A RATIONAL BASIS FOR SPECIFICATIONS FOR PAVING ASPHALTS

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ABSTRACT

Most asphalt specifications presently exclude paving asphalts having from moderate to high temperature susceptibilities. It is the principal objective of this paper to present data for promoting the adoption of specifications that would permit the use of paving asphalts with the entire normal range of temperature susceptibility. It is shown that since they are usually in limited supply, paving asphalts of low temperature susceptibility should be restricted for use in pavements that will carry heavy traffic, while paving asphalts with intermediate and high temperature susceptibilities, which are normally much more plentiful, should be selected for pavements for medium and light traffic. The paper also presents data which indicate that paving asphalts with intermediate and high temperature susceptibilities can be effectively used in asphalt binder or base courses for heavy, medium and light traffic. Data included in the paper provide a rational basis for a specification that would include all paving asphalts regardless of their temperature susceptibilities.

I INTRODUCTION

At present, most asphalt specifications exclude paving asphalts having from moderate to high temperature susceptibilities. It is the primary purpose of this paper to present data that would justify the adoption of specifications that would permit the use of paving asphalts within the entire normal range of temperature susceptibility. The paper will review the important role that paving asphalt temperature susceptibility plays with respect to pavement performance, particularly low temperature transverse pavement cracking, and how this very serious highway engineering problem can be avoided by using softer and softer asphalt cements as their temperature susceptibility increases. Data in the paper show that for the same degree of protection against low temperature transverse pavement cracking, paving asphalts of low temperature susceptibility, which are usually in limited supply, should be reserved for pavements that are to carry heavy traffic, softer paving asphalts of intermediate temperature susceptibility, which are normally most abundant, should be selected for pavements for medium traffic, while still softer paving asphalts of high temperature susceptibility should be chosen for pavements for light traffic. Although for surface courses, paving asphalts of intermediate to high temperature susceptibility should be limited to medium and light traffic respectively, the paper demonstrates that these higher temperature susceptibility paving asphalts can provide adequate pavement stability for use in asphalt binder or base courses for heavy, medium and light traffic. Data are presented to show that paving asphalts that are just soft enough at lowest winter temperatures to avoid low temperature transverse pavement cracking, appear to be hard enough at summer pavement temperatures to provide adequate pavement stability for fast traffic in warm weather. The paper concludes with a chart that indicates the basic requirements for a specification that would include all paving asphalts regardless of their temperature susceptibility values.

II THE TWO MOST IMPORTANT ENGINEERING PROPERTIES OF PAVING ASPHALTS

1. With respect to long term pavement performance, the two most important engineering properties of paving asphalts are:
   a) penetration at 77°F
   b) temperature susceptibility

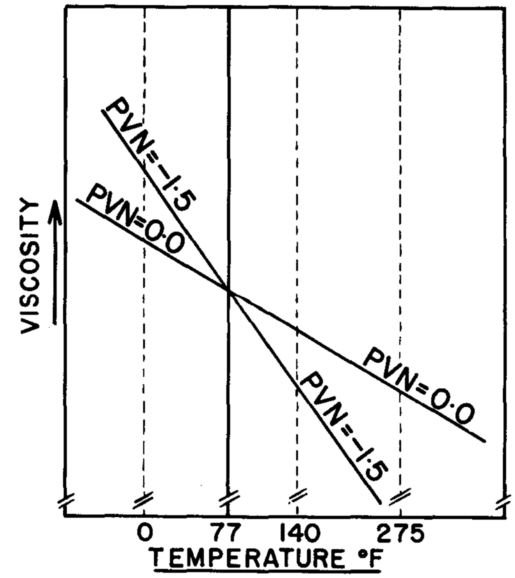
2. While most engineers are quite familiar with penetration at 25°C as a measure of paving asphalt consistency, temperature susceptibility has been largely ignored, except by writing asphalt specifications that exclude paving asphalts of moderate to high temperature susceptibility.

3. Asphalt cements are becoming scarcer and will probably become more so in the future. Furthermore, petroleum refiners now have to run whatever crude oils are available. Since the paving asphalt property that is most widely affected by these changing crude oil sources is temperature susceptibility, it is important that engineers responsible for asphalt paving operations become much more knowledgeable concerning it. Otherwise, they are going to have highly variable pavement performance.

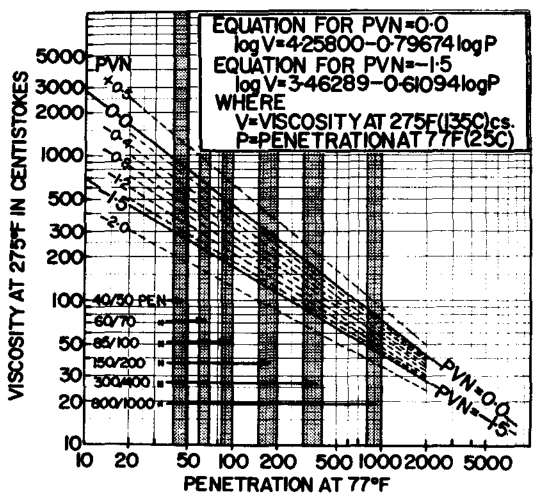
4. As illustrated by Figure 1, the temperature susceptibility value of a paving asphalt depends upon how much its consistency changes over any given range of temperature. In Figure 1 for example, two paving asphalts can have the same consistency (penetration or viscosity) at 77°F (25°C) but their consistencies become quite different at temperatures above and below 77°F (25°C). The asphalt labelled PVN = -1.5 in Figure 1, shows much greater change in consistency for a given change in temperature than the asphalt cement labelled PVN = 0.0. Therefore, we say that the paving asphalt with a PVN = -1.5 has a high temperature susceptibility, while the asphalt with a PVN = 0.0 has a low temperature susceptibility.

5. The temperature susceptibilities of paving asphalts that are manufactured by steam or vacuum distillation (by far the most common method for asphalt production) can be evaluated by their pen-vis numbers (PVN) (1, 2), and determined from Figure 2. As soon as the penetration at 77°F (25°C) and viscosity at 275°F (135°C) have been measured for a paving asphalt, by plotting these two values as the coordinates of a point on Figure 2, the PVN value for the paving asphalt can be determined very closely by interpolation, or its exact value can be calculated (1). Since penetration at 77°F (25°C) and viscosity at 275°F (135°C) are measured during routine inspection of paving asphalts, no additional or special tests are required to determine its PVN value.

6. As shown by Figure 2, the extreme limits for the temperature susceptibilities of paving asphalt in North America are



1. SKETCH ILLUSTRATING INFLUENCE OF PEN-VIS NUMBERS (PVN) ON RELATIONSHIPS BETWEEN VISCOSITY AND TEMPERATURE OF PAVING ASPHALTS.



2. A CHART FOR THE DETERMINATION OF APPROXIMATE VALUES FOR PEN-VIS NUMBERS FOR ASPHALT CEMENTS.

within a PVN range from +0.5 to -2.0, while more than 95 per cent lie within a range from 0.0 to -1.5.

III INFLUENCE OF PAVING ASPHALT TEMPERATURE SUSCEPTIBILITY ON LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING

1. Figure 3 demonstrates that low temperature transverse pavement cracking presents serious highway engineering and pavement maintenance problems in Canada, unless one merely closes his eyes to it. No engineer can take any professional pride in a badly cracked asphalt pavement. Investigation has shown that the simplest method for avoiding this problem is to employ softer grades of asphalt cement in terms of combinations of both their penetrations at 25°C and their temperature susceptibilities (PVN values) (2, 3).

2. Figure 4 illustrates the four types of low temperature transverse pavement cracking that can almost always be observed wherever this type of pavement cracking is occurring. In our experience, only the Type 1 cracks can be correlated with other pavement properties (2).

3. In Figure 5, the importance of paving asphalt temperature susceptibility as a major contributor to low temperature transverse pavement cracking is clearly illustrated. As described in detail elsewhere (2), three 85/100 penetration paving asphalts of different temperature susceptibilities are involved. Figure 5 demonstrates with great clarity that from the first crack count in 1968, the largest number of Type 1 transverse cracks per lane mile has occurred each year in the 2 mile test section made with 85/100 penetration paving asphalt having the highest temperature susceptibility, PVN = -1.34, while the smallest number of these cracks each year has developed in an adjacent 2 mile test section made with 85/100 penetration paving asphalt having the lowest temperature susceptibility, PVN = -0.23. This was particularly true in the early life of this Test Road, that was built in 1960 by the Ontario Ministry of Transportation and Communications, and is still in service, intact. Similar results were obtained at the Ste. Anne Test Road in Manitoba with 150/200 penetration paving asphalt (4), and at two other Ontario Test Roads.

