 (64)	70 (70)
FLIN FLON A	MB	46 (46)	52 (52)	58 (58)	64 (64)
GILLAM A	MB	46 (46)	52 (52)	58 (58)	64 (64)
GIMLI A	MB	52 (52)	58 (58)	58 (64)	64 (70)
ISLAND LAKE A	MB	46 (46)	52 (52)	58 (58)	64 (64)
LYNN LAKE A	MB	46 (46)	52 (52)	58 (58)	64 (64)

Bracketed values based on the simplified selection approach described in Section 4

STATION	Province	Level 1	Level 2	Level 3	Level 4
PORTAGE LA PRAIRIE A	MB	52 (52)	58 (58)	64 (64)	70 (70)
RIVERS A	MB	52 (52)	58 (58)	64 (64)	70 (70)
THE PAS A	MB	46 (46)	52 (52)	58 (58)	64 (64)
THOMPSON A	MB	46 (46)	52 (52)	58 (58)	70 (64)
WINNIPEG INT'L A	MB	52 (52)	58 (58)	64 (64)	70 (70)
CHARLO A	NB	52 (52)	58 (58)	64 (64)	70 (70)
CHATHAM A	NB	52 (52)	58 (58)	64 (64)	70 (70)
FREDERICTON A	NB	52 (52)	58 (58)	64 (64)	70 (70)
MONCTON A	NB	52 (52)	58 (58)	64 (64)	70 (70)
SAINT JOHN A	NB	46 (46)	52 (52)	58 (58)	64 (64)
ARGENTIA A	NF	46 (46)	52 (52)	58 (58)	58 (64)
BUCHANS A	NF	46 (46)	52 (52)	58 (58)	64 (64)
CHURCHILL FALLS A	NF	46 (46)	52 (52)	58 (58)	58 (64)
DEER LAKE A	NF	46 (46)	52 (52)	58 (58)	64 (64)
GANDER INT'L A	NF	46 (46)	52 (52)	58 (58)	64 (64)
GOOSE A	NF	46 (46)	52 (52)	58 (58)	64 (64)
NAIN A	NF	46 (46)	52 (52)	58 (58)	64 (64)
ST JOHN'S A	NF	46 (46)	52 (52)	58 (58)	64 (64)
STEPHENVILLE A	NF	46 (46)	52 (52)	58 (58)	58 (64)
WABUSH LAKE A	NF	46 (46)	52 (52)	58 (58)	64 (64)
GREENWOOD A	NS	52 (52)	58 (58)	64 (64)	70 (70)
HALIFAX INT'L A	NS	52 (52)	58 (58)	58 (64)	64 (70)
SHEARWATER A	NS	46 (46)	52 (52)	58 (58)	64 (64)
SYDNEY A	NS	46 (46)	58 (52)	58 (58)	64 (64)
YARMOUTH A	NS	46 (46)	52 (52)	58 (58)	64 (64)
AKLAVIK A	NT	46 (46)	52 (52)	58 (58)	58 (64)
BAKER LAKE A	NT	46 (46)	52 (52)	58 (58)	58 (64)
BYRON BAY A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CAMBRIDGE BAY A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CAPE DORSET A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CAPE DYER A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CAPE PARRY A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CAPE YOUNG A	NT	46 (46)	52 (52)	58 (58)	58 (64)

Bracketed values based on the simplified selection approach described in Section 4

STATION	Province	Level 1	Level 2	Level 3	Level 4
CLYDE A	NT	46 (46)	52 (52)	58 (58)	58 (64)
CORAL HARBOUR A	NT	46 (46)	52 (52)	58 (58)	58 (64)
FORT GOOD HOPE A	NT	46 (46)	52 (52)	58 (58)	58 (64)
FORT NORMAN A	NT	46 (46)	52 (52)	58 (58)	58 (64)
FORT RESOLUTION A	NT	46 (46)	52 (52)	58 (58)	64 (64)
FORT SIMPSON A	NT	46 (46)	52 (52)	58 (58)	64 (64)
FORT SMITH A	NT	46 (46)	52 (52)	58 (58)	64 (64)
GLADMAN POINT A	NT	46 (46)	52 (52)	58 (58)	58 (64)
HALL BEACH A	NT	46 (46)	52 (52)	58 (58)	58 (64)
HAY RIVER A	NT	46 (46)	52 (52)	58 (58)	64 (64)
INUVIK A	NT	46 (46)	52 (52)	58 (58)	58 (64)
IQALUIT A	NT	46 (46)	52 (52)	58 (58)	58 (64)
JENNY LIND ISLAND A	NT	46 (46)	52 (52)	58 (58)	58 (64)
LADY FRANKLIN POINT A	NT	46 (46)	52 (52)	58 (58)	58 (64)
MOULD BAY A	NT	46 (46)	52 (52)	58 (58)	58 (64)
NORMAN WELLS A	NT	46 (46)	52 (52)	58 (58)	58 (64)
RESOLUTE A	NT	46 (46)	52 (52)	58 (58)	58 (64)
SACHS HARBOUR A	NT	46 (46)	52 (52)	58 (58)	58 (64)
SHEPHERD BAY A	NT	46 (46)	52 (52)	58 (58)	58 (64)
TUKTOYAKTUK A	NT	46 (46)	52 (52)	58 (58)	58 (64)
WRIGLEY A	NT	46 (46)	52 (52)	58 (58)	64 (64)
YELLOWKNIFE A	NT	46 (46)	52 (52)	58 (58)	58 (64)
ARMSTRONG A	ON	46 (46)	52 (52)	58 (58)	64 (64)
CENTRALIA A	ON	52 (52)	58 (58)	64 (64)	70 (70)
DRYDEN A	ON	52 (52)	58 (58)	64 (64)	70 (70)
EARLTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
GORE BAY A	ON	52 (52)	58 (58)	64 (64)	70 (70)
GRAHAM A	ON	46 (46)	58 (52)	64 (58)	70 (64)
HAMILTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
KAPUSKASING A	ON	46 (46)	58 (52)	58 (58)	70 (64)
KENORA A	ON	46 (46)	58 (52)	58 (58)	70 (64)
KINGSTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
LONDON A	ON	52 (52)	58 (58)	64 (64)	70 (70)

Bracketed values based on the simplified selection approach described in Section 4

