SOME ALBERTA EXPERIENCE WITH PENETRATION-GRADED ASPHALT CEMENTS HAVING DIFFERING VISCOSITIES AT 140 F

K. O. Anderson, University of Alberta; and
B. P. Shields, Research Council of Alberta, Edmonton, Canada

Experience in Alberta with 150 to 200 and 200 to 300 penetration grade asphalt cements has shown that those asphalts with low viscosities at 140 F are particularly susceptible to transverse cracking at low winter temperatures. This was verified in a carefully conducted paving project wherein three 200 to 300 penetration-grade asphalts representing low, intermediate, and high viscosities at 140 F were incorporated in the surfacing. The low viscosity section cracked earliest and most extensively and exhibited the most rapid densification under moderate traffic. Details of physical changes of the 3 asphalts during a 34-month service period are discussed. The tensile splitting test, conducted at 0 F, demonstrates the different strain capabilities of the 3 asphalts in order with their relative viscosities at 140 F. A general relationship among penetration at 77 F, absolute viscosity at 140 F, and tensile strain capability at 0 F is presented. A specification incorporating a minimum penetration of 250 at 77 F and minimum viscosity of 275 poises at 140 F was adopted in 1967. This has resulted in a more uniform product from provincial refiners, elimination of tender mixes, and a reduction in early transverse cracking.

•THERE is a great deal of controversy over the current approaches of grading asphalt cements according to penetration at 77 F or by absolute viscosity at 140 F. It is considered beyond the scope of this paper to attempt to present the various views, even by way of a brief summary; therefore, this paper will deal with information gathered from studies in our particular locale. This will necessarily limit direct application to the materials, construction procedures, load, and environmental conditions in Alberta; however, general conclusions may be considered valid for similar situations.

Until 1967, asphalt cements for use in highway construction were graded according to penetration at 77 F. Except for some early postwar pavements constructed in the late 1940's in which SC-6 materials were used, 200 to 300 or 150 to 200 penetration grade materials produced by as many as 10 different suppliers have been used through 1966. In 1967, a specification incorporating a viscosity requirement at 140 F was introduced by the Alberta Department of Highways. The grade most commonly used calls for a minimum penetration of 250 at 77 F and a minimum viscosity of 275 poises at 140 F, hence termed AC 275. Prior to this, variation in crude sources and refining methods of different suppliers resulted in asphalt cements of a given penetration grade that exhibited large differences in viscosity at 140 F. Extensive field performance surveys have been conducted on pavements built with these asphalt cements in which particular attention was given to the extent of transverse cracking exhibited under the low temperatures experienced in our western Canadian climate (1). These studies showed that the most extensive transverse cracking was associated with certain asphalt sources and that these sources usually had the lowest viscosity at 140 F. In order to bring the

Sponsored by Committee on Characteristics of Bituminous Materials and presented at the 50th Annual Meeting.

penetration-viscosity aspect into focus, the following discussion will be based primarily on field observations and related laboratory tests for a single paving contract in which 3 contiguous flexible pavement sections were constructed in 1966 by utilizing 200 to 300 penetration grade asphalt cements from 3 major refineries in Alberta. Details of this project have been reported elsewhere (2).

TEST PROJECT

During the summer of 1966, the Construction Branch of the Alberta Department of Highways undertook final asphaltic concrete paving of approximately 37 miles of 4-lane divided freeway in central Alberta within sections 2-D-2/1 and 2/2 of the highway system. In order to evaluate more precisely the possible environmental conditions contributing to low temperature transverse cracking and the influence of asphalt source, the department decided to incorporate within one 13-mile contract 3 different sources of 200 to 300 penetration grade asphalt cement. These 3 asphalt sources obtained from the major refiners in the province represented high, intermediate, and low viscosity materials, as measured at 140 F. It was felt that, within a single paving contract with uniform subgrade and base properties, it would be possible to obtain reasonably homogeneous, contiguous surfaces wherein the relative behavior of the asphalt cements could be evaluated. By careful planning, it was possible to change the asphalt supplier so that 1 source was present on one roadway and the other 2 sources abutted at a common point on the parallel roadway, satisfying the requirement that the 3 sources could be observed within an area where subsurface conditions would be uniform.

