CEMP-ET

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

ETL 1110-l-139

Engineer Technical
Letter 1110-l-139

22 June 1990

Engineering and Design
SELECTING ASPHALT CEMENTS

1. Purpose. This letter updates, guidance for selecting asphalt cements for pavement construction as outlined in section 6-2 of TM 5-822-8/AFM 88-6, Chapter 9, "Bituminous Pavements Standard Practice".

2. Applicability. This letter is applicable to all HQUSACE elements and field operating activities (FOA) having Army, Air Force and military and civil works construction design responsibility.

3. References. The following references provide necessary general information, definitions and design guidance for pavements:

a. TM 5-822-5/AFM 88-7, Chap. 3.

b. TM 5-822-8/AFM 88-6, Chap. 9.

c. TM 5-818-2/AFM 88-6, Chap. 4.

d. ASTM D 946.

e. ASTM D 3381.

4. Background. Asphalt cements used in pavement construction are currently graded or classified on the basis of two different systems: penetration or viscosity. Within the continental United States (CONUS), penetration grading of asphalt cement has been generally replaced by viscosity grading. Outside the continental United States (OCONUS), penetration grading of asphalt cements is still common. Because of effects of the grading system change and the accumulation of many years of pavement performance data based on the penetration grading system, this letter is needed to provide guidance in selecting asphalt cements.

5. Action to be Taken. Pending publication of permanent media guidance, the criteria provided at Enclosures 1 and 2 will be used as an interim for selecting asphalt cements. Selection of asphalt cement grades for Army facilities in cold regions will be coordinated with HQUSACE (CEMP-ET), WASH, DC 20314-1000. Approval and selection of asphalt cements for Air Force airfields will be coordinated with the appropriate CEMP-ET mandatory center of expertise.

This ETL supersedes ETL 1110-3-369, 28 March 1986.

6. Implementation. This letter will have routine application for military construction as defined in paragraph 6c, ER 1110-345-100.

FOR THE COMMANDER:

2 Encls

HERBERT H. KENNON
Chief, Engineering Division
Directorate of Military Programs

Chapter.1
SELECTING ASPHALT CEMENTS

General

Asphalt cements for use in pavement design and construction are graded or classified in one of two ways. Grading can be done on the basis of penetration depth of a standard test needle into asphalt cement at a standard test temperature. The other method of grading is based on the use of a viscosity test. Currently, in the continental United States (CONUS), viscosity grades of asphalt are common. However, outside the continental United States (OCONUS), penetration grades of asphalt may be more easily obtained. Tables 1 and 2 give specifications for the two types of viscosity graded asphalts. Table 3 gives specifications for penetration grades. All three tables are from current standards of ASTM D 3381 for viscosity grades and ASTM D 946 for penetration grades.

Selecting a grade of asphalt cement should be based on several items. Among the most important are climate, traffic conditions, economics of asphalt availability, and previous regional experiences. Traffic conditions and economic considerations will vary from project to project, but environmental conditions and regional experiences should have some similarity. For example, warm and hot regions should have similar experiences in avoiding unstable asphalt concrete mixes during the summer months, and cold regions should have similar experiences in avoiding crack-prone pavements during winter months.

Asphalt Cement Selection by Temperature Region

Table 4 gives guidance for selecting an asphalt cement by temperature region. Climatological data are required to provide input into the selection method. First, average monthly maximum temperature data are required to compute a pavement temperature index (PTI).[1] When project locations have average monthly maximum temperatures above 75" F (23.9' C), the PTI is defined as the sum of the monthly increments exceeding 75° F (23.9' C). Conversely, when no monthly temperature exceeds 75" F (23.9' C), the PTI is defined as the difference between the highest average maximum temperature for the warmest month and 75° F (23.9' C). Enclosure 2 (Example 1) shows an example of PTI computations.

When it is determined that a project will exist in a cold region, as defined in Table 4, additional climate data are required. For the project area under consideration, a design air freezing index (DFI) is also required to further satisfy cold region requirements. (Reference TM 5-818-2/AFM 88-6, Chap. 4 for determination of DFI.) Cold regions are areas where the penetration-viscosity number (PVN) method is used to aid in selecting an asphalt cement.

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[1] Headquarters, Departments of the Army and the Air Force, Bituminous Pavements Standard Practice, TM 5-822-8/AFM 88-6, Chap. 9.