STATION	Province	Level 1	Level 2	Level 3	Level 4
MUSKOKA A	ON	52 (52)	58 (58)	64 (64)	70 (70)
NAKINA A	ON	46 (46)	52 (52)	58 (58)	64 (64)
NORTH BAY A	ON	52 (52)	58 (58)	64 (64)	70 (70)
OTTAWA INT'L A	ON	52 (52)	58 (58)	64 (64)	70 (70)
OTTAWA ROCKCLIFFE A	ON	52 (52)	58 (58)	64 (64)	70 (70)
PAGWA A	ON	46 (46)	58 (52)	64 (58)	70 (64)
PETAWAWA A	ON	52 (52)	58 (58)	64 (64)	70 (70)
PETERBOROUGH A	ON	52 (52)	58 (58)	64 (64)	70 (70)
RED LAKE A	ON	46 (46)	58 (52)	64 (58)	70 (64)
SARNIA A	ON	52 (52)	58 (58)	64 (64)	70 (70)
SAULT STE MARIE A	ON	52 (52)	58 (58)	64 (64)	70 (70)
SIOUX LOOKOUT A	ON	46 (46)	58 (52)	58 (58)	70 (64)
SUDBURY A	ON	52 (52)	58 (58)	64 (64)	70 (70)
THUNDER BAY A	ON	46 (46)	58 (52)	58 (58)	64 (64)
TIMMINS A	ON	52 (52)	58 (58)	64 (64)	70 (70)
TORONTO DOWNSVIEW A	ON	52 (52)	58 (58)	64 (64)	76 (70)
TORONTO ISLAND A	ON	52 (52)	58 (58)	64 (64)	70 (70)
TORONTO PEARSON INT'L A	ON	52 (52)	58 (58)	64 (64)	70 (70)
TRENTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
WATERLOO WELLINGTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
WIARTON A	ON	52 (52)	58 (58)	64 (64)	70 (70)
WINDSOR A	ON	52 (52)	64 (58)	64 (64)	76 (70)
CHARLOTTETOWN A	PE	46 (46)	52 (52)	58 (58)	64 (64)
SUMMERSIDE A	PE	46 (46)	58 (52)	58 (58)	64 (64)
BAGOTVILLE A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
BAIE COMEAU A	PQ	46 (46)	52 (52)	58 (58)	64 (64)
GAGNON A	PQ	46 (46)	52 (52)	58 (58)	70 (64)
GASPE A	PQ	46 (46)	52 (52)	58 (58)	64 (64)
KUUJJUAQ A	PQ	46 (46)	52 (52)	58 (58)	58 (64)
KUUJJUARAPIK A	PQ	46 (46)	52 (52)	58 (58)	64 (64)
LA MACAZA A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
MEGANTIC A	PQ	46 (46)	58 (52)	64 (58)	70 (64)
MONT JOLI A	PQ	46 (46)	52 (52)	58 (58)	64 (64)

Bracketed values based on the simplified selection approach described in Section 4

STATION	Province	Level 1	Level 2	Level 3	Level 4
MONTREAL/DORVAL INT'L A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
NATASHQUAN A	PQ	46 (46)	52 (52)	58 (58)	58 (64)
QUEBEC A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
ROBERVAL A	PQ	46 (46)	58 (52)	64 (58)	70 (64)
SCHEFFERVILLE A	PQ	46 (46)	52 (52)	58 (58)	64 (64)
SEPT-ILES A	PQ	46 (46)	52 (52)	58 (58)	58 (64)
SHERBROOKE A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
ST HUBERT A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
VAL D'OR A	PQ	52 (52)	58 (58)	64 (64)	70 (70)
BROADVIEW A	SK	52 (52)	58 (58)	64 (64)	70 (70)
DAFOE A	SK	46 (46)	58 (52)	64 (58)	70 (64)
ESTEVAN A	SK	52 (52)	58 (58)	64 (64)	70 (70)
LA RONGE A	SK	46 (46)	52 (52)	58 (58)	64 (64)
MOOSE JAW A	SK	52 (52)	58 (58)	64 (64)	70 (70)
NORTH BATTLEFORD A	SK	46 (46)	52 (52)	58 (58)	64 (64)
PRINCE ALBERT A	SK	46 (46)	52 (52)	58 (58)	64 (64)
REGINA A	SK	52 (52)	58 (58)	64 (64)	70 (70)
SASKATOON A	SK	52 (52)	58 (58)	64 (64)	70 (70)
SWIFT CURRENT A	SK	52 (52)	58 (58)	64 (64)	70 (70)
URANIUM CITY A	SK	46 (46)	52 (52)	58 (58)	64 (64)
YORKTON A	SK	52 (52)	58 (58)	64 (64)	70 (70)
AISHIHIK A	YT	46 (46)	52 (52)	58 (58)	58 (64)
BEAVER CREEK A	YT	46 (46)	52 (52)	58 (58)	58 (64)
BURWASH A	YT	46 (46)	52 (52)	58 (58)	64 (64)
KOMAKUK BEACH A	YT	46 (46)	52 (52)	58 (58)	58 (64)
MAYO A	YT	46 (46)	52 (52)	58 (58)	64 (64)
OLD CROW A	YT	46 (46)	52 (52)	58 (58)	70 (64)
ROSS RIVER A	YT	46 (46)	52 (52)	58 (58)	64 (64)
SHINGLE POINT A	YT	46 (46)	52 (52)	58 (58)	58 (64)
SNAG A	YT	46 (46)	52 (52)	58 (58)	64 (64)
TESLIN A	YT	46 (46)	52 (52)	58 (58)	70 (64)
WATSON LAKE A	YT	46 (46)	52 (52)	58 (58)	64 (64)
WHITEHORSE A	YT	46 (46)	52 (52)	58 (58)	64 (64)

Bracketed values based on the simplified selection approach described in Section 4

APPENDIX C

ASPHALT GRADE SELECTION IGNORING RELIABILITY (Approach #1)

Asphalt Grade Selection Ignoring Reliability (Approach 1)

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
CALGARY GLENMORE DA	AB	46	52	58	64	-34
COLD LAKE A	AB	46	52	58	64	-40
CORONATION A	AB	46	52	58	64	-34
COWLEY A	AB	46	58	64	64	-34
EDMONTON INT'L A	AB	46	52	58	64	-40
EDMONTON MUNICIPAL A	AB	46	52	58	64	-34
EDMONTON NAMAO A	AB	46	52	58	64	-34
EDSON A	AB	46	52	58	64	-40
EMBARRAS A	AB	46	52	58	64	-40
FORT CHIPEWYAN A	AB	46	52	58	64	-40
FORT MCMURRAY A	AB	46	52	58	64	-40
GRANDE PRAIRIE A	AB	46	52	58	64	-40
HIGH LEVEL A	AB	46	46	58	64	-40
LETHBRIDGE A	AB	52	58	64	70	-34
PEACE RIVER A	AB	46	52	58	64	-40
RED DEER A	AB	46	52	58	64	-34
SLAVE LAKE A	AB	46	52	58	64	-34
SUFFIELD A	AB	52	58	64	70	-34
VERMILION A	AB	46	52	58	64	-40
ABBOTSFORD A	BC	46	52	58	64	-16
BEATTON RIVER A	BC	46	46	58	64	-40
BLUE RIVER A	BC	46	58	64	64	-34
CAMPBELL RIVER A	BC	46	58	64	64	-22
CASTLEGAR A	BC	52	58	64	70	-22
COMOX A	BC	46	52	58	64	-16
CRANBROOK A	BC	52	58	64	70	-34

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
CRANBROOK A	BC	52	58	64	70	-34
DAWSON CREEK A	BC	46	52	58	64	-40
FORT NELSON A	BC	46	52	58	64	-40
FORT ST JOHN A	BC	46	52	58	64	-34
HOPE A	BC	46	58	64	64	-16
KAMLOOPS A	BC	52	58	64	70	-28
KELOWNA A	BC	52	58	64	70	-28
KIMBERLEY A	BC	52	58	64	70	-34
NANAIMO A	BC	46	58	64	64	-16
PENTICTON A	BC	52	58	64	70	-22
PORT ALBERNI A	BC	52	58	64	70	-16
PORT HARDY A	BC	46	46	58	64	-10
POWELL RIVER A	BC	46	52	58	64	-16
PRINCE GEORGE A	BC	46	52	58	64	-40
PRINCE RUPERT A	BC	46	46	58	64	-22
PRINCETON A	BC	52	58	64	70	-34
QUESNEL A	BC	46	58	64	64	-34
REVELSTOKE A	BC	46	58	64	64	-28
SANDSPIT A	BC	46	46	58	64	-16
SMITH RIVER A	BC	46	46	58	64	-46
SMITHERS A	BC	46	52	58	64	-34
TERRACE A	BC	46	52	58	64	-22
TOFINO A	BC	46	52	58	64	-10
VANCOUVER INT'L A	BC	46	52	58	64	-16
VICTORIA INT'L A	BC	46	52	58	64	-16
WILLIAMS LAKE A	BC	46	52	58	64	-34
BRANDON A	MB	46	58	64	64	-34
BROCHET A	MB	46	46	58	64	-40
CHURCHILL A	MB	46	46	58	64	-40