The pavement structure consisted of 4 in. of asphaltic concrete placed in 2 equal lifts on 2 in. of asphalt-bound base and 12 in. of compacted granular base. The asphaltic concrete surfacing was prepared from a single aggregate source within one contract; the sole major surfacing variable was the source of the asphalt cement.

TESTING PLAN AND PROCEDURES

Because the only major variable to be incorporated into the pavement surface was the source of 200 to 300 penetration grade asphalt cement, a comprehensive construction sampling and testing program was evolved. Three separate Marshall mix designs were prepared with the single source of aggregate to be used on the project. These are shown in Figure 1. They are similar in design characteristics, with the exception of stability where the mixture using the low viscosity asphalt cement exhibited a somewhat lower stability than the other 2 mixtures. The design mixes are generally of medium stability with somewhat low flow characteristics and low percentages of voids filled at optimum bitumen content.

Normal construction quality control procedures of the Alberta Department of Highways were maintained throughout the project. In addition, an extensive evaluation and testing program, primarily directed toward determining changes in the asphalt cement, was implemented. Because considerable time was involved in the procedures adopted, it was not intended that the construction process would be controlled by this method, but rather that reliance would be placed on the normal testing procedures undertaken for a project of this magnitude. Thus, the randomized test location procedure adopted involved single, composite samples for each phase of the mixing and placing process but did not involve replicate samples that would normally be used for preparation and application of statistically based quality control charts. In other words, the special testing program was designed to determine normally occurring quality variations. At each random testing time selected, usually at midmorning and at midafternoon when it was considered that plant operating conditions were stable, a sample of the bitumen supply was obtained immediately before entering the pug mill. The corresponding batch truck was noted, and a loose sample of the mix was obtained from behind the spreader on the road. Location and lift were recorded. Following completion of rolling, a minimum of three 4-in. diameter cores were obtained from the surface by using a diamond core barrel. Hot aggregate, mixture, and asphalt storage temperatures were obtained manually for each random sample, supplemented by air and mat temperatures at time of placing at commencement of breakdown rolling on the paving site. A total of 105