Enclosure 1

Table 1

Requirements for Asphalt Cement Viscosity Graded at 140" F (60° C)[1]

(Grading Based on Original Asphalt)

Test	Viscosity Grade					
	AC - 2.5	AC - 5	AC - 10	AC - 20	AC - 30	AC - 40
Viscosity, 140° F (60° C), P	250 ± 50	500 ± 100	1,000 ± 200	2,000 ± 400	3,000 ± 600	4,000 ± 800
Viscosity, 275° F (135° C), min, cSt	125	175	250	300	350	400
Penetration, 77° F (25° C), 100 g, 5 s, min	220	140	80	60	50	40
Flash point, (Cleveland open cup), min, ° F (° C)	325 (163)	350 (177)	425 (219)	450 (232)	450 (232)	450 (232)
Solubility in trichloro-ethylene, min, percent	99.0	99.0	99.0	99.0	99.0	99.0
Tests on residue from thin-film oven test viscosity, 140° F (60" C), max, P	1,250	2,500	5,000	10,000	15,000	20,000
Ductility, 77° F (25° C), 5 cm/min, min, cm	100[2]	100	75	50	40	25

[1] From American Society for Testing and Materials Standard Specification D 3381-83, Table 2.

[2] If ductility is less than 100, material will be accepted if ductility at 60" F (15.5" C) is 100 minimum at a pull rate of 5 cm/min.

Table 2

Requirements for Asphalt Cement Viscosity Graded at 140" F (60" C)[1]

(Grading Based on Residue from Rolling Thin-Film Oven Test)

Tests on Residue from Rolling Thin-Film Oven Test[2]	Viscosity Grade				
	AR-1000	AR-2000	AR-4000	AR-8000	AR-16000
Viscosity, 140" F (60° C), P	1,000 ± 250	2,000 ± 500	4,000 ± 1,000	8,000 ± 2,000	16,000 ± 4,000
Viscosity, 275° F (135° C), min, cSt	140	200	275	400	550
Penetration, 77" F (25° C), 100 g, 5 s, min	65	40	25	20	20
Percent of original penetration, 77° F (25° C), min	--	40	45	50	52
Ductility, 77° F (25° C), 5 cm/min, min, cm	100[3]	100[3]	75	75	75
Tests on original asphalt: Flash point, (Cleveland open cup), min, ° F (° C)	400 (205)	425 (219)	440 (227)	450 (232)	460 (238)
Solubility in trichloroethylene, min, percent	99.0	99.0	99.0	99.0	99.0

[1] Prom American Society for Testing and Materials Standard Specification D 3381-83, Table 3.

[2] Thin-film oven test may be used but the rolling thin-film oven test shall be the referee method.

[3] If ductility is less than 100, material will be accepted if ductility at 60" F (15.5" C) is 100 minimum at a pull rate of 5 cm/min.

Table 3

Requirements for Asphalt Cement Graded by Penetration at 77° F (25" C)[1]

(Grading Based on Original Asphalt)

Test	Penetration Grade									
	40 - 50		60 - 70		85 - 100		120 - 150		200 - 300	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 77° F (25" C) 100 g, 5 s	40	50	60	70	85	100	120	150	200	300
Flash point, ° F (Cleveland open cup)	450	--	450	--	450	--	425	--	350	--
Ductility at 77" F (25° C) 5 cm/min, cm	100	--	100	--	100	--	100	--	100[2]	--
Solubility in trichloroethylene, percent	99.0	--	99.0	--	99.0	--	99.0	--	99.0	--
Retained penetration after thin-film oven test, percent	55+	--	52-k	--	47+	--	42+	--	37+	--
Ductility at 77" F (25" C) 5 cm/min, cm after thin-film oven test	--	--	50	--	75	--	100	--	100[2]	--

[1] From American Society for Testing and Materials Standard Specification D 946-82, Table 1.

[2] If ductility at 77" F (25" C) is less than 100 cm, material will be accepted if ductility at 60 ° F (15.5" C) is 100 cm minimum at the pull rate of 5 cm/min.