3. ILLUSTRATING LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING.

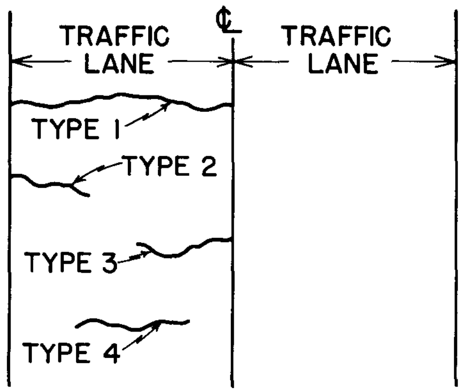
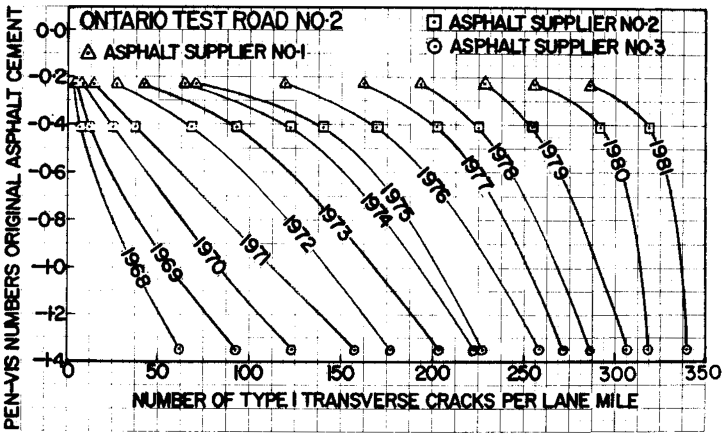
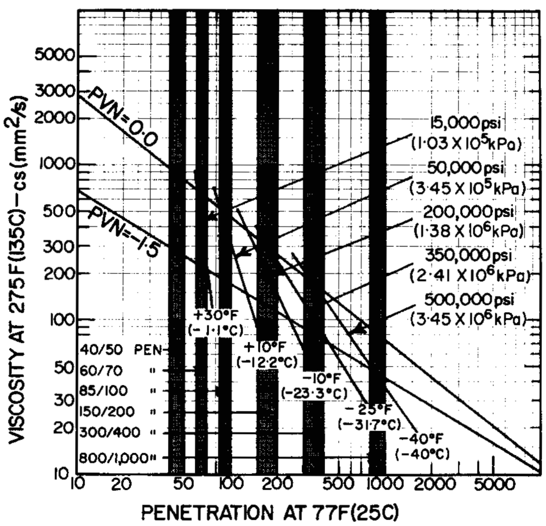


FIG.4 TYPES OF TRANSVERSE PAVEMENT CRACKS.

4. TYPES OF TRANSVERSE PAVEMENT CRACKS.



5. INFLUENCE OF PAVING ASPHALT TEMPERATURE SUSCEPTIBILITIES ON ANNUAL COUNT OF TYPE 1 LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKS PER LANE MILE.



6. CHART FOR SELECTING GRADES OF PAVING ASPHALTS TO AVOID LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING.

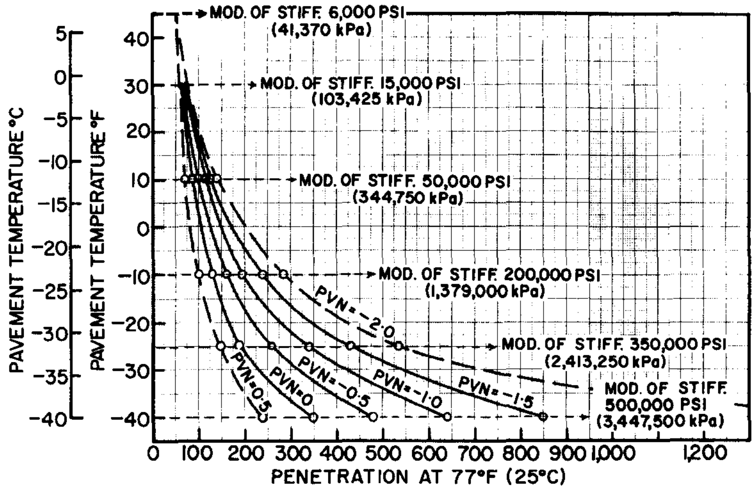
4. As a result of many years of investigation, and to avoid exceeding a critical low temperature pavement modulus of stiffness of one million psi (6.895 million kPa) after a service life of 20 years, Figure 6 has been prepared as a guide for selecting paving asphalts that will eliminate or at least greatly reduce low temperature transverse pavement cracking. The oblique temperature labelled lines in Figure 6 indicate the lowest temperature expected at the midpoint depth of a pavement layer during its service life. By selecting asphalt cements with the combinations of PVN values and penetrations at 25°C that lie either on one of these lines or to the right of it, low temperature transverse pavement cracking will be avoided or greatly decreased at the low pavement temperature indicated by the line.

5. The oblique temperature labelled lines in Figure 6, each with its own associated low temperature pavement modulus of stiffness, emphasize the very important fact that if this constant modulus of stiffness value is to be maintained, as the temperature susceptibility of the paving asphalt increases (PVN value decreases) a softer and softer grade of paving asphalt (higher and higher penetration at 25°C) must be employed.

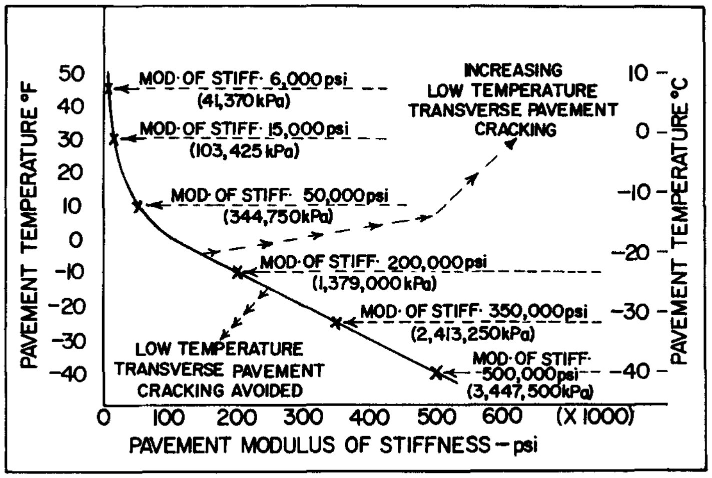
6. Figure 6 guides the choice of paving asphalt for only a few selected low pavement service temperatures. The data of Figure 6 have been rearranged in Figure 7 to provide a continuous scale for low pavement service temperatures as ordinate, versus the corresponding minimum paving asphalt penetrations at 25°C that will just avoid low temperature transverse pavement cracking as abscissa. Each curve on Figure 7 refers to a single PVN value which is clearly marked.

7. Figure 6 also refers to only a limited number of critical low temperature paving mixture modulus of stiffness values that should not be exceeded at the low temperature indicated by each pertinent oblique temperature labelled line, if low temperature transverse pavement cracking is to be avoided. Figure 8 provides a rearrangement of Figure 6 in which a continuous scale of these critical modulus of stiffness values is provided as abscissa versus the corresponding low pavement temperatures as ordinate.

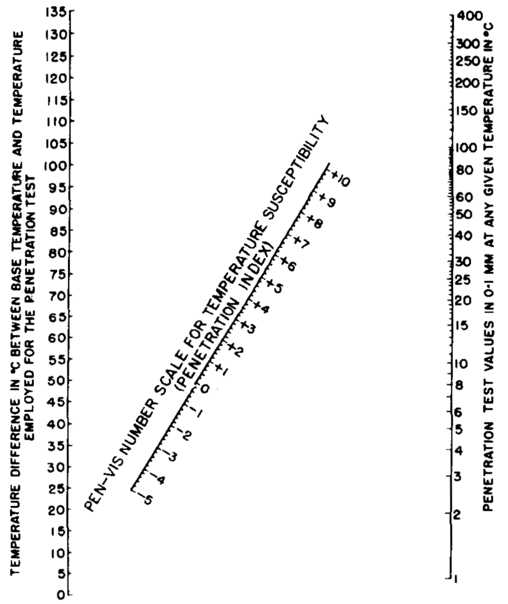
8. The numerical values and the relationships between low temperature pavement modulus of stiffness, PVN value, penetration at 25°C and low pavement temperature due to slow chilling on a cold winter night (time of loading 20,000 seconds), that are illustrated in Figures 6, 7 and 8, were derived from Figures 9, 10 and 11, which are based on nomographs developed by Pfeiffer and Van Doormaal (6), Heukelom and Klomp (7) and Van der Poel (8), respectively. The use of these nomographs has been described elsewhere (1, 9).