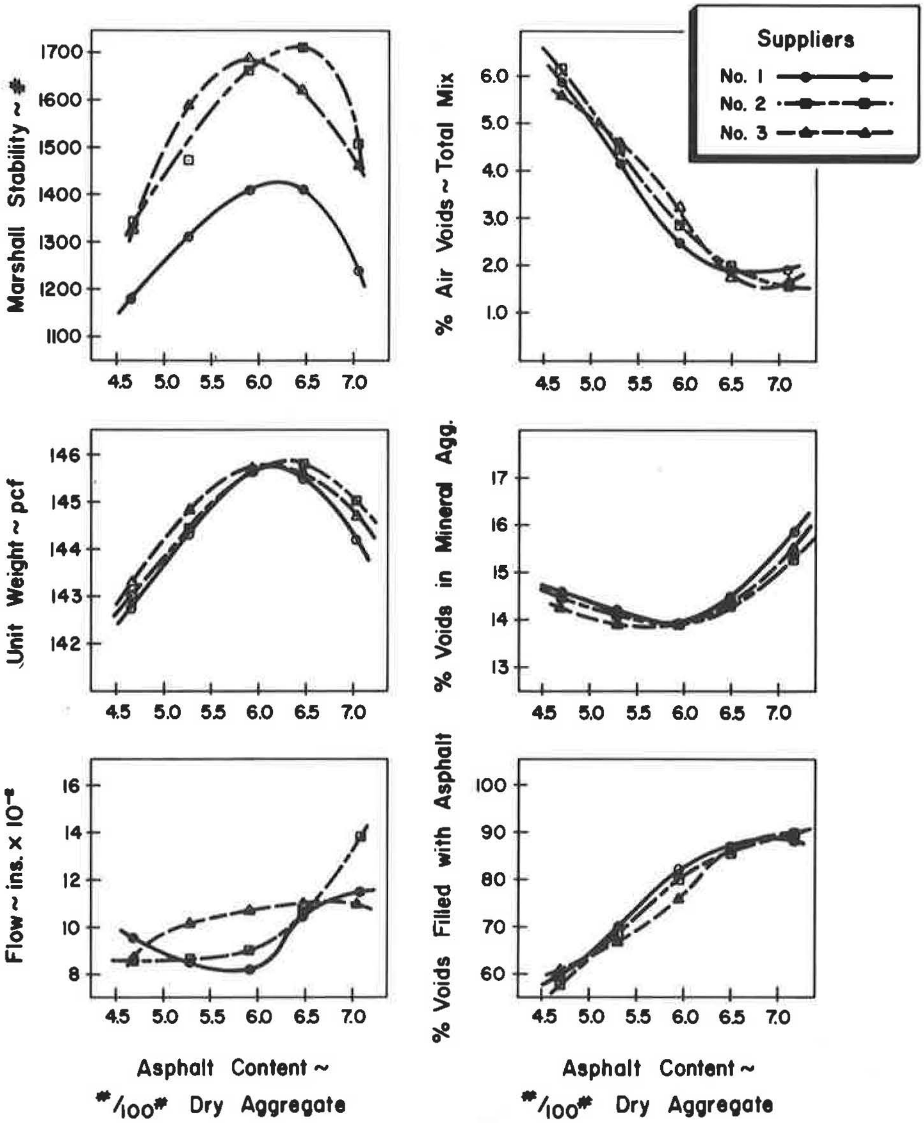

Figure 1. Marshall stability test results.

random test locations were sampled by this procedure during paving. Because of the large amount of laboratory work involved, it was necessary with some test procedures, particularly the thin-film oven test (TFOT) phase and subsequent testing of asphalt properties, to reduce the number of random samples tested; this was usually done by a subsequent random selection of a reduced number of samples for further testing.

RESULTS OF ASPHALT TESTING PROGRAM

The results of the bituminous testing program are given in Table 1 and shown in Figures 2, 3, and 4. The asphalt cement from supplier 1 was the most variable material supplied to the project, and in several cases samples exceeding 300 penetration were recorded. Supplier 2 provided the most uniform product. The intermediate vis-

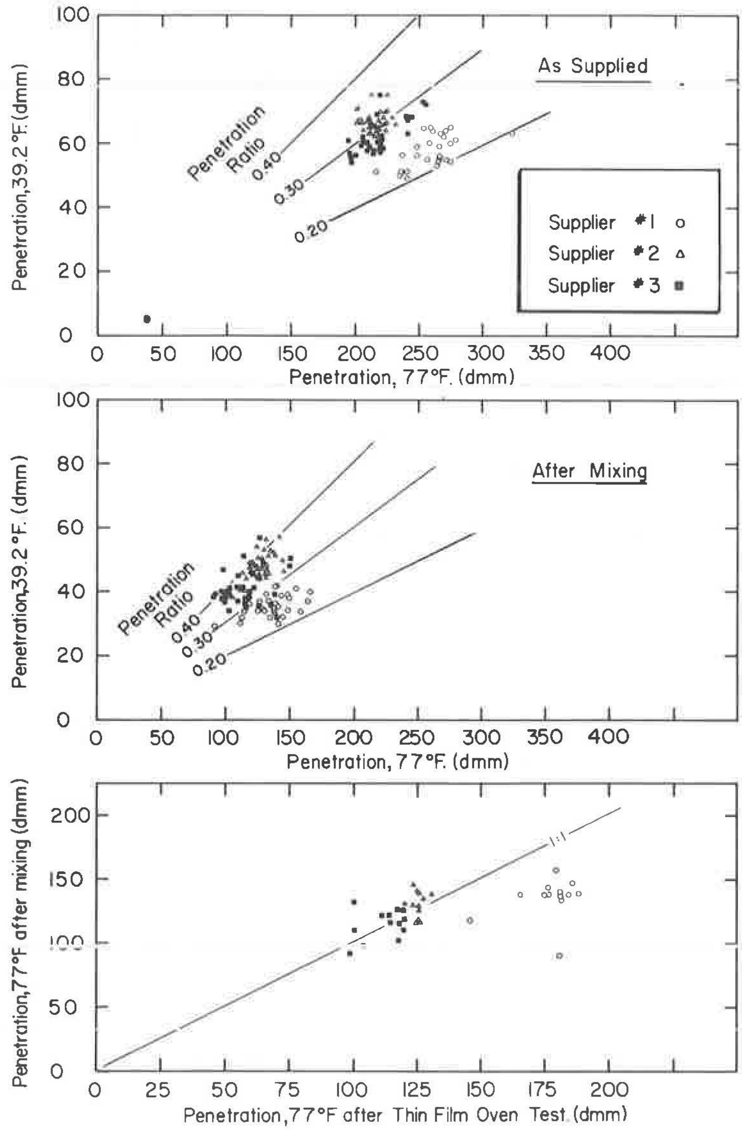

Figure 2. Penetration relationships.