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
DAUPHIN A	MB	46	58	64	64	-34
FLIN FLON A	MB	46	52	58	64	-40
GILLAM A	MB	46	52	58	64	-40
GIMLI A	MB	46	58	64	64	-34
ISLAND LAKE A	MB	46	52	58	64	-34
LYNN LAKE A	MB	46	52	58	64	-40
PORTAGE LA PRAIRIE A	MB	46	58	64	64	-34
RIVERS A	MB	46	58	64	64	-34
THE PAS A	MB	46	52	58	64	-40
THOMPSON A	MB	46	52	58	64	-40
WINNIPEG INT'L A	MB	52	58	64	70	-34
CHARLO A	NB	46	58	64	64	-28
CHATHAM A	NB	52	58	64	70	-28
FREDERICTON A	NB	52	58	64	70	-28
MONCTON A	NB	46	58	64	64	-28
SAINT JOHN A	NB	46	52	58	64	-28
ARGENTIA A	NF	46	46	58	64	-16
BUCHANS A	NF	46	52	58	64	-28
CHURCHILL FALLS A	NF	46	52	58	64	-34
DEER LAKE A	NF	46	52	58	64	-28
GANDER INT'L A	NF	46	52	58	64	-22
GOOSE A	NF	46	52	58	64	-34
NAIN A	NF	46	46	58	64	-34
ST JOHN'S A	NF	46	52	58	64	-22
STEPHENVILLE A	NF	46	52	58	64	-22
WABUSH LAKE A	NF	46	52	58	64	-40
GREENWOOD A	NS	52	58	64	70	-22
HALIFAX INT'L A	NS	46	58	64	64	-22
SHEARWATER A	NS	46	52	58	64	-22

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
SYDNEY A	NS	46	52	58	64	-22
YARMOUTH A	NS	46	52	58	64	-22
AKLAVIK A	NT	46	46	58	64	-40
BAKER LAKE A	NT	46	46	58	64	-40
BYRON BAY A	NT	46	46	58	64	-40
CAMBRIDGE BAY A	NT	46	46	58	64	-40
CAPE DORSET A	NT	46	46	58	64	-40
CAPE DYER A	NT	46	46	58	64	-40
CAPE PARRY A	NT	46	46	58	64	-40
CAPE YOUNG A	NT	46	46	58	64	-40
CLYDE A	NT	46	46	58	64	-40
CORAL HARBOUR A	NT	46	46	58	64	-40
FORT GOOD HOPE A	NT	46	46	58	64	-46
FORT NORMAN A	NT	46	46	58	64	-46
FORT RESOLUTION A	NT	46	46	58	64	-40
FORT SIMPSON A	NT	46	52	58	64	-40
FORT SMITH A	NT	46	52	58	64	-40
GLADMAN POINT A	NT	46	46	58	64	-40
HALL BEACH A	NT	46	46	58	64	-40
HAY RIVER A	NT	46	46	58	64	-40
INUVIK A	NT	46	46	58	64	-40
IQALUIT A	NT	46	46	58	64	-40
JENNY LIND ISLAND A	NT	46	46	58	64	-40
LADY FRANKLIN POINT A	NT	46	46	58	64	-40
MOULD BAY A	NT	46	46	58	64	-40
NORMAN WELLS A	NT	46	46	58	64	-40
RESOLUTE A	NT	46	46	58	64	-40
SACHS HARBOUR A	NT	46	46	58	64	-40
SHEPHERD BAY A	NT	46	46	58	64	-46

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
TUKTOYAKTUK A	NT	46	46	58	64	-40
WRIGLEY A	NT	46	46	58	64	-46
YELLOWKNIFE A	NT	46	46	58	64	-40
ARMSTRONG A	ON	46	52	58	64	-40
CENTRALIA A	ON	52	58	64	70	-22
DRYDEN A	ON	46	58	64	64	-34
EARLTON A	ON	46	58	64	64	-40
GORE BAY A	ON	46	58	64	64	-28
GRAHAM A	ON	46	52	58	64	-40
HAMILTON A	ON	52	58	64	70	-22
KAPUSKASING A	ON	46	52	58	64	-34
KENORA A	ON	46	52	58	64	-34
KINGSTON A	ON	46	58	64	64	-28
LONDON A	ON	52	58	64	70	-28
MUSKOKA A	ON	52	58	64	70	-34
NAKINA A	ON	46	52	58	64	-40
NORTH BAY A	ON	46	58	64	64	-34
OTTAWA INT'L A	ON	52	58	64	70	-28
OTTAWA ROCKCLIFFE A	ON	52	58	64	70	-28
PAGWA A	ON	46	52	58	64	-34
PETAWAWA A	ON	52	58	64	70	-34
PETERBOROUGH A	ON	52	58	64	70	-34
RED LAKE A	ON	46	52	58	64	-40
SARNIA A	ON	52	58	64	70	-22
SAULT STE MARIE A	ON	46	58	64	64	-34
SIOUX LOOKOUT A	ON	46	52	58	64	-34
SUDBURY A	ON	46	58	64	64	-34
THUNDER BAY A	ON	46	52	58	64	-34
TIMMINS A	ON	46	58	64	64	-34

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
TORONTO DOWNSVIEW A	ON	52	58	64	70	-28
TORONTO ISLAND A	ON	52	58	64	70	-22
TORONTO PEARSON INT'L	ON	52	58	64	70	-28
TRENTON A	ON	52	58	64	70	-28
WATERLOO WELLINGTON	ON	52	58	64	70	-28
WIARTON A	ON	46	58	64	64	-28
WINDSOR A	ON	52	58	64	70	-22
CHARLOTTETOWN A	PE	46	52	58	64	-22
SUMMERSIDE A	PE	46	52	58	64	-22
BAGOTVILLE A	PQ	46	58	64	64	-34
BAIE COMEAU A	PQ	46	52	58	64	-34
GAGNON A	PQ	46	46	58	64	-40
GASPE A	PQ	46	52	58	64	-28
KUUJJUAQ A	PQ	46	46	58	64	-40
KUUJJUARAPIK A	PQ	46	46	58	64	-40
LA MACAZA A	PQ	46	58	64	64	-40
MEGANTIC A	PQ	46	52	58	64	-34
MONT JOLI A	PQ	46	52	58	64	-28
MONTREAL/DORVAL INT'	PQ	52	58	64	70	-28
NATASHQUAN A	PQ	46	46	58	64	-28
QUEBEC A	PQ	46	58	64	64	-28
ROBERVAL A	PQ	46	52	58	64	-34
SCHEFFERVILLE A	PQ	46	46	58	64	-40
SEPT-ILES A	PQ	46	52	58	64	-34
SHERBROOKE A	PQ	46	58	64	64	-34
ST HUBERT A	PQ	52	58	64	70	-28
VAL D'OR A	PQ	46	58	64	64	-34
BROADVIEW A	SK	46	58	64	64	-34
DAFOE A	SK	46	52	58	64	-40