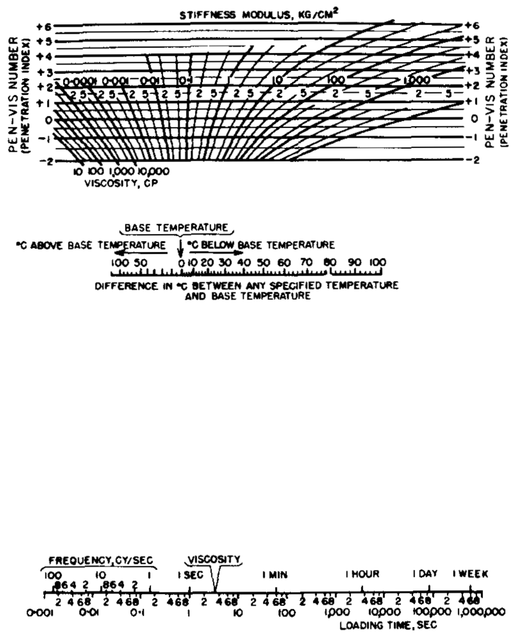
7. CONTINUOUS SCALE FOR LOW PAVEMENT TEMPERATURES VERSUS CORRESPONDING MINIMUM PAVING ASPHALT PENETRATIONS AT 77F (25C) TO AVOID LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING.



8. CONTINUOUS SCALE FOR PAVEMENT MODULI OF STIFFNESS VERSUS CORRESPONDING MINIMUM ASPHALT PENETRATION AT 77F (25C) TO AVOID LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING.



9. RELATIONSHIP BETWEEN PENETRATION AT 77F (25C), PEN-VIS NUMBER (PVN), AND BASE TEMPERATURE, FOR PAVING ASPHALTS (WITH CREDIT TO PFEIFFER, VAN DOORMAAL AND VAN DER POEL).



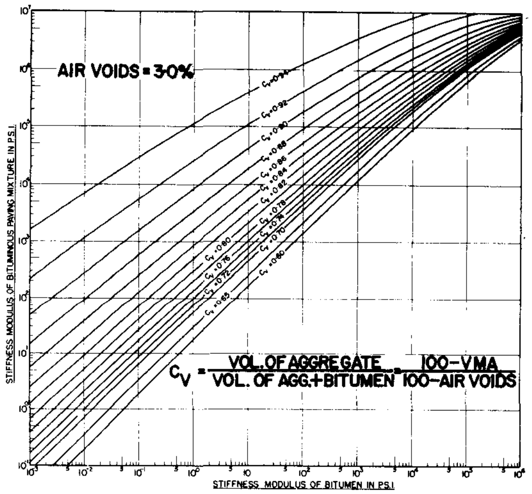
10. NOMOGRAPH FOR DETERMINING MODULI OF STIFFNESS OF ASPHALT CEMENTS (WITH CREDIT TO VAN DER POEL, HEUKELOM AND KLOMP).

IV PAVING ASPHALT TEMPERATURE SUSCEPTIBILITY VERSUS TRAFFIC VOLUME

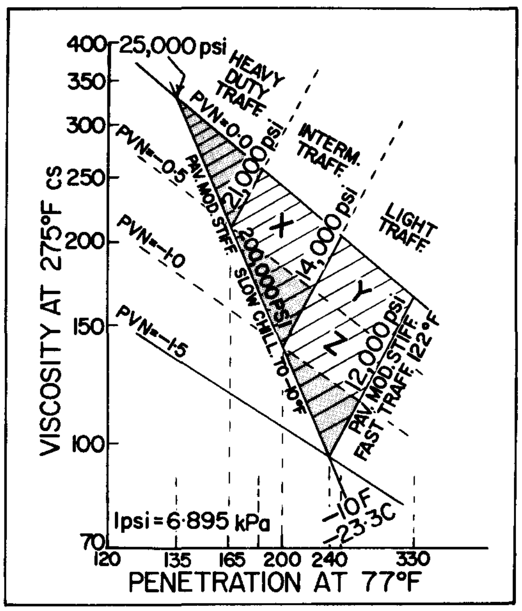
1. Ontario stipulates a minimum Marshall stability at 140°F (60°C) of 8000 N (1800 lb) for paving mixtures for heavy traffic, 5800 N (1300 lb) for paving mixtures for medium traffic, and 4400 N (1000 lb) for paving mixtures for light traffic. Consequently, the principle is well established that the heaviest traffic requires the highest paving mixture stability, light traffic can be carried on pavements of much lower stability, while the stability requirement for paving mixtures for medium traffic is in between.

2. Modulus of stiffness is a basic engineering expression that can be substituted for the Marshall stability term that is commonly applied as an empirical strength measurement to asphalt paving mixtures. Therefore, in accordance with Ontario practice, paving mixtures for heavy traffic require a high minimum modulus of stiffness, those for light traffic need a much lower minimum modulus of stiffness, while the minimum modulus of stiffness for medium traffic is intermediate.

3. The major triangle in Figure 12 is a portion of the chart of Figure 6, and has the following construction and significance:
   a) The upper boundary of this triangle is a portion of the upper boundary of Figure 6, and represents a PVN value of 0.0
   b) The lower boundary of the charts of both Figure 6 and Figure 12 denotes a PVN value of -1.5.
   c) The lower oblique boundary of the major triangle in Figure 12 is the oblique temperature labelled line -10°F (-23.3°C) in Figure 6. Paving mixtures containing asphalt cements taken from this line -10°F (-23.3°C) will all develop a modulus of stiffness of 200,000 psi (1,379,000 kPa) when chilled on a cold winter night to -10°F (-23.2°C). The grades of asphalt along this line range from a penetration at 25°C of 135 for a PVN of 0.0 to a much softer penetration of 240 at 25°C for a PVN of -1.5.
   d) The lower boundary of the major triangle in Figure 12 establishes for each PVN value the corresponding lowest penetration at 25°C for the asphalt cement in a paving mixture that will not exceed a pavement modulus of stiffness of 200,000 psi, which if surpassed would result in low temperature transverse pavement cracking at -10°F (-23.3°C).
   e) In addition to avoiding low temperature transverse pavement cracking, an engineer is concerned about pavement stability for warm weather traffic. Figure 12 shows that a paving mixture containing asphalt cement of 240 penetration at 25°C with a PVN of -1.5 (on the right hand boundary of the major triangle in Figure 12), would develop a modulus of stiffness of 12, 000 psi



11. NOMOGRAPH FOR DETERMING MODULI OF STIFFNESS OF ASPHALT PAVING MIXTURES (WITH CREDIT TO VAN DER POEL).



12. INTERRELATIONSHIP BETWEEN TRAFFIC VOLUME, TEMPERATURE SUSCEPTIBILITY, PENETRATION AT 77F (25C), AVOIDANCE OF LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING, AND ADEQUATE STABILITY FOR WARM WEATHER TRAFFIC.

(82,740 kPa) under heavy truck traffic travelling at 100 km/hr over a pavement with a temperature of 122 °F (50°C). For similar traffic and temperature conditions, a pavement containing paving asphalt with a penetration of 135 at 25°C and a PVN of 0.0 (the left hand apex of the major trangle in Figure 12), would develop a modulus of stiffness of 25,000 psi (172,375 kPa). Similarly, paving mixtures containing asphalt cements with a penetration of 165 at 25°C with a PVN of -0.5, and with a penetration of 200 at 25°C with a PVN of -1.0, would develop pavement moduli of stiffness of 21,000 psi (144,795 kPa) and 14,000 psi (96,530), respectively, under the same traffic and temperature conditions.

f) For heavy trucks travelling at 100 km/hr over a pavement at 122°F (50°C), Figure 12 shows the following relationships between penetration at 25°C, PVN value, and the pavement modulus of stiffness that is developed:

(1) For a pavement modulus of stiffness of 12,000 psi (82,740 kPa)

PVN	Penetration at 25°C
-1.5	240
-1.0	270
-0.5	300
0.0	330

(2) For a pavement modulus of stiffness of 14,000 psi (96,530 kPa)

PVN	Penetration at 25°C
-1.0	200
-0.5	230
0.0	250

(3) For a pavement modulus of stiffness of 21,000 psi (144,795 kPa)

PVN	Penetration at 25°C
-0.5	165
0.0	185

It is apparent moreover, that for the conditions associated in Figure 12 with each of these four cases (pavement temperature = 122 °F (50°C), and heavy truck traffic travelling at 100 km/hr), for paving asphalts ranging from high to low temperature susceptibility (PVN from -1.5 to 0.0), the same pavement modulus of stiffness value can be developed by successively softer paving asphalts (higher penetrations at 25°C).