cosity asphalt cement from supplier 3 exhibited somewhat more variability than that from supplier 2. The penetration relationships shown in Figure 2 indicate that suppliers 2 and 3 are roughly similar in terms of retained penetration both for the as-supplied condition and after extraction from the mix. The low viscosity asphalt cement (supplier 1) exhibited a lower retained penetration for both conditions. Figure 2 also shows that the TFOT appears to represent adequately penetration changes effected during mixing for suppliers 2 and 3. However, supplier 1 showed a marked deviation from this relationship. A similar relationship is evident in Figure 3, where the absolute viscosity at 140 F after TFOT is about twice the as-supplied viscosity for suppliers 2 and 3, and a somewhat smaller relative change occurs with supplier 1. A much higher variability in resultant viscosity after mixing is evident for suppliers 2

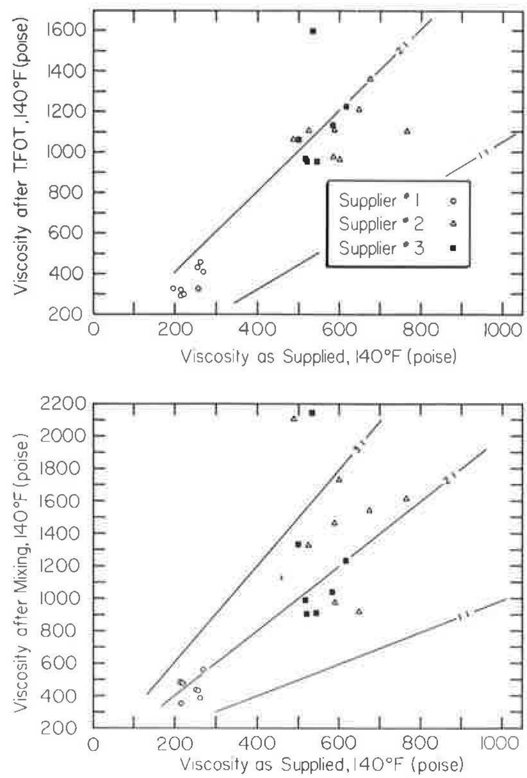

Figure 3. Viscosity relationships.

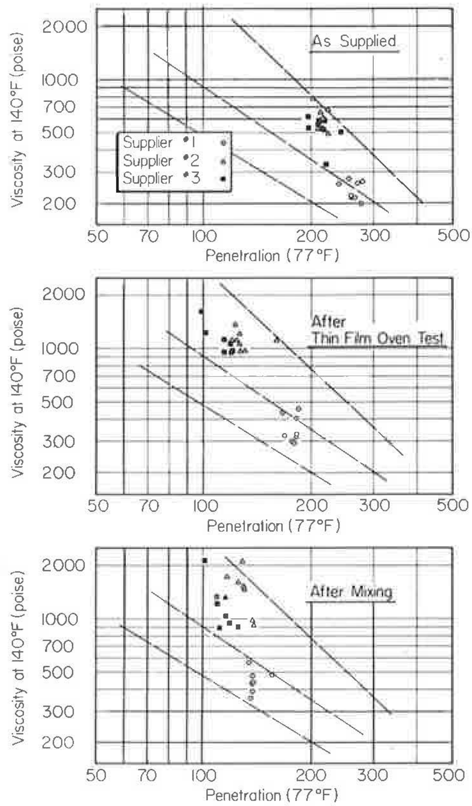

Figure 4. Relationships of penetration at 77 F and viscosity at 140 F.

and 3 as shown in Figure 3. It is evident that marked changes in the viscosity of these soft asphalt cements can occur through the normal mixing process, which is discussed in greater detail later; and it is also evident that, for the higher viscosity materials, the TFOT provides a reasonable indication of what viscosity changes might be expected. Figure 4 shows penetration at 77 F versus viscosity at 140 F for the 3 supplied materials from a smaller, randomized group of samples. Again it can be seen that supplier 1 occupies a lower level on the penetration-viscosity chart, and this remains consistent for the TFOT residues and for bitumen extracted from the plant mix.