Table 4

Asphalt Cement Selection Criteria Based on Pavement Temperature Index

Pavement Temperature Index, Cumulative °F ("C)	Temperature Region	Asphalt Cement Selection Criteria
Less than 30 (16.7)	Cold	Penetration-viscosity method for cold regions (Table 5)
30 to 80 (16.7 to 44.4)	Warm	85 to 100 penetration (original asphalt)
Greater than 80 (44.4)	Hot	60 to 70 penetration (original asphalt)

DFI's are used to differentiate between climates in cold temperature regions. A DFI of 3,000 degree-Fahrenheit-days (degree-days) or 1,667 degree-Celsius-days is used as the delineation between moderately cold and severely cold (extremely cold) climates. Moderately cold climates have DFI's up to 3,000 degree-days, and severely cold climates have DFI's greater than 3,000 degree-days.

Penetration-Viscosity Number: For Cold Regions

Penetration-Viscosity Number (PVN), also called Pen-Vis Number, is an empirical correlation between asphalt cement factors and low temperature pavement cracking experiences in Canada. Asphalt cement factors considered in the original correlation were penetrations at 77" F (25" C), viscosity at 275" F (135° C), and penetration index.[2] McLeod[3] proposed PVN for selecting asphalt cements to prevent low temperature cracking of asphalt concrete pavements. The PVN method is used to quantify temperature susceptibility of an asphalt cement and estimate its ability to prevent low-temperature cracking.

Required input data are penetration at 77" F (25° C) and kinematic viscosity at 275" F (135° C). Figure 1 allows estimation of PVN for asphalt cements in cold regions. Table 5 provides minimum PVN selection criteria for asphalts in cold regions. Table 5 and Figure 1 should always be used when selecting asphalts for use in cold regions. Table 5 also shows requirements for airfields and roads and other pavements. A design index is required for

[2] Ad Hoc Committee, "Design Techniques to Minimize Low-Temperature Asphalt Pavement Transverse Cracking," Research Report 81-1, Asphalt Institute, December 1981.

[3] McLeod, N. W., "A 4-Year Survey of Low-Temperature Transverse Pavement Cracking on Three Ontario Test-Roads," Proceedings, Association of Asphalt Paving Technologists, Vol. 41, 1972.

Table 5

Minimum PVN Selection Criteria for Asphalt Cements in Cold Region Use

Cold Region	Airfields	Roads and Other Pavements by Design Index	
		6 4	> 4
Moderate cold (DFI ≤ 3,000 degree-days*)	-0.5	-0.5	-0.5
Severe cold (DFI > 3,000 degree-days*)	-0.2	-0.5	-0.2

* Degree-Fahrenheit-days (1,667 degree-Celsius-days).