4. With respect to warm weather traffic therefore, and remembering Ontario's practice of assigning successively lower pavement stability requirements for successively smaller traffic volumes, Figure 12 demonstrates that the following division of traffic categories and corresponding paving asphalt temperature susceptibility limits could be established for the fast traffic and summer temperature conditions that were assumed:

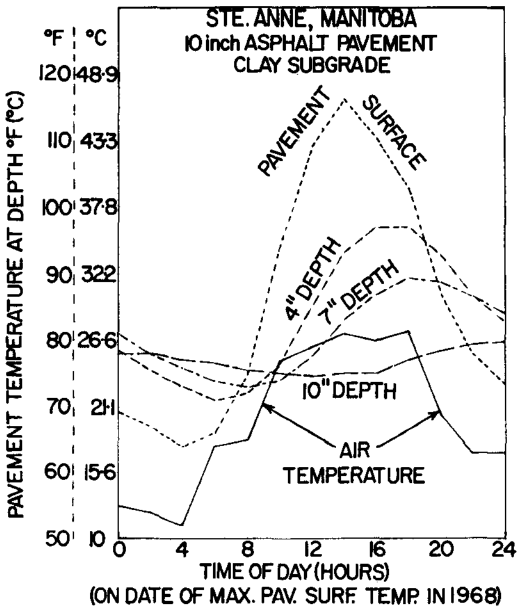
Traffic Category	Range of PVN	Range of Warm Weather Pavement Modulus of Stiffness
Heavy	-0.5 to 0.0	21,000 to 25,000 psi (144,800 to 172,500 kPa)
Medium	-1.0 to -0.5	14,000 to 21,000 psi (96,500 to 145,000 kPa)
Light	-1.5 to -1.0	12,000 to 14,000 psi (82,750 to 96,530 kPa)

5. Figure 12 also demonstrates that to achieve highest pavement stability for warm weather traffic (pavement moduli of stiffness from 21,000 to 25,000 psi), paving asphalts of low temperature susceptibility with a PVN range from -0.5 to 0.0 should be specified, and if they are in short supply they should be restricted for use in pavements that are to carry heavy traffic. Areas X and Y in Figure 9 emphasize that to employ softer grades of paving asphalt of low temperature susceptibility (PVN = -0.5 to 0.0), or even harder grades, for light or medium traffic, ordinarily represents very questionable engineering judgement, and a waste of a valuable resource that is usually relatively scarce. Softer asphalt cements of higher temperature susceptibility (PVN = -1.0 to -0.5 and PVN = -1.5 to -1.0) which provide the lower pavement stabilities required, should be stipulated for pavements that are being designed for medium and light traffic, respectively.

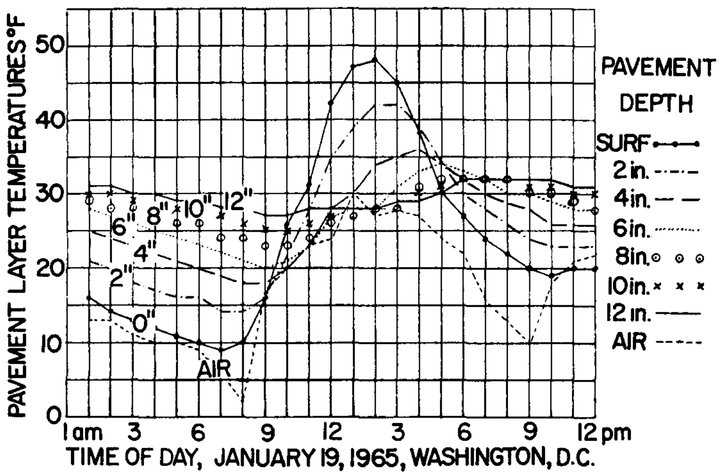
V INFLUENCE OF PAVEMENT DEPTH ON SELECTION OF PAVING ASPHALTS OF HIGHER TEMPERATURE SUSCEPTIBILITY

1. While Figure 12 contains much useful information, it provides no guidance as to whether or how paving asphalts of higher temperature susceptibility could also be used for pavement layers beneath the surface course. Before this information could be obtained, data were required on the variation of pavement temperature with pavement depth, preferably from several widely different climatic sources. A limited minimum quantity of this information has only recently become available.

2. In 1965, The Asphalt Institute measured pavement temperatures at hourly intervals for one year at the surface and at depths of 2, 4, 6, 8, 10 and 12 inches in a dense graded asphalt concrete pavement 12 inches thick at Washington, D.C. (10). During 1968 and 1969 the Manitoba Department of Highways and Shell Canada conducted similar studies of pavement temperature with pavement depth on two pavements 4 inches thick and one pavement 10 inches thick at Ste. Anne, Manitoba, and published the low temperature data in 1969 (4). Recently, Mr. Fred Young of the Manitoba Department of Highways and Transportation arranged to have an analysis made of the warm weather temperature data that had been measured at the Ste. Anne Road Test. Grateful acknowledgement is made to Mr. Young for his kind permission some weeks ago,



13. HOURLY CHANGE IN PAVEMENT TEMPERATURE WITH PAVEMENT DEPTH ON HOTTEST DAY IN 1968, STE. ANNE, MANITOBA.



14. HOURLY CHANGE IN PAVEMENT TEMPERATURE WITH PAVEMENT DEPTH ON COLDEST DAY IN 1965, WASHINGTON, D.C.

to use a small portion of this information, which is now being published in total for the first time in the form of a discussion of this paper.

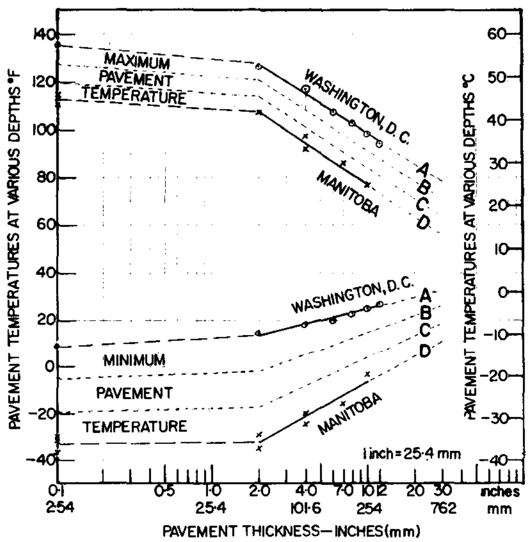
3. Figure 13, based on Mr. Young's analysis, shows that during the warm part of the hottest day in 1968, the pavement surface temperature was highest and that the pavement temperature decreased with pavement depth, as would be expected. Also there is a temperature lag between layers, and each layer attains its maximum temperature at a different time. For warm weather traffic, pavement structural design should be based on the anticipated minimum overall pavement load carrying capacity, without overloading any individual layer. This means that the critical temperature when this occurs, will normally be an hour or more after the pavement surface temperature has reached its peak.

4. Figure 14 illustrates data for the coldest day in 1965 in Washington, D.C., for the test pavement 12 inches thick. Figure 14 demonstrates that in winter, the pavement surface temperature is normally lowest during the night or early morning, and that pavement temperature increases with pavement depth. As with Figure 13, there is a temperature lag between layers, and they do not all reach their minimum temperatures at the same time. Because of the need or desireability to choose paving asphalts that will avoid low temperature transverse pavement cracking, the lowest temperature attained by each layer can become the criterion for paving asphalt selection.

5. Figure 15 shows the range of pavement temperature with pavement depth for the warmest and coldest days in the year at Washington, D.C. (1965), and at the Ste. Anne Test Road (1968). As would be expected, at all pavement depths, the Washington, D.C. pavement was hotter in summer and warmer in winter than at the same depths in the pavements at Ste. Anne, Manitoba.