FIELD CONSTRUCTION

Table 2 gives test results obtained on the finished surface. At each sampling location, whether lower course or upper course, a minimum of three 4-in. diameter cores were taken from the compacted mat, and densities determined in the laboratory. Bitumen contents and aggregate gradations were determined from the bulk sample obtained from the compacted mat. The pavement mixtures using asphalt from suppliers 1 and 2 appear to be rather similar (Table 2). Gradations in all cases were similar, as would be expected because the aggregate was produced from a single, large gravel pit. However, it will be noted that, for both suppliers 1 and 2, the average field density was just equal to 95 percent of Marshall density, which would suggest that approximately 50 percent of the finished pavement did not meet this specification level. With supplier 3 the major deviation from design was in the asphalt content; on the average approximately 1 percent asphalt less than the design recommendation was incorporated in the mixture, resulting in low densities and exceedingly high air voids. Variability in unit

TABLE 1

SUMMARY OF ASPHALT CEMENT QUALITY TESTS IN 1966

Supplier	Condition	Penetration (1/10 mm) 77 F	39.2 F	32 F	Softening Point[a] (deg F)	Viscosity 275 F (centistoke)	140 F[b] (poise x 10^0)	77 F[c] (poise x 10^5)	39.2 F[c] (poise x 10^8)	Penetration Index	Penetration Retained (percent)
1	Supply	265	68	40	103	139	237	3.0	1.2	+1.0	22.3
	σ	(28)	(8)	(4)	(7)	(8)	(26)				
	TFOT	177	43	22	108	—	358	8.6	2.5	+0.2	24.3
	σ	(12)	(7)	(2)	(1)		(60)				
	Mix	138	34	23	109	204	445	5.9	3.8	-1.0	25.3
	σ	(16)	(3)	(2)	(2)	(15)	(63)				
2	Supply	215	62	38	101	217	610	2.8	1.0	-1.0	31.2
	σ	(8)	(3)	(2)	(2)	(3)	(81)				
	TFOT	125	41	25	110	—	1,111	7.8	2.4	-0.8	32.8
	σ	(3)	(2)	(1)	(4)		(119)				
	Mix	113	41	27	111	309	1,415	13.4	3.4	-1.0	37.8
	σ	(9)	(4)	(2)	(3)	(20)	(350)				
3	Supply	217	58	35	102	184	544	2.3	0.8	-0.8	28.1
	σ	(15)	(4)	(3)	(2)	(10)	(36)				
	TFOT	112	38	24	110	—	1,127	24.3	2.0	-0.9	34.0
	σ	(7)	(1)	(1)	(1)		(212)				
	Mix	102	38	26	111	271	1,217	14.5	4.5	-1.3	36.3
	σ	(13)	(5)	(2)	(2)	(31)	(403)				

[a]ASTM D 36-26. [b]ASTM D 2171-66. [c]Sliding-plate microviscometer at shear rate of 10^{-2} sec^{-1}.

TABLE 2

SUMMARY OF ASPHALT CONCRETE QUALITY TEST IN 1966

Supplier	Condition	Bitumen Content (lb/100 lb)	Unit Weight (pcf)	Air Voids (percent)	Voids in Mineral Aggregate (percent)	Voids Filled (percent)	Gradation (percent passing) 3/4 in.	No. 4	No. 10	No. 40	No. 200
1	Design	5.4	144.5	3.9	14.1	72.5	100	50	34	14	6.3
	Constructed	5.2	138.2	8.3	17.6	53.7	100	49.9	36.8	16.5	6.6
	σ	(0.46)	(4.5)	(2.1)	(1.4)	(9.0)	—	(2.9)	(1.9)	(1.7)	(0.8)
2	Design	5.4	144.6	4.2	14.1	70.5	100	51	34	15	6.8
	Constructed	5.3	136.7	9.5	18.8	49.1	100	51.1	37.6	14.8	5.8
	σ	(0.36)	(2.6)	(1.6)	(1.3)	(5.9)	—	(2.4)	(1.8)	(1.8)	(0.7)
3	Design	5.5	145.3	4.1	13.9	70.0	100	51	35	15	6.7
	Constructed	4.4	134.2	12.0	19.5	38.5	100	50.0	37.8	17.1	6.0
	σ	(0.43)	(2.4)	(1.7)	(1.3)	(5.4)	—	(3.7)	(2.4)	(2.6)	(1.2)

Note. n = 29 for supplier 1, 37 for supplier 2, and 39 for supplier 3.

weight and bitumen content was greatest with supplier 1; it will be noted, however, that with this low viscosity asphalt the highest initial densities were achieved.