Station	Province	Level 1	Level 2	Level 3	Level 4	Low Temp Grade 98%
ESTEVAN A	SK	52	58	64	70	-34
LA RONGE A	SK	46	52	58	64	-40
MOOSE JAW A	SK	52	58	64	70	-34
NORTH BATTLEFORD A	SK	46	52	58	64	-34
PRINCE ALBERT A	SK	46	52	58	64	-40
REGINA A	SK	52	58	64	70	-40
SASKATOON A	SK	46	58	64	64	-40
SWIFT CURRENT A	SK	52	58	64	70	-34
URANIUM CITY A	SK	46	46	58	64	-40
YORKTON A	SK	46	58	64	64	-34
AISHIHIK A	YT	46	46	58	64	-46
BEAVER CREEK A	YT	46	46	58	64	-46
BURWASH A	YT	46	46	58	64	-46
KOMAKUK BEACH A	YT	46	46	58	64	-40
MAYO A	YT	46	46	58	64	-46
OLD CROW A	YT	46	46	58	64	-46
ROSS RIVER A	YT	46	46	58	64	-46
SHINGLE POINT A	YT	46	46	58	64	-40
SNAG A	YT	46	46	58	64	-46
TESLIN A	YT	46	46	58	64	-40
WATSON LAKE A	YT	46	46	58	64	-46
WHITEHORSE A	YT	46	46	58	64	-40

APPENDIX D

EXAMPLE DAMA OUTPUT

```
DDDDDDDD        AAAAA       MMM     MMM       AAAAA
DDDDDDDDD      AAAAAAA      MMMM   MMMM      AAAAAAA
DD     DDD    AAA   AAA     MMMMM MMMMM     AAA   AAA
DD      DDD  AAA     AAA    MM MMMMM MM    AAA     AAA
DD       DD  AAA     AAA    MM  MMM  MM    AA       AA
DD       DD  AA       AA    MM       MM    AA       AA
DD       DD  AAAAAAAAAAA    MM       MM    AAAAAAAAAAA
DD      DDD  AAAAAAAAAAA    MM       MM    AAAAAAAAAAA
DD     DDD   AA       AA    MM       MM    AA       AA
DDDDDDDDD    AA       AA    MM       MM    AA       AA
DDDDDDDD     AA       AA    MM       MM    AA       AA
```

THIS PROGRAM WAS DEVELOPED FOR THE ASPHALT INSTITUTE
BY PROF. M. W. WITCZAK AND DAEKYOO HWANG.

UPDATED BY R. W. MAY - LATEST REVISION: APRIL 1993

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ASPHALT INSTITUTE
RESEARCH PARK DRIVE
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LEXINGTON, KENTUCKY 40512-4052

TELEPHONE :(606) 288-4960

DAMA USES THE CHEVRON N-LAYER PROGRAM AS THE
ANALYTICAL STRESS-STRAIN-DISPLACEMENT MODEL.

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***************************************************
*                                                 *
* ALL REASONABLE CARE HAS BEEN TAKEN IN THE       *
* PREPARATION OF THIS COMPUTER PROGRAM, DAMA,     *
* AND THE REPORT RR 82-2; HOWEVER, THE ASPHALT    *
* INSTITUTE CAN ACCEPT NO RESPONSIBILITY FOR      *
* THE CONSEQUENCES OF ANY INACCURACIES WHICH THEY *
* MAY CONTAIN, NOR THEIR SUITABILITY OR UTILITY   *
* FOR USE IN ANY SPECIFIC SET OF CIRCUMSTANCES.   *
*                                                 *
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***** NOTE *****

THE COMPUTER PROGRAM, DAMA, WAS WRITTEN FOR USE
WITH U.S. CUSTOMARY UNITS OF MEASUREMENTS, UNLESS
OTHERWISE STATED FOR A SPECIFIC INPUT VARIABLE.

Calgary Taxi Juliet - Example for Fatigue 737-800

LAYER AND MATERIAL PROPERTIES

LAYER NUMBER	MATERIAL TYPE	POISSON'S RATIO	THICKNESS (in.)	THICKNESS (mm)
1	ASPH. CONC.	.35	8.00	203.20
2	AGGREGATE	.35	12.00	304.80
3	SUBGR. SOIL	.45	41.00	1041.40
4	SUBGR. SOIL	.45		

CURING CONDITIONS

LAYER NUMBER	MATERIAL TYPE	CURE TIME (MONTHS)	MONTH OPENED TO TRAFFIC	MONTHS CURED BEFORE OPENING
1	ASPH. CONC.	.0	JAN.	0

TRAFFIC CONDITION

NUMBER OF REPETITIONS PER MONTH 100

ENVIRONMENTAL CONDITIONS

	JAN.	FEB.	MAR.	APR	MAY	JUNE	JULY	AUG.	SEPT	OCT.	NOV.	DEC.
(MEAN MONTHLY AIR TEMPERATURES, DEG. F)	45.0	38.0	43.0	45.0	56.0	70.0	78.0	81.0	78.0	73.0	58.0	54.0
(MEAN MONTHLY AIR TEMPERATURES, DEG. C)	7.2	3.3	6.1	7.2	13.3	21.1	25.6	27.2	25.6	22.8	14.4	12.2

LOAD CONFIGURATION AND COMPUTATIONAL POINTS

LOAD PER TIRE = 41087. lbs (183. kN)
CONTACT PRESSURE = 205.00 psi (1413.47 kPa)
RADIUS OF LOAD = 7.99 in. (203. mm)
LOAD SPACING = 34.00 in. (864. mm)

COMPUTATIONAL POINT 1 X = 0.0 in. (0.0 mm) (CENTER OF ONE TIRE)
COMPUTATIONAL POINT 2 X = 7.99in. (203.mm) (EDGE OF ONE TIRE)
COMPUTATIONAL POINT 3 X = 17.00in. (432.mm) (MIDPOINT OF TWO TIRES)

MODULI CONDITIONS

ASPHALT CONCRETE

LAYER NUMBER	MATERIAL TYPE	MONTH	MODULUS (psi)	(MPa)
1	ASPH. CONC.			
		JAN.	580131.	4000.
		FEB.	580131.	4000.
		MAR.	580131.	4000.
		APR	580131.	4000.
		MAY	580131.	4000.
		JUNE	580131.	4000.
		JULY	580131.	4000.
		AUG.	580131.	4000.
		SEPT	580131.	4000.
		OCT.	580131.	4000.
		NOV.	580131.	4000.
		DEC.	580131.	4000.

UNTREATED GRANULAR BASE/SUBBASE

LAYER NUMBER	MATERIAL TYPE	MONTH	MODULUS (psi)	(MPa)
2	AGGREGATE			
		JAN.	72516.	500.
		FEB.	72516.	500.
		MAR.	72516.	500.
		APR	72516.	500.
		MAY	72516.	500.
		JUNE	72516.	500.
		JULY	72516.	500.
		AUG.	72516.	500.
		SEPT	72516.	500.
		OCT.	72516.	500.
		NOV.	72516.	500.
		DEC.	72516.	500.