6. The data shown in Figure 15 provide the only information of which the writer is aware for the reliable measurement of pavement temperature with pavement depth. These data are of particular value, because those for Washington, D.C. are for a very warm climate, while those from Ste. Anne, Manitoba are for a climate that can be very cold in winter. It would be very helpful if more reliable information of this kind could be obtained at strategically located test sites across Canada.

7. For pavement temperature measurements usually at 2-inch intervals of pavement depth, Figure 15 indicates that a least squares straight line relationship appears to exist when pavement temperature is plotted versus logarithm of



15. CHANGE IN MAXIMUM AND MINIMUM TEMPERATURES WITH PAVEMENT DEPTH AT STE. ANNE, MANITOBA AND AT WASHINGTON, D.C.

pavement depth. This relationship appears to hold for both cold weather and warm weather conditions at Ste. Anne, Manitoba, as well as at Washington, D.C. Surface temperatures shown on Figure 15 for the coldest days are the minimums reported. For the hottest days, the surface temperature values given on Figure 15 are for an hour or more after the pavement surface has reached its peak, because of the temperature lag in the lower layers, and because structural design would ordinarily be based on the minimum overall load carrying capacity of the pavement structure. The surface temperatures in each case are shown for a pavement depth of 0.1 inch. A sharp break in the temperature versus depth relationship appears to occur at the 2-inch depth.

8. Line A in Figure 15 demonstrates the relationship between pavement temperature and pavement depth at Washington, D.C., for both the coldest and hottest days in 1965. It seems unlikely that the data represented by Line A would apply anywhere in Canada. Line D provides a similar relationship between pavement temperature and pavement depth for the warmest and coldest days at Ste. Anne, Manitoba, during the 2-year period of 1968 and 1969, and could be considered representative for many parts of Western Canada, Northern Ontario, and Northern Quebec, where the freezing index exceeds 3000 (°F).

9. Lines B and C have been arbitrarily drawn at distances of one-third and two-thirds of the span between Lines A and D. Line C probably represents pavement temperature versus pavement depth conditions in regions with freezing indices of 1500 to 2000, and could apply to Ottawa, Montreal, parts of New Brunswick, and portions of the interior of British Columbia. Pavement temperature conditions indicated by Line B could be representative for Southwestern Ontario, and Atlantic and Pacific coastal areas where the freezing index is roughly from 500 to 1000.

10. Figure 15 together with Figures 7, 8, 9, 10 and 11 will now be used to investigate in the form of a sample calculation, whether paving asphalts of moderate to high temperature susceptibility can be used effectively in binder or base course layers below the surface course. For this purpose a 6-inch pavement will be employed consisting of a 2-inch surface layer, a 2-inch top binder course and a 2-inch bottom binder course. The average temperature for each 2-inch layer will be assumed to be at the middepth of that layer, that is, at a depth of 1-inch for the surface course layer, at a depth of 3-inches for the top 2-inch binder course, and at a depth of 5-inches for the bottom 2-inch binder course. For this sample calculation the temperature conditions associated with Line C in Figure 15 will be employed. The approach to be used is quite simple. The combinations of penetration at 25°C and PVN that will just avoid low temperature transverse pavement cracking in each

of the three 2-inch pavement layers at the low pavement temperatures indicated by Line C, will be first determined. Then for the warm weather pavement temperatures at the same pavement depths, Line C, and for heavy trucks travelling at 100 km/hr, the pavement moduli of stiffness that are developed will be determined. Later these warm weather pavement moduli of stiffness will be compared with target values. The sample calculation for a 2-inch surface course at its midpoint depth of 1 inch, involves the following steps:

Step 1

Read from Line C in Figure 15 the minimum winter temperature for a pavement depth of 1-inch, which is -18°F (-27.8°C).

Step 2

Read from Figure 8, the low temperature pavement modulus of stiffness associated with this low temperature. It is 280,000 psi (1,930,600 kPa).

Step 3

From Figure 7, for a pavement temperature of -18°F (-27.8°C), read the corresponding penetrations at 25°C for PVN values of 0.0, -0.5, -1.0 and -1.5. These are:

For PVN = 0.0	Pen. = 160
For PVN = -0.5	Pen. = 205
For PVN = -1.0	Pen. = 260
For PVN = -1.5	Pen. = 320

These are the critical corresponding combinations of PVN and penetration at 25°C in each case that will just avoid low temperature transverse pavement cracking at a temperature of -18°F (-27.8°C).

Step 4

From Figure 15, read the highest summer temperature indicated by Line C for a pavement depth of 1-inch. This is 115°F (46.1°C)

Step 5

From Figure 9, using a straight edge placed on each of the corresponding values for PVN and penetration at 25°C listed under Step 3, read the associated base temperature, as follows:

PVN	Pen at 25°C	Base Temperature °C
0.0	160	17+25 = 42
-0.5	205	13+25 = 38
-1.0	260	10+25 = 35
-1.5	320	7.5+25 = 32.5

Note: The base temperature corresponds roughly to the ring and ball softening point on Van der Poel's original nomograph.

Step 6

Determine whether and by how much the service temperature, 115°F (46.1°C), is above or below the base temperature for each of the four corresponding combinations of PVN and penetration at 25°C, from Step 3. This follows:

PVN	Pen at 25°C	Service Temp °C	Base Temp °C	Service Temp. - Base Temp. °C
0.0	160	46.1	42	46.1 - 42 = 4.1
-0.5	205	46.1	38	46.1 - 38 = 8.1
-1.0	260	46.1	35	46.1 - 35 = 11.1
-1.5	320	46.1	32.5	46.1 - 32.5 = 13.6

Step 7

Note: Figure 10 provides the modulus of stiffness of the asphalt cement that is developed in a pavement under fast truck traffic at summer temperatures, and also under slow chilling (time of loading 20,000 seconds) to various low temperatures on a cold winter night. For this sample calculation, heavy truck traffic is assumed to travel at 100 km/hr, which provides a time of loading of 0.008 second at a point on a pavement surface, giving a tire contact area about 220 mm (9 inches) in length. Assuming a 45° angle of load distribution, this loading time increases to 0.01 second at a pavement depth of 1-inch, to 0.013 second at a depth of 3-inches, and to 0.017 second at a pavement depth of 5-inches.

To continue:

From Figure 10 determine the modulus of stiffness of the asphalt cement for a time of loading of 0.01 second and for each of the four temperature differences above the base temperature indicated by the right hand column under Step 6. For example, for the combination of PVN = 0.0 and penetration at 25°C = 160, using a straight edge, join the value of 0.01 second for time of loading on the bottom line of Figure 10, with a temperature 4.1°C above the base temperature on the temperature scale, and project to intersect the horizontal line representing PVN = 0.0 in the group of lines at the top of the chart. By interpolation, read the modulus of stiffness value in kg/cm^2 indicated by this point of intersection. In this case the value is 1.4 kg/cm^2 or 1.4 x 14.2 = 19.9 psi (137.2 kPa). This is the modulus of stiffness of this particular asphalt cement in a pavement, that is developed at a pavement depth of 1-inch at a pavement temperature of 115°F (46.1°C) by a heavy truck travelling at 100 km/hr. Repeating this procedure, the following asphalt cement moduli of stiffness values are determined for the four corresponding combinations of PVN and penetration at 25°C listed in Step 3:

PVN	Pen at 25°C	Service - Base Temp °C	Modulus of Stiffness of Asphalt Cement psi
0.0	160	4.1	1.4 x 14.2 = 19.9
-0.5	205	8.1	0.9 x 14.2 = 12.8
-1.0	260	11.1	0.65 x 14.2 = 9.2
-1.5	320	13.6	0.45 x 14.2 = 6.4

Note: 1 psi = 6.895 kPa

Step 8
Enter the abscissa of Figure 11 with each of the four paving asphalt modulus of stiffness values given in the right hand column of Step 7, and proceed vertically upward to intersect the curve $C_v = 0.88$. From this point of intersection, proceed horizontally to the ordinate axis and read off the modulus of stiffness for a pavement containing each asphalt cement. For example, for the asphalt cement with a modulus of stiffness of 19.9 psi in Step 7, the corresponding modulus of stiffness of the asphalt pavement containing this asphalt cement as taken from the $C_v = 0.88$ curve in Figure 11, is 32,000 psi. That is, this particular pavement, containing this particular asphalt cement, at a pavement temperature of 115°F (46.1°C) will develop a modulus of stiffness of 32,000 psi under heavy truck traffic travelling at 100 km/hr.