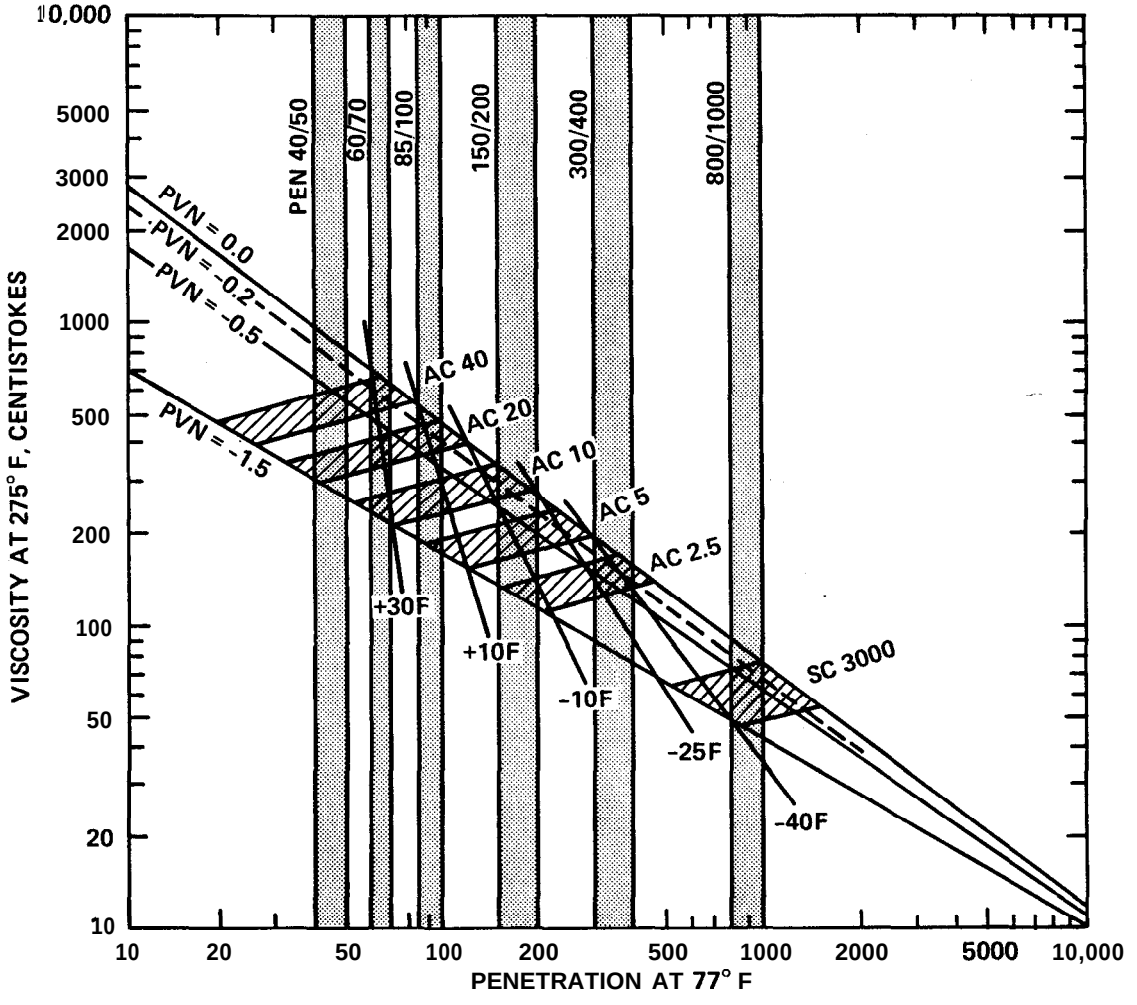

Figure 1. PVN chart for cold region asphalt selection (McLeod 1972)

roads and other pavements; it is an index of traffic estimate and is defined in TM 5-822-5/AFM 88-7, Chap. 3.

Temperature at a 2-in. depth of pavement can be estimated from a DFI for a given project location or site as shown in Figure 2. This "minimum anticipated pavement temperature" and minimum PVN criteria of Table 5 can be used with Figure 1 to select an asphalt cement.

An asphalt with given penetration and viscosity can be checked for satisfying PVN criteria of Table 5 by plotting in Figure 1. If its penetration and viscosity point falls on or above the minimum PVN value and to the right of the minimum anticipated pavement temperature, it is estimated that low temperature contraction cracking of the asphalt concrete layer will be prevented. If it plots to the left of the anticipated pavement temperature, the pavement will likely crack at low temperatures. PVN values should be calculated for more accurate results.

Examples of Asphalt Cement Selection

Enclosure 2 contains examples of asphalt cement selection by use of this Engineer Technical Letter.