SUBGRADE LAYER

LAYER NUMBER	MATERIAL TYPE	MONTH	MODULUS (psi)	MODULUS (MPa)
3	SUBGR. SOIL			
		JAN.	43510.	300.
		FEB.	43510.	300.
		MAR.	43510.	300.
		APR	43510.	300.
		MAY	43510.	300.
		JUNE	43510.	300.
		JULY	43510.	300.
		AUG.	43510.	300.
		SEPT	43510.	300.
		OCT.	43510.	300.
		NOV.	43510.	300.
		DEC.	43510.	300.

SUBGRADE LAYER

LAYER NUMBER	MATERIAL TYPE	MONTH	MODULUS (psi)	MODULUS (MPa)
4	SUBGR. SOIL			
		JAN.	2901.	20.
		FEB.	2901.	20.
		MAR.	2901.	20.
		APR	2901.	20.
		MAY	2901.	20.
		JUNE	2901.	20.
		JULY	2901.	20.
		AUG.	2901.	20.
		SEPT	2901.	20.
		OCT.	2901.	20.
		NOV.	2901.	20.
		DEC.	2901.	20.

```
                              DAMAGE  MODELS

 FATIGUE DAMAGE :  NF = (F0) * M(F1) * (10**M) * (ET)**(-F2) * (MOD)**(-F3)

           WHERE

           NF IS LOAD REPETITIONS TO FAILURE
           F0 IS DISTRESS TO PERFORMANCE FACTOR
           10**M IS A MIX FACTOR (M= F4*(VBE/(VBE+VV)-F5)

                     VV IS VOLUME OF VOIDS IN ASPHALT MIX (PERCENT)
                     VBE IS VOLUME OF EFFECTIVE ASPHALT IN MIX (PERCENT)

           ET IS TENSILE STRAIN IN ASPHALT LAYER
           MOD IS MODULUS OF ASPHALT CONCRETE (psi)
           F1, F2 AND F3 ARE COEFFICIENTS OF LAB FATIGUE EQUATION
                     GIVEN BY    NF = F1 * ET**(-F2) * MOD**(-F3)


           PARAMETERS OF LAYER 1

           F0 =.18400E+02  F1 =.43250E-02  F2 =.32910E+01  F3 =.85400E+00

           F4 =.48400E+01  F5 = .69000E+00  VBE = 12.50     VV =  6.00


FINAL FATIGUE EQUATION: NF=.67838E-01*(ET)**(-.32910E+01)*MOD**(-.85400E+00)


 DEFORMATION DAMAGE :  NF = D0 * EC**(-D1)

           WHERE

           NF IS LOAD REPETITIONS TO FAILURE
           D0 AND D1 ARE COEFFICIENTS FOR SUBGRADE DEFORMATION MODEL
           EC IS VERTICAL COMPRESSIVE STRAIN AT TOP OF SUBGRADE LAYER(S)

           D0 =.13650E-08       D1 =.44770E+01
```

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

STRESS(psi) AND STRAIN(in/in) VALUES

	R	Z	VERTICAL	RADIAL	SHEAR	BULK	DEFLECTION
STRESS	.00	.00	-.2050E+03	-.4012E+03	.0000E+00	-.1007E+04	
STRAIN			.1307E-03	-.3259E-03			.6347E-01
STRESS	.00	8.00	-.6571E+02	.2294E+03	.0000E+00	.3931E+03	
STRAIN			-.3901E-03	.2967E-03			.6221E-01
STRESS	.00	20.00	-.2039E+02	.1271E+02	.0000E+00	.5027E+01	
STRAIN			-.4039E-03	.2124E-03			.5539E-01
STRESS	.00	20.00	-.2039E+02	.1138E+00	.0000E+00	-.2017E+02	
STRAIN			-.4711E-03	.2124E-03			.5539E-01
STRESS	.00	61.00	-.1073E+01	-.1380E+00	.0000E+00	-.1349E+01	
STRAIN			-.3271E-03	.1403E-03			.4524E-01
STRESS	7.99	.00	-.1025E+03	-.2109E+03	.2507E-04	-.5867E+03	
STRAIN			.1154E-03	-.1368E-03			.5958E-01
STRESS	7.99	8.00	-.4135E+02	.8711E+02	-.2004E+02	.1912E+03	
STRAIN			-.2116E-03	.8738E-04			.5911E-01
STRESS	7.99	20.00	-.1698E+02	.8850E+01	-.4847E+01	.2855E+01	
STRAIN			-.3298E-03	.1510E-03			.5431E-01
STRESS	7.99	20.00	-.1698E+02	-.9714E+00	-.4847E+01	-.1773E+02	
STRAIN			-.3824E-03	.1510E-03			.5431E-01
STRESS	7.99	61.00	-.1055E+01	-.1456E+00	-.7198E-01	-.1339E+01	
STRAIN			-.3195E-03	.1349E-03			.4504E-01
STRESS	17.00	.00	-.1583E+01	-.1865E+02	.1122E-04	-.1080E+03	
STRAIN			.6148E-04	.2176E-04			.5197E-01
STRESS	17.00	8.00	-.1166E+02	-.3442E+02	-.1294E+02	-.8636E+01	
STRAIN			-.2193E-04	-.7490E-04			.5214E-01
STRESS	17.00	20.00	-.9636E+01	.1675E+01	-.6248E+01	-.8156E+00	
STRAIN			-.1755E-03	.3513E-04			.5033E-01
STRESS	17.00	20.00	-.9636E+01	-.2605E+01	-.6248E+01	-.1179E+02	
STRAIN			-.1992E-03	.3513E-04			.5033E-01
STRESS	17.00	61.00	-.8313E+00	-.1063E+00	-.1393E+00	-.1014E+01	
STRAIN			-.2581E-03	.1042E-03			.4376E-01
STRESS	26.01	.00	-.8042E+00	.9691E+00	.2865E-05	-.4682E+02	
STRAIN			.2638E-04	.3050E-04			.4572E-01
STRESS	26.01	8.00	-.3416E+01	-.3497E+02	-.6991E+01	-.3136E+02	
STRAIN			.1097E-04	-.6244E-04			.4587E-01
STRESS	26.01	20.00	-.4490E+01	-.1736E+01	-.5159E+01	-.1867E+01	
STRAIN			-.7458E-04	-.2331E-04			.4529E-01
STRESS	26.01	20.00	-.4490E+01	-.2732E+01	-.5159E+01	-.6549E+01	
STRAIN			-.8191E-04	-.2331E-04			.4529E-01
STRESS	26.01	61.00	-.7434E+00	-.1158E+00	-.1852E+00	-.9167E+00	
STRAIN			-.2294E-03	.8433E-04			.4061E-01
STRESS	34.00	.00	.3003E+00	.1405E+01	.6708E-05	-.3026E+02	
STRAIN			.1896E-04	.2153E-04			.4295E-01
STRESS	34.00	8.00	-.1123E+01	-.2608E+02	-.4324E+01	-.2836E+02	
STRAIN			.1450E-04	-.4359E-04			.4309E-01
STRESS	34.00	20.00	-.2078E+01	-.2395E+01	-.3997E+01	-.1578E+01	
STRAIN			-.3106E-04	-.3698E-04			.4292E-01
STRESS	34.00	20.00	-.2078E+01	-.2207E+01	-.3997E+01	-.3536E+01	
STRAIN			-.3266E-04	-.3698E-04			.4292E-01
STRESS	34.00	61.00	-.6718E+00	-.1446E+00	-.2047E+00	-.8788E+00	
STRAIN			-.1995E-03	.6402E-04			.3948E-01