The curve $C_v = 0.88$ in Figure 11 refers to a dense graded paving mixture with a VMA of 14.5 per cent (5/8 inch or 16 mm nominal maximum aggregate particle size) and with 3 per cent air voids ($C_v = \frac{100-14.5}{100-77} = 0.88$). For dense graded paving mixtures with other air voids values, the modulus of stiffness value can be adjusted by means of Van Draat's and Sommer's equation (1,5). For other VMA values associated with other nominal maximum aggregate particle sizes, C_v curves in Figure 11 other than that for 0.88 can be used. Unless specifically stated to be otherwise, all references to pavement moduli of stiffness in this paper are for thoroughly compacted, dense graded asphalt paving mixtures with a VMA value of 14.5 per cent and an air voids value of 3.0 per cent and are therefore represented by the curve, $C_v = 0.88$ in Figure 11.

11. This step by step procedure has been repeated to obtain the average pavement temperature, corresponding values for PVN and penetration at 25°C, and pavement modulus of stiffness values for the top 2-inch and bottom 2-inch binder courses, and the data obtained are summarized in Table 1 for each of the three 2-inch layers. The warm weather service temperatures for which these data were obtained were taken from Line C, Figure 15, and were 106°F (41.1°C) for the average pavement depth of 3 inches representing the top 2-inch binder course, and 96°F (35.6°C) for the average pavement depth of 5-inches, representing the bottom 2-inch binder course.

12. The data for Line C in Figure 15, that have been listed in Table 1, are of little value by themselves as a criterion for paving asphalt selection. They require a target for comparison. A survey by The Asphalt Institute a number of years ago showed that throughout the United States, 85/100 penetration asphalt was by far the most widely used paving asphalt grade. For tropical climates outside of North America, 85/100 penetration paving asphalt is also commonly selected.

Table 1

Data for Sample Calculation For Three 2-inch Pavement Layers
Based on Line C, Figure 15

At 1 inch pavement depth minimum pavement temperature = -18°F (-27.8°C) Figure 15.

At -18°F (-27.8°C) critical low temperature pavement modulus of stiffness = 280,000 psi (1,930,600 kPa), Figure 8.

For pavement temperature of -18°F (-27.8°C), for PVN = 0.0, Pen = 160, Figure 7
PVN = -0.5, Pen = 205
PVN = -1.0, Pen = 260
PVN = -1.5, Pen = 320

At 1 inch pavement depth maximum pavement temperature = 115°F (46.1°C), Figure 15.

To determine pavement moduli of stiffness developed by fast truck traffic in a 2-inch surface layer at an average temperature of 115°F (46.1°C):

1	2	3	4	5	6	7
PVN	Pen. at 25°C	Service Temp. °C	Base Temp. °C (Fig. 9)	Service-Base Temp. °C	Paving Asphalt Mod. of Stiff. psi (Fig. 10)	Pavement Mod. of Stiff. psi (Fig. 1)
0.0	160	46.1	17+25=42	46.1-42=4.1	1.4x14.2=19.9	32,000
-0.5	205	46.1	13+25=38	46.1-38=8.1	0.9x14.2=12.8	23,500
-1.0	260	46.1	10+25=35	46.1-35=11.1	0.6x14.2=8.5	16,500
-1.5	320	46.1	7.5+25=32.5	46.1-32.5=13.6	0.45x14.2=6.4	13,500

At 3 inch pavement depth minimum pavement temperature = -12°F (-24.4°C), Figure 15.

At -12°F (-24.4°C) critical low temperature pavement modulus of stiffness = 220,000 psi (1,516,900 kPa), Figure 8.

For pavement temperature of -12°F (-24.4°C), for PVN = 0.0, Pen = 135, Figure 7.
PVN = -0.5, Pen = 170
PVN = -1.0, Pen = 210
PVN = -1.5, Pen = 257

At 3 inch pavement depth maximum pavement temperature = 106°F (41.1°C), Figure 15.

To determine pavement moduli of stiffness developed by fast truck traffic in a 2-inch upper binder course layer at an average temperature of 106°F (41.1°C):

0.0	135	41.1	19+25=44	41.1-44=-2.9	2.5x14.2=35.5	48,000
-0.5	170	41.1	15+25=40	41.1-40=1.1	1.8x14.2=25.6	38,000
-1.0	210	41.1	12+25=37	41.1-37=4.1	1.4x14.2=19.9	32,000
-1.5	257	41.1	9.5+25=34.5	41.1-34.5=6.6	1.0x14.2=14.2	25,000

At 5 inch pavement depth minimum pavement temperature = -6°F (-21.1°C), Figure 15.

At -6°F (-21.1°C) critical low temperature pavement modulus of stiffness = 160,000 psi (1,103,200 kPa), Figure 8.

For pavement temperature of -6°F (-21.1°C), for PVN = 0.0, Pen = 120, Figure 7
PVN = -0.5, Pen = 145
PVN = -1.0, Pen = 175
PVN = -1.5, Pen = 205

At 5 inch pavement depth maximum pavement temperature = 96°F (35.6°C), Figure 15.

To determine pavement moduli of stiffness developed by fast truck traffic in a 2 inch lower binder course layer at an average temperature of 96°F (35.6°C):

0.0	120	35.6	20+25=45	35.6-45=-9.4	5x14.2=71.0	78,000
-0.5	145	35.6	16+25=41	35.6-41=-5.4	3.5x14.2=49.7	61,000
-1.0	175	35.6	14+25=39	35.6-39=-3.4	3.0x14.2=42.6	54,000
-1.5	205	35.6	11+25=36	35.6-36=-0.4	2.0x14.2=28.4	41,000

Table 2

Comparison of Warm Weather, Fast Traffic, Pavement Modulus of Stiffness Values Based on Line C, Figure 15, Versus Target Pavement, For a Pavement 6 Inches Thick

Line C			Target Pavement		
PVN	Pen.at 25°C	Pav.Mod. of Stiff.	PVN	Pen.at 25°C	Pav.Mod. of Stiff.
2 inch surface course at average 1 inch depth					
0.0	160	32,000 psi	0.0	85	28,500 psi
				100	25,000 psi
-0.5	205	23,500 psi	-0.5	85	25,000 psi
				100	21,500 psi
-1.0	260	16,500 psi	-1.0	85	22,500 psi
				100	19,500 psi
-1.5	320	13,500 psi	-1.5	85	19,500 psi
				100	14,000 psi
2 inch upper binder course at average 3 inch depth					
0.0	135	48,000 psi	0.0	85	39,500 psi
				100	32,000 psi
-0.5	170	38,000 psi	-0.5	85	32,000 psi
				100	30,000 psi
-1.0	210	32,000 psi	-1.0	85	29,500 psi
				100	27,000 psi
-1.5	257	25,000 psi	-1.5	85	27,000 psi
				100	23,500 psi
2 inch lower binder course at average 5 inch depth					
0.0	120	78,000 psi	0.0	85	55,000 psi
				100	44,000 psi
-0.5	145	61,000 psi	-0.5	85	48,000 psi
				100	41,000 psi
-1.0	175	54,000 psi	-1.0	85	44,000 psi
				100	38,000 psi
-1.5	205	41,000 psi	-1.5	85	40,000 psi
				100	33,500 psi

Note: 1 psi = 6.895 kPa

Therefore, even under high tropical temperatures, pavements made with 85/100 penetration paving asphalt are providing satisfactory service. Consequently, while there are hotter climates than Washington, D.C., warm weather pavement moduli of stiffness data for 85/100 penetration paving asphalts, based on maximum pavement temperatures taken from Line A in Figure 15 for pavement depths of 1, 3 and 5 inches, representing average pavement temperatures for a 2-inch surface course, a 2-inch top binder course and a 2-inch bottom binder course, respectively, have been selected to provide the required target for comparison with the similar warm weather pavement moduli of stiffness data reported in Table 1. These target moduli of stiffness data for the three 2-inch pavement layers were calculated by the procedure described under Paragraph 10 above. These warm weather target pavement modulus of stiffness data are listed in Table 2 for comparison with similar pavement modulus of stiffness data for the same pavement layers for the corresponding condition represented by Line C in Figure 15, and for fast heavy truck traffic.