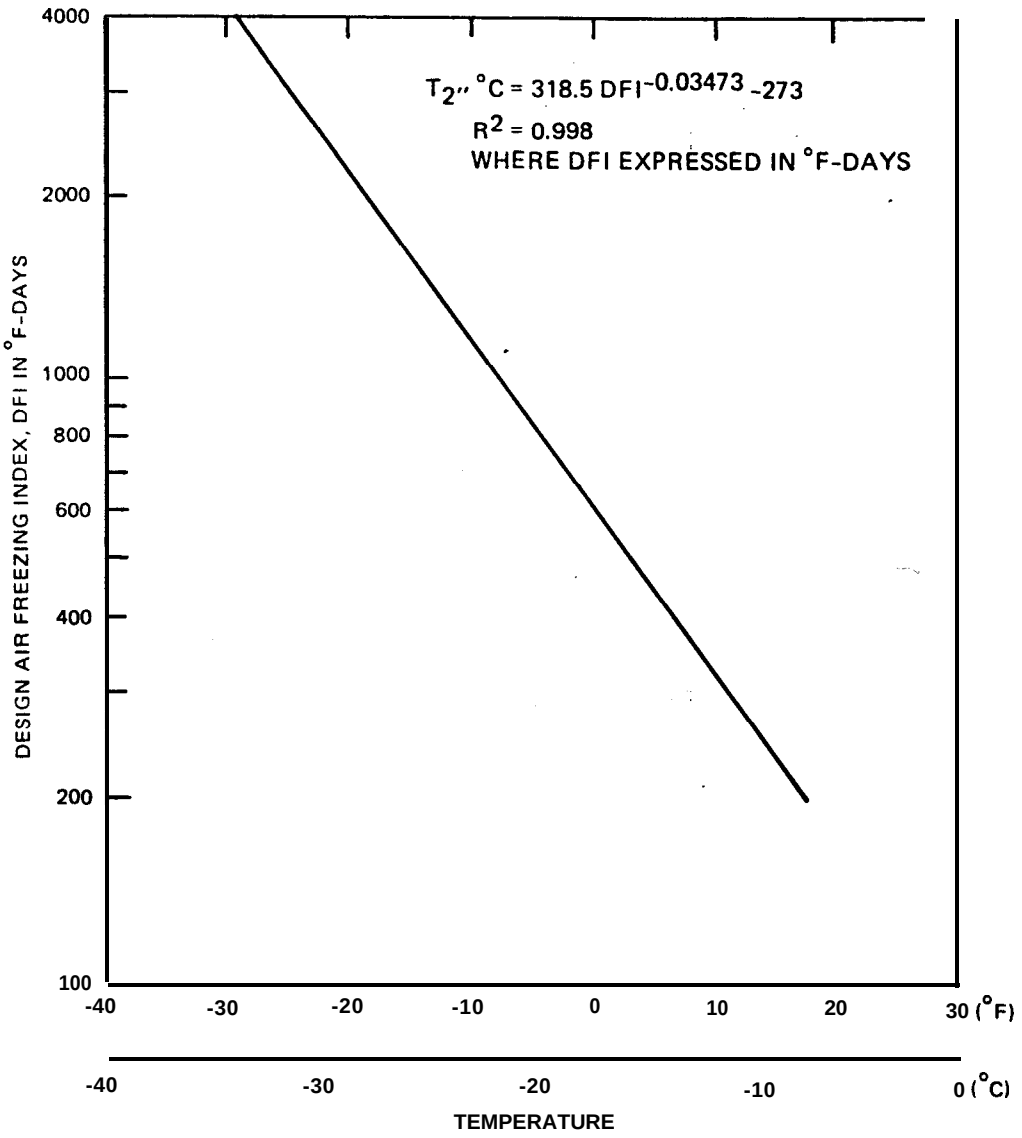

Figure 2. Pavement temperature as a function of design air freezing index

Chapter 2
EXAMPLE ANALYSES FOR SELECTING AN ASPHALT CEMENT

Example 1. Calculating Pavement Temperature Index

The method for calculating the pavement temperature index for two construction sites is given in this example.

The average monthly maximum temperature and the difference above 75" F (23.9" C) for Site A and Site B are given below.

	Site A		Site B	
Month	Avg. Max. Temperature °F	Difference Above 75" F	Avg. Max. Temperature °F	Difference Above 75" F
Jan	60.5		29.8	--
Feb	68.5	--	27.8	--
Mar	73.7	--	43.0	
Apr	79.9	4.9	58.2	--
May	88.5	13.5	67.2	--
Jun	94.5	19.5	70.4	--
Jul	97.6	22.6	77.0	2.0
Aug	92.0	17.0	74.2	--
Sep	90.2	15.2	66.9	--
Oct	80.3	5.3	57.5	--
Nov	74.0	--	43.4	--
Dec	60.3	--	36.8	--
Cumulative Total		98.0		2.0

The temperature index at these sites is the sum of the increments of average monthly maximums above 75" F; therefore, the pavement temperature index for each site is as follows:

Site A = 98.0, cumulative °F (54.4, cumulative °C)

Site B = 2.0, cumulative °F (1.1, cumulative °C)

Based on Table 4 of Enclosure 1, Site A is a hot region, and Site B is a cold region. Site B requires the use of the PVN method to select an asphalt cement.

Example 2. Asphalt Cement Selection in a Hot Region

A parking lot should be built in a region that has a pavement temperature index of 98, cumulative °F (54.4, cumulative °C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 1 of Enclosure 1 (from ASTM D 3381). Viscosity and penetration data for the asphalt cements are given below.

	AC-10	AC-20	AC-40
Viscosity, 140" F, P	872	2,200	4,104
275° F, cSt	298	435	605
Penetration, 77° F, 0.1 mm	123	70	46

From Table 4 of Enclosure 1, an asphalt cement that has a penetration of approximately 60 to 70 should be selected. The AC-20 asphalt cement should be selected for this pavement.