***** MONTHLY STRUCTURAL RESPONSE *****

TYPES OF STRUCTURAL RESPONSES

DZ   VERTICAL DEFORMATION AT THE TOP OF LAYER (in.)
ET   TENSILE STRAIN AT THE BOTTOM OF LAYER (in/in)
EC   COMPRESSIVE STRAIN AT THE TOP OF LAYER (in/in)
(MPa = psi x 0.006895) (degC = (degF-32) x 5/9)

STRUCTURAL RESPONSES

MON	L	PVT. TEMP	MODULUS (PSI)	RESP TYPE	COMPUTATIONAL POINTS CENTER	EDGE	MID. PT.
1	1	52	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
1	1	52	580131.	ET	.3111E-03	.2583E-03	.1847E-03
1	2		72516.				
1	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
1	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
2	1	44	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
2	1	44	580131.	ET	.3111E-03	.2583E-03	.1847E-03
2	2		72516.				
2	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
2	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
3	1	50	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
3	1	50	580131.	ET	.3111E-03	.2583E-03	.1847E-03
3	2		72516.				
3	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
3	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
4	1	52	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
4	1	52	580131.	ET	.3111E-03	.2583E-03	.1847E-03
4	2		72516.				
4	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
4	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
5	1	65	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
5	1	65	580131.	ET	.3111E-03	.2583E-03	.1847E-03
5	2		72516.				
5	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
5	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
6	1	81	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
6	1	81	580131.	ET	.3111E-03	.2583E-03	.1847E-03
6	2		72516.				
6	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
6	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03

MON	L	PVT. TEMP	MODULUS (PSI)	RESP TYPE	COMPUTATIONAL POINTS CENTER	EDGE	MID. PT.
7	1	90	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
7	1	90	580131.	ET	.3111E-03	.2583E-03	.1847E-03
7	2		72516.				
7	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
7	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
8	1	94	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
8	1	94	580131.	ET	.3111E-03	.2583E-03	.1847E-03
8	2		72516.				
8	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
8	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
9	1	90	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
9	1	90	580131.	ET	.3111E-03	.2583E-03	.1847E-03
9	2		72516.				
9	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
9	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
10	1	84	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
10	1	84	580131.	ET	.3111E-03	.2583E-03	.1847E-03
10	2		72516.				
10	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
10	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
11	1	67	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
11	1	67	580131.	ET	.3111E-03	.2583E-03	.1847E-03
11	2		72516.				
11	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
11	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03
12	1	63	580131.	DZ	.1064E+00	.1053E+00	.1039E+00
12	1	63	580131.	ET	.3111E-03	.2583E-03	.1847E-03
12	2		72516.				
12	3		43510.	EC	.5037E-03	.4643E-03	.3984E-03
12	4		2901.	EC	.5265E-03	.5489E-03	.5163E-03

***** MONTHLY DAMAGES *****

TYPES OF STRUCTURAL RESPONSES

DZ VERTICAL DEFORMATION AT THE TOP OF LAYER (in.)
ET TENSILE STRAIN AT THE BOTTOM OF LAYER (in/in)
EC COMPRESSIVE STRAIN AT THE TOP OF LAYER (in/in)
(MPa = psi x 0.006895) (degC = (degF-32) x 5/9)

MON	L	PVT. TEMP	MODULUS (PSI)	RESP TYPE	COMPUTATIONAL POINTS CENTER	EDGE	MID. PT.
1	1	52	580131.	DZ			
1	1	52	580131.	ET	.3537E-03	.1918E-03	.6363E-04
1	2		72516.				
1	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
1	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
2	1	44	580131.	DZ			
2	1	44	580131.	ET	.3537E-03	.1918E-03	.6363E-04
2	2		72516.				
2	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
2	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
3	1	50	580131.	DZ			
3	1	50	580131.	ET	.3537E-03	.1918E-03	.6363E-04
3	2		72516.				
3	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
3	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
4	1	52	580131.	DZ			
4	1	52	580131.	ET	.3537E-03	.1918E-03	.6363E-04
4	2		72516.				
4	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
4	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
5	1	65	580131.	DZ			
5	1	65	580131.	ET	.3537E-03	.1918E-03	.6363E-04
5	2		72516.				
5	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
5	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
6	1	81	580131.	DZ			
6	1	81	580131.	ET	.3537E-03	.1918E-03	.6363E-04
6	2		72516.				
6	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
6	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03

MON	L	PVT. TEMP	MODULUS (PSI)	RESP TYPE	COMPUTATIONAL POINTS CENTER	EDGE	MID. PT.
7	1	90	580131.	DZ			
7	1	90	580131.	ET	.3537E-03	.1918E-03	.6363E-04
7	2		72516.				
7	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
7	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
8	1	94	580131.	DZ			
8	1	94	580131.	ET	.3537E-03	.1918E-03	.6363E-04
8	2		72516.				
8	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
8	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
9	1	90	580131.	DZ			
9	1	90	580131.	ET	.3537E-03	.1918E-03	.6363E-04
9	2		72516.				
9	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
9	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
10	1	84	580131.	DZ			
10	1	84	580131.	ET	.3537E-03	.1918E-03	.6363E-04
10	2		72516.				
10	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
10	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
11	1	67	580131.	DZ			
11	1	67	580131.	ET	.3537E-03	.1918E-03	.6363E-04
11	2		72516.				
11	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
11	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03
12	1	63	580131.	DZ			
12	1	63	580131.	ET	.3537E-03	.1918E-03	.6363E-04
12	2		72516.				
12	3		43510.	EC	.1261E-03	.8750E-04	.4409E-04
12	4		2901.	EC	.1537E-03	.1852E-03	.1408E-03

DAMAGE SUM FOR 12 MONTHS

LAYER 1	.4244E-02	.2301E-02	.7636E-03
LAYER 3	.1513E-02	.1050E-02	.5290E-03
LAYER 4	.1845E-02	.2222E-02	.1689E-02

********** DESIGN LIFE OF PAVEMENT **********

LAYER	DAMAGE TYPE	CUMULATIVE DAMAGE	CRITICAL POSITION	DESIGN LIFE(YEARS)	DESIGN REPETITIONS
1	FATIGUE	1.000	1	235.6	.2827E+06
3	DEFORMATION	1.000	1	660.9	.7931E+06
4	DEFORMATION	1.000	2	450.0	.5400E+06

LAYER 1 CONTROLS DESIGN LIFE

APPENDIX E

PWGSC SGL TABLE

TABLE A1 - AIRCRAFT CORRESPONDING TO STANDARD GEAR LOADINGS

S.G.L	Aircraft
1	Piper Apache/Aztec Cessna Cutlass/Skylane Beech Bonanza/Baron DHC2 Beaver
2	Beech King Air 90 Srs Cessna 421 Golden Eagle DHC6 Twin Otter
3	Cessna Citation I Swearingen Metro/Merlin Pipe Cheyenne III
4	DC 3 DHC8 Dash 8 Gates Learjet 55, 56
5	Gulfstream G159 F27 HS748 Dart Herald
6	Convair 580/640 Canadair CL215 Dassault Falcon 50