13. While paving asphalts from Venezuelan crude oils that were the common source for paving asphalt in Eastern Canada for many years tend to have PVN values from -0.5 to 0.0, because of their different crude oil origin, paving asphalts from Middle East crude oils, which are a common source for paving asphalt in many tropical countries, tend to be noticeably higher in temperature susceptibility, with PVN values from -1.0 to -0.5. Consequently, from the warm weather pavement moduli of stiffness data for 85/100 penetration asphalt reported in Table 2, those for a PVN of -0.5 have been selected as the target for comparison in this paper. These target modulus of stiffness data are as follows:

Pavement Depth	PVN	Pen at 25°C	Target Mod. of Stiffness psi
1 inch	-0.5	85	25,000
	-0.5	100	21,500
3 inches	-0.5	85	32,000
	-0.5	100	30,000
5 inches	-0.5	85	48,000
	-0.5	100	41,000

14. A comparison of these target warm weather pavement modulus of stiffness values for each of the three pavement depths, with corresponding values associated with Line C in Figure 15 taken from Table 1 or Table 2, indicates the following favourable parallelism:

Line C			Target		
1 inch depth					
PVN	Pen.at 25°C	Pav.Mod.of Stiff.	PVN	Pen.at 25°C	Pav.Mod.of Stiff.
0.0	160	32,000 psi	-0.5	85	25,000 psi
-0.5	205	23,500 psi	-0.5	100	21,500 psi

3 inch depth					
-0.5	170	38,000 psi	-0.5	85	32,000 psi
-1.0	210	32,000 psi	-0.5	100	30,000 psi
5 inch depth					
-1.0	175	54,000 psi	-0.5	85	48,000 psi
-1.5	205	41,000 psi	-0.5	100	41,000 psi

The above data show clearly that for the conditions associated with Line C, Figure 15, for the 1-inch average depth for the 2-inch surface course, asphalt cements of low temperature susceptibility, PVN = -0.5 to 0.0, are needed to equal the target pavement moduli of stiffness. For the 3-inch depth representing the top 2-inch binder course, for the Line C conditions, pavements containing paving asphalts of intermediate temperature susceptibility PVN = -1.0 to -0.5, at least equal the pavement moduli of stiffness for the target 85/100 penetration asphalt. For the 5-inch pavement depth representing the bottom 2-inch binder course, for the Line C conditions, paving asphalts of high temperature susceptibility PVN = -1.0 to -1.5, equal or exceed the target pavement moduli of stiffness.

15. Consequently, for the conditions represented by Line C in Figure 15, and for the related penetrations at 25°C, a 6-inch pavement consisting of a 2-inch surface course made with paving asphalt of low temperature susceptibility, PVN = -0.5 to 0.0, a 2-inch top binder course containing paving asphalt of intermediate temperature susceptibility, PVN = -1.0 to -0.5, and a 2-inch bottom binder course constructed with paving asphalt of high temperature susceptibility, PVN = -1.5 to -1.0, would provide a pavement structure resistant to low temperature transverse pavement cracking, that would at the same time be at least equal in load carrying capacity for summer traffic to that provided by the target pavements for which 85/100 penetration paving asphalt was used for all pavement layers. Therefore, the data in the above comparison indicate the widely extended application that could be made of paving asphalts of medium to high temperature susceptibility, PVN = -0.5 to -1.5, for binder course layers for heavy, medium and light traffic.

16. In Tables 3 and 4, a comparison is made between the target data versus information similar to that developed in Table 1, that was obtained by the procedure described in Paragraph 10 above, for the conditions represented by Lines B and D in Figure 15, respectively. This comparison also shows that for a 2-inch surface course for heavy traffic, paving asphalts with the lowest temperature susceptibility, PVN = -0.5 to 0.0, should be selected, but that paving asphalts of intermediate temperature susceptibility, PVN = -0.5 to -1.0, could provide adequate stability for a top 2-inch binder course, while paving asphalts of high temperature susceptibility, PVN = -1.0 to -1.5,could develop adequate stability for the bottom 2-inch binder course, in an asphalt pavement 6-inches thick. It is understood of course, that the corresponding penetrations

Table 3

Comparison of Warm Weather, Fast Traffic, Pavement Modulus of Stiffness Values Based on Line B, Figure 15, Versus Target Pavement, For a Pavement 6 Inches Thick

Line B			Target Pavement		
PVN	Pen.at 25°C	Pav.Mod. of Stiff.	PVN	Pen.at 25°C	Pav.Mod. of Stiff.
2 inch surface course at average 1 inch depth					
0.0	110	30,500 psi	0.0	85	28,500 psi
				100	25,000 psi
-0.5	135	25,000 psi	-0.5	85	25,000 psi
				100	21,500 psi
-1.0	160	20,000 psi	-1.0	85	22,500 psi
				100	19,500 psi
-1.5	190	14,000 psi	-1.5	85	19,500 psi
				100	14,000 psi
2 inch upper binder course at average 3 inch depth					
0.0	100	41,000 psi	0.0	85	39,500 psi
				100	32,000 psi
-0.5	120	32,000 psi	-0.5	85	32,000 psi
				100	30,000 psi
-1.0	140	25,000 psi	-1.0	85	29,500 psi
				100	27,000 psi
-1.5	160	21,500 psi	-1.5	85	27,000 psi
				100	23,500 psi
2 inch lower binder course at average 5 inch depth					
0.0	90	73,000 psi	0.0	85	55,000 psi
				100	44,000 psi
-0.5	105	61,000 psi	-0.5	85	48,000 psi
				100	41,000 psi
-1.0	120	48,000 psi	-1.0	85	44,000 psi
				100	38,000 psi
-1.5	135	41,000 psi	-1.5	85	40,000 psi
				100	33,500 psi

Note: 1 psi = 6.895 kPa

Table 4

Comparison of Warm Weather, Fast Traffic, Pavement Modulus of Stiffness Values Based on Line D, Figure 15, Versus Target Pavement, For a Pavement 6 Inches Thick

Line D			Target Pavement		
PVN	Pen.at 25°C	Pav.Mod. of Stiff.	PVN	Pen.at 25°C	Pav.Mod. of Stiff.
2 inch surface course at average 1 inch depth					
0.0	250	28,500 psi	0.0	85	28,500 psi
				100	25,000 psi
-0.5	345	21,500 psi	-0.5	85	25,000 psi
				100	21,500 psi
-1.0	460	14,000 psi	-1.0	85	22,500 psi
				100	19,500 psi
-1.5	595	12,000 psi	-1.5	85	19,500 psi
				100	14,000 psi
2 inch upper binder course at average 3 inch depth					
0.0	200	48,000 psi	0.0	85	39,500 psi
				100	32,000 psi
-0.5	275	33,500 psi	-0.5	85	32,000 psi
				100	30,000 psi
-1.0	355	25,000 psi	-1.0	85	29,500 psi
				100	27,000 psi
-1.5	460	20,500 psi	-1.5	85	27,000 psi
				100	23,500 psi
2 inch lower binder course at average 5 inch depth					
0.0	155	78,000 psi	0.0	85	55,000 psi
				100	44,000 psi
-0.5	205	72,000 psi	-0.5	85	48,000 psi
				100	41,000 psi
-1.0	255	55,000 psi	-1.0	85	44,000 psi
				100	38,000 psi
-1.5	315	41,000 psi	-1.5	85	40,000 psi
				100	33,500 psi

Note: 1 psi = 6.895 kPa

at 25°C indicated by Tables 3 and 4 for Lines B and D would be associated with the paving asphalts with each of the above ranges of temperature susceptibility.

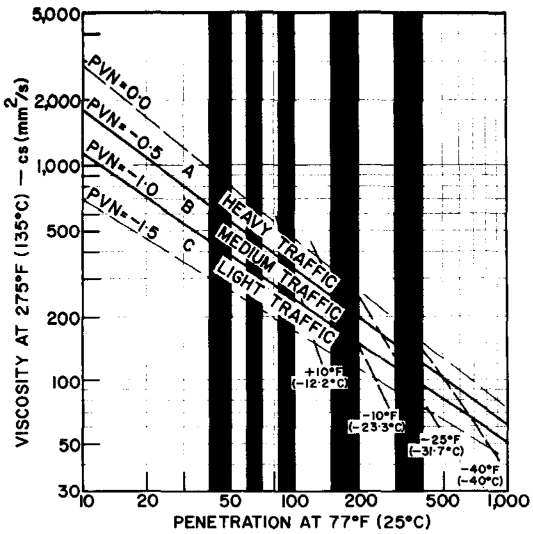
17. For medium and light traffic, paving asphalts of intermediate, PVN = -0.5 to -1.0, and high temperature susceptibility, PVN = -1.0 to -1.5, respectively, could be used for surface courses, Figure 12, while either range of temperature susceptibility would provide adequate pavement stability when used as binder course layers.