Example 3. Asphalt Cement Selection in a Warm Region

A street should be constructed in a region that has a pavement temperature index of 42, cumulative °F (23.3, cumulative "C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 1 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AC-5	AC-10	AC-20
Viscosity, 140° F, P	560	1,120	2,170
275" F, cSt	180	335	450
Penetration, 77° F, 0.1 mm	145	96	70

Based on Table 4 of Enclosure 1, an asphalt cement that has a penetration of approximately 85 to 100 should be selected. The AC-10 asphalt cement is selected.

Example 4. Asphalt Cement Selection in a Cold Region

At Fort Drum, NY, a heavy duty open storage area (design index of 10) for use by 50,000 lb forklift trucks has to be constructed in a region with a pavement temperature index of 2, cumulative °F (1.1, cumulative °C) and a DFI of 2,300 degree-Fahrenheit-days (1,278 degree-Celsius-days) calculated using TM 818-2.

An asphalt supplier can provide two asphalt cements that meet the requirements in Table 1 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AC-Z.5	AC-5
Viscosity, 140" F, P	280	466
275° F, cSt	140	220
Penetration, 77" F, 0.1 mm	296	240

Analysis and Asphalt Selection

The climatological data allow classification of the site by temperature region and allow an estimate of pavement temperature. According to Table 4 of Enclosure 1, the pavement temperature index classifies the site as a cold region where the PVN method should be used to select the grade of asphalt cement, The DFI allows the use of Figure 2 (Enclosure 1) to estimate a minimum pavement temperature at a 2-in. (5 cm) depth. From Figure 2, a minimum anticipated pavement temperature is about -22" F (-30" C).

Table 5 of Enclosure 1 shows that this cold region can be further classified as a moderately cold region since its DFI is less than 3,000 degree-Fahrenheit-days. Table 5 also indicates that the required PVN of the asphalt selected must be greater than -0.5 for a design index of 10. This will minimize low temperature pavement cracking.

Now, PVN values must be determined for the available asphalt cements. This can be done by either plotting penetration and viscosity at 275" F (135" C) in Figure 1 of Enclosure 1 or by using PVN equations. If the details of Figure 1 are not sufficient to accurately determine PVN values, equations should be used.

The general PVN equation1 is as follows:

$$PVN = \frac{(L - X)(-1.5)}{(L - M)}$$

where

L = logarithm of viscosity in centistokes at 275" F (135° C) for a PVN of 0.0 at the given penetration

X = logarithm of viscosity in centistokes at 275" F (135° C) of a given asphalt

M = logarithm of viscosity in centistokes at 275° F (135° C) for a PVN of -1.5 at the given penetration

Values of X can be determined directly from asphalt cement viscosity data as provided in this example, but values of L and M are a function of the penetration values of each asphalt. Equations for the values of L and M are:

$$L = 4.25800 - 0.79674 \log (Pen)$$

[1] McLeod, N. W., "Using Paving Asphalt Rheology to Impair or Improve Asphalt Pavement Design and Performance", Asphalt Rheology: Relationship to Mixture, ASTM STP 941, 0. E. Briscoe, Ed., American Society for Testing and Materials, Philadelphia, 1987.

and

$$M = 3.46289 - 0.61094 \log (PEN)$$

where PEN = penetration at 77" F (25" C) of a given asphalt cement.

Calculated PVN values of the two available asphalt cements are:

PVN = -0.638 for AC-2.5

PVN = -0.081 for AC-5

Based on Table 5 of Enclosure 1, an asphalt cement that has a PVN greater than -0.5 and lies on or to the right of the minimum temperature diagonal line should be selected. The AC-5 asphalt cement is selected because it has a PVN of -0.081 and lies to the right of the -22" F temperature diagonal line. This asphalt cement satisfies the requirements of Table 5 and should prevent low-temperature pavement cracking.

Example 5. Asphalt Cement Selection in a Warm Region

A parking lot should be constructed in a region that has a pavement temperature index of 42, cumulative °F (23.3, cumulative °C).

An asphalt supplier can provide asphalt cements that meet the requirements in Table 2 of Enclosure 1. Viscosity and penetration data for the asphalt cements are given below.

	AR-1000	AR-2000	AR-4000
Viscosity, 140° F, P	851	1,962	3,544
275" F, cSt	162	247	334
Penetration, 77" F, 0.1 mm			
Original	141	87	53
Residue	99	55	39

Based on Table 4 of Enclosure 1, an asphalt cement.that has a penetration of approximately 85 to 100 should be selected. The AR-2000 asphalt cement is selected based on the original penetration of the material.