S.G.L.	Aircraft
7	DC-4 BAE-146-100 Canadair CL699, 601
8	DC-9-15 DC-6, 6B Gulfstream II, III Argosy A W650 BAE-146-200
9	BAC-111-500 DC-9-21, 32 Hercules C130
10	B707-120B B737-200/300 B767-200 DC-7 L1049 Super Constellation
11	B-747-100 DC-10-20 B707 320/420 Airbus A-300 VC-10-1100, 1150 Super
12	Concore B-747-200 DC-10-10, 30, 40 L-1011-100, 200, 500 B727-200 DC-8-62, 63, 72, 73

Note: Listing above is for selected aircraft when at maximum operating weight and tire pressure. For other aircraft and aircraft operating at reduced operating weights and tire pressures, see AK-77-68-500, AK-67-09-140 or AK-68-30.
(From Table 2.2 of PWGSC Pavement Structure Design Training Manual (ATR-021)

APPENDIX F

LOW PAVEMENT TEMPERATURES
FOR THREE ALGORITHIMS

Pavement Temperatures as Calculated From Low Temperature Algorithms

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
CALGARY GLENMORE DAM	AB	-33.3	-30.2	-34.5
COLD LAKE A	AB	-40.4	-35.2	-41.4
CORONATION A	AB	-36.8	-32.5	-37.5
COWLEY A	AB	-36.4	-31.6	-36.1
EDMONTON INT'L A	AB	-44.0	-35.8	-43.6
EDMONTON MUNICIPAL A	AB	-36.4	-31.6	-37.7
EDMONTON NAMAO A	AB	-35.1	-31.0	-36.7
EDSON A	AB	-40.6	-35.3	-41.2
EMBARRAS A	AB	-43.7	-38.8	-46.1
FORT CHIPEWYAN A	AB	-42.6	-38.0	-45.5
FORT MCMURRAY A	AB	-40.2	-35.8	-42.5
GRANDE PRAIRIE A	AB	-41.6	-36.5	-42.8
HIGH LEVEL A	AB	-41.9	-37.7	-45.0
LETHBRIDGE A	AB	-35.4	-31.1	-35.3
PEACE RIVER A	AB	-41.3	-36.3	-43.0
RED DEER A	AB	-37.6	-33.2	-38.3
SLAVE LAKE A	AB	-37.6	-33.2	-39.6
SUFFIELD A	AB	-36.1	-31.8	-36.2
VERMILION A	AB	-40.6	-36.0	-41.3
ABBOTSFORD A	BC	-16.0	-14.4	-18.9
BEATTON RIVER A	BC	-40.0	-35.4	-42.6
BLUE RIVER A	BC	-39.2	-32.6	-39.1
CAMPBELL RIVER A	BC	-19.1	-16.6	-21.7
CASTLEGAR A	BC	-21.5	-19.1	-23.5
COMOX A	BC	-13.2	-12.1	-16.9
CRANBROOK A	BC	-32.1	-28.2	-32.5

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
CRANBROOK A	BC	-33.9	-29.0	-33.8
DAWSON CREEK A	BC	-40.6	-36.3	-42.5
FORT NELSON A	BC	-40.9	-36.1	-44.0
FORT ST JOHN A	BC	-37.6	-33.2	-40.0
HOPE A	BC	-17.9	-15.6	-20.5
KAMLOOPS A	BC	-29.9	-25.4	-30.9
KELOWNA A	BC	-28.5	-24.4	-29.5
KIMBERLEY A	BC	-34.4	-28.9	-34.2
NANAIMO A	BC	-15.7	-13.9	-18.5
PENTICTON A	BC	-21.0	-18.5	-23.1
PORT ALBERNI A	BC	-13.9	-12.8	-17.3
PORT HARDY A	BC	-10.0	-9.9	-14.8
POWELL RIVER A	BC	-12.9	-11.9	-16.7
PRINCE GEORGE A	BC	-40.4	-34.5	-41.0
PRINCE RUPERT A	BC	-20.3	-17.8	-24.5
PRINCETON A	BC	-33.7	-28.6	-33.5
QUESNEL A	BC	-38.0	-32.7	-38.7
REVELSTOKE A	BC	-26.1	-22.6	-28.0
SANDSPIT A	BC	-11.9	-11.1	-17.3
SMITH RIVER A	BC	-47.6	-41.7	-50.0
SMITHERS A	BC	-34.5	-29.7	-36.6
TERRACE A	BC	-23.6	-20.4	-27.3
TOFINO A	BC	-10.2	-9.6	-14.1
VANCOUVER INT'L A	BC	-13.8	-12.7	-17.1
VICTORIA INT'L A	BC	-12.0	-11.2	-15.5
WILLIAMS LAKE A	BC	-36.6	-31.3	-37.1
BRANDON A	MB	-37.1	-32.6	-36.9
BROCHET A	MB	-44.0	-39.3	-46.3
CHURCHILL A	MB	-37.3	-34.1	-41.5

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
DAUPHIN A	MB	-35.1	-32.0	-36.2
FLIN FLON A	MB	-38.0	-34.8	-40.3
GILLAM A	MB	-38.5	-35.3	-41.6
GIMLI A	MB	-36.8	-32.8	-37.1
ISLAND LAKE A	MB	-36.6	-33.8	-39.0
LYNN LAKE A	MB	-39.5	-36.2	-42.7
PORTAGE LA PRAIRIE A	MB	-34.4	-30.6	-34.7
RIVERS A	MB	-35.4	-32.2	-36.0
THE PAS A	MB	-38.3	-34.6	-40.0
THOMPSON A	MB	-40.7	-37.1	-43.1
WINNIPEG INT'L A	MB	-35.1	-31.7	-35.5
CHARLO A	NB	-29.2	-26.2	-29.6
CHATHAM A	NB	-27.8	-25.5	-28.4
FREDERICTON A	NB	-29.6	-26.7	-29.2
MONCTON A	NB	-26.3	-24.1	-26.7
SAINT JOHN A	NB	-28.5	-25.5	-28.0
ARGENTIA A	NF	-16.2	-15.2	-18.6
BUCHANS A	NF	-30.6	-25.8	-30.7
CHURCHILL FALLS A	NF	-37.3	-33.7	-39.0
DEER LAKE A	NF	-30.9	-27.3	-31.4
GANDER INT'L A	NF	-22.5	-20.6	-24.5
GOOSE A	NF	-31.5	-28.9	-34.2
NAIN A	NF	-34.0	-29.8	-37.1
ST JOHN'S A	NF	-19.3	-18.0	-21.4
STEPHENVILLE A	NF	-21.8	-19.9	-23.8
WABUSH LAKE A	NF	-38.8	-35.2	-40.0
GREENWOOD A	NS	-23.7	-21.8	-24.2
HALIFAX INT'L A	NS	-21.7	-20.2	-22.5
SHEARWATER A	NS	-21.3	-19.7	-22.0