18. The approach that has been recommended here, namely, the use of paving asphalts of low temperature susceptibility for surface courses for heavy traffic, and of selected higher temperature susceptibilities for binder courses, is supported in principle by the performance of test pavements in Manitoba and Saskatchewan (11).

VI GENERAL COMMENTS

1. A triangular configuration similar to Figure 12, can be drawn for each of the 1, 3 and 5 inch depths in the three 2 inch pavement layers used for the sample calculation described above. In each of these and similar cases, as demonstrated by Figure 12, it would ordinarily be a waste of relatively scarce paving asphalts of low temperature susceptibility to use them in surface courses for medium or light traffic, or in binder courses for any traffic category, if paving asphalts of higher temperature susceptibility are available, as they normally are. Of course an exception to this would be made in those regions that are favoured with paving asphalts having only low temperature susceptibility.

2. The data in Table 3 indicate that for the conditions associated with Line B, Figure 15, the same paving asphalt grade, 120/150 penetration, could be used for each 2-inch layer of a 6-inch pavement but with a higher temperature susceptibility for the asphalt in each layer. That is, for the 2-inch surface course, 120/150 penetration asphalt with a PVN range from -0.5 to 0.0 would be required. For the top 2-inch binder course, 120/150 penetration asphalt with a PVN range of -1.0 to -0.5 could be used, while for the bottom 2-inch binder course 120/150 penetration asphalt with a PVN range of -1.5 to -1.0 would be adequate. Similarly for the conditions represented by Line C, Figure 15, the data in Table 2 show that 150/200 penetration paving asphalt could be used for each of the three 2-inch layers, but with a PVN of -0.5 to 0.0 for the 2-inch surface, a PVN of -1.0 to -0.5 for the top 2-inch binder course, and a PVN of -1.5 to -1.0 for the bottom 2-inch binder course. For the conditions represented by Line D, the data included in Table 4 indicate that for each 2-inch layer, 250/350 penetration paving asphalt would



16. RATIONAL BASIS FOR SPECIFICATIONS FOR PAVING ASPHALTS IN TERMS OF TRAFFIC VOLUME, PENETRATION AT 77F (25C), VISCOSITY AT 275F (135C), TEMPERATURE SUSCEPTIBILITY, AND AVOIDANCE OF LOW TEMPERATURE TRANSVERSE PAVEMENT CRACKING.

be required with the same sequence of increasing PVN requirements for the three layers.

3. It is of more than usual interest that for Lines B, C, and D in Figure 15, that although successively softer paving asphalts are required for winter conditions represented by each of these three lines, respectively, because of the consecutively lower warm weather temperatures for Lines B, C and D, the paving asphalt grades that are just soft enough to provide protection against low temperature transverse pavement cracking, appear to be hard enough to provide adequate stability for warm weather traffic at the corresponding summer temperatures. For example, from Line C for a 2-inch surface course, for the low winter temperature of -18°F (27.8°C), paving asphalt of 160 penetration with a PVN of 0.0 is just soft enough to avoid low temperature transverse pavement cracking at this low temperature. Nevertheless, it is hard enough at the maximum summer surface course pavement temperature of 115°F (46.1°C) for Line C, to develop a pavement modulus of stiffness of 32,000 psi under heavy truck traffic travelling at 100 km/hr which exceeds the pavement modulus of stiffness value of 21,500 to 25,000 psi indicated for the target of comparison.

4. It is realized that if an engineer believes that the corresponding penetration at 25°C and PVN value for any paving grade referred to in Tables 1, 2, 3 and 4 would provide too soft an asphalt cement for warm weather traffic in his area, he could select a harder grade of asphalt. When he does this however, he should realize that for the higher pavement stability thereby achieved for warm weather traffic, he can expect to pay a penalty in the form of the much greater number of low temperature transverse pavement cracks that will develop.

VII A MORE RATIONAL SPECIFICATION FOR PAVING ASPHALTS

1. Data contained in this paper indicate that:
   (a) When they are in limited supply as they frequently are, paving asphalts of lowest temperature susceptibility should be reserved for use in the surface course layer of pavements that are to carry heavy traffic.
   (b) Paving asphalts of intermediate to high temperature susceptibility, which are usually much more abundant, should be used for surface courses for medium and light traffic.
   (c) These data indicate that there is engineering justification for the wide use of paving asphalt with moderate to high temperature susceptibilities for binder or base courses for heavy, medium and light traffic.

2. Consequently, there is great need for an asphalt specification that will include all paving asphalts regardless of their

temperature susceptibilities, and that would at the same time provide useful guidance for the selection of the paving grade or grades to be used for any paving project.

3. Figure 16 is an attempt to provide the technical basis for such a specification. It gives emphasis to the following items:
   (a) The need to select paving asphalt of lowest temperature susceptibility (PVN = -0.5 to 0.0) for surface courses for heavy traffic, since as shown by Figure 12, for the same protection against low temperature transverse pavement cracking, they provide the highest pavement stability, which is required for highest volume warm weather traffic.
   (b) Also as indicated by Figure 12, paving asphalts of intermediate temperature susceptibility (PVN = -1.0 to -0.5) could be specified for surface courses for medium traffic since less pavement stability is required.
   (c) Figure 12 similarly demonstrates that paving asphalts of highest temperature susceptibility (PVN = -1.5 to -1.0) should be considered for surface courses for light traffic for which still lower pavement stability is needed.
   (d) Paving asphalts with intermediate temperature susceptibility, PVN = -0.5 to -1.0, and with high temperature susceptibility, PVN = -1.0 to -1.5, that are marked for medium and light traffic, respectively, in Figure 16, have been shown to provide paving mixtures with adequate stability for asphalt binder and base courses.
   (e) One of the greatest mistakes made currently and in the past, has been specifying paving asphalt grades without regard for their temperature susceptibility. Consequently, there is need for guidance (the oblique lines with low temperature labels in Figure 16) when selecting paving asphalts that will provide protection against low temperature transverse pavement cracking, and particularly for choosing softer and softer asphalts as the temperature susceptibility of the asphalt increases. When properly selected on this basis, Tables 2, 3 and 4 indicate that these paving asphalts also appear to provide the required stability for warm weather traffic.
   (f) The abscissa for Figure 16, penetration at 25°C, pertains to paving asphalt consistency at a representative average pavement service temperature.
   (g) The ordinate for Figure 16, viscosity at 275°F (135°C), provides useful information for the high temperature construction operations of mixing, spreading and breakdown rolling.
   (h) In combination, the temperature at 25°C and the viscosity at 275°F (135°C) enable the temperature susceptibility of a paving asphalt manufactured by steam or vacuum distillation to be expressed in terms of its PVN value, Figure 2. This paper has emphasized the need and the economic value of giving far more attention to the temperature susceptibility of paving asphalts with

respect to their initial selection, because of its important influence on pavement service performance.

SUMMARY

1. The two most important engineering properties of paving asphalts, penetration at 25°C and temperature susceptibility have been referred to and emphasized.

2. Because petroleum refiners now have to run whatever crude oil is available, the paving asphalt property that becomes most variable is its temperature susceptibility.

3. The important influence of paving asphalt temperature susceptibility on low temperature transverse pavement cracking is demonstrated.

4. A chart for selecting paving asphalts that will avoid low temperature transverse pavement cracking has been prepared.

5. It is demonstrated that for pavement surface courses containing paving asphalts that will just avoid low temperature transverse pavement cracking, those with the lowest temperature susceptibility, PVN = -0.5 to 0.0, which are usually in limited supply, should be segregated, if necessary, for heavy traffic, those with intermediate temperature susceptibility, PVN = -1.0 to -0.5, which are normally plentiful, could be selected for medium traffic, while paving asphalts of highest temperature susceptibility, PVN = -1.5 to -1.0 could be used for light traffic.

6. A chart illustrating the change of pavement temperature with pavement depth has been prepared, based on measured data for both the warmest and coldest days in certain years from test pavements at Washington, D.C., and Ste. Anne, Manitoba.

7. Based on this chart, by means of a procedure described and illustrated in the paper, it is shown that paving asphalts of intermediate to high temperature susceptibility could be employed very effectively in asphalt binder or base courses for heavy, medium and light traffic.

8. Using the information contained in the paper, a rational basis is provided for a specification that would include all paving asphalts regardless of their temperature susceptibility.

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