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
SYDNEY A	NS	-21.7	-19.8	-22.8
YARMOUTH A	NS	-16.7	-16.1	-18.1
AKLAVIK A	NT	-42.8	-38.7	-50.9
BAKER LAKE A	NT	-41.8	-37.9	-48.0
BYRON BAY A	NT	-41.9	-38.0	-50.4
CAMBRIDGE BAY A	NT	-42.3	-38.5	-51.1
CAPE DORSET A	NT	-41.9	-34.2	-47.0
CAPE DYER A	NT	-40.0	-35.7	-47.3
CAPE PARRY A	NT	-38.5	-35.0	-48.3
CAPE YOUNG A	NT	-39.2	-36.0	-48.6
CLYDE A	NT	-39.7	-35.9	-49.4
CORAL HARBOUR A	NT	-43.1	-38.6	-48.7
FORT GOOD HOPE A	NT	-51.7	-42.9	-56.3
FORT NORMAN A	NT	-52.2	-42.5	-55.9
FORT RESOLUTION A	NT	-41.1	-36.6	-45.4
FORT SIMPSON A	NT	-43.3	-38.6	-47.6
FORT SMITH A	NT	-45.0	-39.1	-47.8
GLADMAN POINT A	NT	-43.5	-39.4	-51.7
HALL BEACH A	NT	-42.8	-38.7	-51.2
HAY RIVER A	NT	-41.1	-36.9	-45.4
INUVIK A	NT	-44.5	-39.9	-52.1
IQALUIT A	NT	-38.5	-35.0	-44.9
JENNY LIND ISLAND A	NT	-41.9	-38.0	-50.4
LADY FRANKLIN POINT A	NT	-38.0	-35.1	-47.5
MOULD BAY A	NT	-44.3	-39.8	-56.6
NORMAN WELLS A	NT	-43.5	-38.7	-49.5
RESOLUTE A	NT	-43.1	-38.6	-54.6
SACHS HARBOUR A	NT	-42.6	-38.3	-52.6
SHEPHERD BAY A	NT	-47.8	-42.8	-55.2

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
TUKTOYAKTUK A	NT	-44.5	-38.2	-52.1
WRIGLEY A	NT	-50.5	-41.7	-53.7
YELLOWKNIFE A	NT	-41.3	-37.3	-46.5
ARMSTRONG A	ON	-41.8	-37.2	-41.1
CENTRALIA A	ON	-23.2	-20.9	-22.9
DRYDEN A	ON	-35.6	-32.2	-36.0
EARLTON A	ON	-38.2	-34.1	-37.1
GORE BAY A	ON	-30.4	-27.1	-29.8
GRAHAM A	ON	-43.5	-38.4	-42.0
HAMILTON A	ON	-22.0	-20.7	-22.3
KAPUSKASING A	ON	-37.3	-33.7	-37.3
KENORA A	ON	-34.7	-31.5	-35.2
KINGSTON A	ON	-31.6	-26.6	-29.8
LONDON A	ON	-24.4	-22.2	-23.9
MUSKOKA A	ON	-34.2	-30.6	-32.7
NAKINA A	ON	-40.6	-35.6	-39.9
NORTH BAY A	ON	-32.0	-28.8	-31.5
OTTAWA INT'L A	ON	-29.6	-26.7	-29.0
OTTAWA ROCKCLIFFE A	ON	-30.8	-27.6	-30.0
PAGWA A	ON	-37.8	-34.0	-37.8
PETAWAWA A	ON	-34.5	-31.4	-33.7
PETERBOROUGH A	ON	-32.3	-28.6	-30.8
RED LAKE A	ON	-43.1	-36.1	-42.0
SARNIA A	ON	-23.0	-21.2	-22.9
SAULT STE MARIE A	ON	-32.8	-29.2	-32.1
SIOUX LOOKOUT A	ON	-36.6	-33.1	-36.9
SUDBURY A	ON	-31.3	-28.5	-31.1
THUNDER BAY A	ON	-33.9	-30.4	-33.8
TIMMINS A	ON	-37.5	-33.8	-37.0

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
TORONTO DOWNSVIEW A	ON	-24.6	-22.6	-24.4
TORONTO ISLAND A	ON	-21.0	-19.5	-21.4
TORONTO PEARSON INT'L A	ON	-25.3	-22.9	-24.8
TRENTON A	ON	-26.8	-24.3	-26.3
WATERLOO WELLINGTON A	ON	-26.0	-23.6	-25.4
WIARTON A	ON	-27.7	-24.4	-27.0
WINDSOR A	ON	-21.0	-19.2	-20.8
CHARLOTTETOWN A	PE	-23.4	-21.7	-24.4
SUMMERSIDE A	PE	-23.6	-21.8	-24.6
BAGOTVILLE A	PQ	-34.9	-30.9	-34.4
BAIE COMEAU A	PQ	-36.6	-31.3	-35.9
GAGNON A	PQ	-38.0	-34.1	-38.7
GASPE A	PQ	-28.5	-25.8	-29.5
KUUJJUAQ A	PQ	-38.3	-34.6	-41.8
KUUJJUARAPIK A	PQ	-39.9	-35.6	-41.7
LA MACAZA A	PQ	-45.9	-37.8	-42.4
MEGANTIC A	PQ	-32.5	-29.1	-31.5
MONT JOLI A	PQ	-27.0	-24.8	-28.3
MONTREAL/DORVAL INT'L A	PQ	-28.4	-25.7	-28.2
NATASHQUAN A	PQ	-30.6	-27.8	-31.9
QUEBEC A	PQ	-29.4	-26.9	-29.7
ROBERVAL A	PQ	-33.3	-29.8	-33.3
SCHEFFERVILLE A	PQ	-40.7	-36.0	-42.0
SEPT-ILES A	PQ	-32.8	-29.6	-33.7
SHERBROOKE A	PQ	-33.0	-30.0	-32.1
ST HUBERT A	PQ	-29.9	-26.8	-29.3
VAL D'OR A	PQ	-36.6	-33.1	-36.1
BROADVIEW A	SK	-36.6	-33.1	-37.0
DAFOE A	SK	-38.7	-34.4	-39.1

STATION	Province	SP-1 Model (98%)	TAC Model (98%)	LTPP Model (98%)
ESTEVAN A	SK	-33.7	-30.3	-34.0
LA RONGE A	SK	-40.2	-35.5	-41.7
MOOSE JAW A	SK	-35.4	-31.5	-35.7
NORTH BATTLEFORD A	SK	-37.5	-33.1	-38.4
PRINCE ALBERT A	SK	-41.4	-36.7	-42.0
REGINA A	SK	-39.5	-34.8	-39.1
SASKATOON A	SK	-43.0	-36.4	-42.4
SWIFT CURRENT A	SK	-35.2	-31.4	-35.6
URANIUM CITY A	SK	-40.0	-36.8	-44.5
YORKTON A	SK	-37.5	-33.5	-37.9
AISHIHIK A	YT	-48.0	-41.2	-50.9
BEAVER CREEK A	YT	-46.4	-41.1	-50.4
BURWASH A	YT	-46.4	-40.8	-49.8
KOMAKUK BEACH A	YT	-41.3	-37.0	-50.0
MAYO A	YT	-53.4	-45.1	-56.4
OLD CROW A	YT	-48.1	-42.3	-54.4
ROSS RIVER A	YT	-52.6	-45.1	-55.0
SHINGLE POINT A	YT	-42.1	-37.7	-50.4
SNAG A	YT	-53.3	-45.7	-55.7
TESLIN A	YT	-44.2	-38.0	-47.1
WATSON LAKE A	YT	-47.1	-41.5	-49.8
WHITEHORSE A	YT	-42.3	-37.5	-46.1