The extensive quality variation studies carried out indicated that the objectives of the paving project were not met entirely. It was desirable to construct 3 uniform and similar paving mats, with the only variable the source of penetration grade asphalt cement used. However, because of unforeseen conditions, during construction the bitumen content was highly variable and was gradually changed from the beginning to the completion of the project. As a result asphalt cement from supplier 3 was placed at an asphalt content approximately 1 percent less than the suggested Marshall optimum, resulting in lower densities and higher air voids. Most other factors remained relatively constant and consistent, and it is not believed that the measured variations in gradation were particularly significant in terms of differences in mix properties.

CHANGES IN ASPHALT PROPERTIES IN SERVICE

Subsequent to completion in 1966, the test sections have been reexamined in the summers of 1967, 1968, and 1969 to determine changes in the characteristics of the asphalt and the asphaltic concrete in service. For the first 2 testing periods, approximately

TABLE 3

CHANGES IN ASPHALT PROPERTIES WITH TIME

Supplier	Age	Asphalt Content (percent)	Unit Weight (pcf)	Physical Properties of Asphalt Cement: Penetration ($^1/_{10}$ mm) 77 F	Penetration 39.3 F	Softening Point (deg F)	Absolute Viscosity at 140 F (poise)	Viscosity at 77 F (poise x 10^5) 10^{-3} sec^{-1}	10^{-1} sec^{-1}
1	As supplied			265	68	103	237	4.1	2.2
	After TFOT			117	43	108	358	17.9	4.1
	After plant mixing and spreading	5.2	138.2	138	34	109	446	15.9	4.0
	12 mo.	5.9	146.8	191	41	105	258	7.3	2.3
	24 mo.	5.75	146.6	196	44	102	258	2.8	2.0
	34 mo.	5.5	147.9	144	29	107	343		
2	As supplied			215	62	101	610	3.0	2.6
	After TFOT			125	41	110	1,111	9.2	6.7
	After plant mixing and spreading	5.3	136.7	113	41	111	1,460	22.5	7.8
	12 mo.	5.7	142.2	136	41	107	860	8.8	5.0
	24 mo.	5.4	143.1	127	38	107	954	6.2	4.9
	34 mo.	5.4	144.1	105	30	111	1,281		
3	As supplied			217	58	102	544	2.6	2.6
	After TFOT			112	38	110	1,127	12.1	10.2
	After plant mixing and spreading	4.4	134.2	102	38	111	1,217	15.2	8.6
	12 mo.	5.5	139.4	116	36	110	844	12.9	6.1
	24 mo.	5.3	141.6	90	28	113	1,215	11.7	10.6
	34 mo.	4.3	142.3	70	26	117	1,801		

ten 6-in. diameter cores were extracted from randomly selected outer wheelpath positions in the travel lane in each pavement section. Cores were subsequently trimmed and measured in the laboratory and extracted by the Abson process for determination of the characteristics of the recovered asphalt. The samples taken in 1969 were similarly selected and processed except that they were 4-in. diameter cores used for the tensile splitting test, discussed in more detail later. This information is given in Table 3 and compared with asphalt properties determined during the construction phase. Average penetration-viscosity relationships for the construction phase and for 2 in-service periods are shown in Figure 5. It is apparent that in-service asphalt properties determined 1 and 2 years after construction indicate less hardening of the asphalt cement than was indicated by the TFOT or from asphalt extracted from the uncompacted mix immediately before breakdown rolling (Table 3). This is indicated by higher retained penetrations and lower absolute viscosities at 140 F. There is fair agreement between penetration after the TFOT and penetration after 12 months of service, but the viscosities at 140 F are lower for in-service conditions than from the TFOT for all 3 asphalt sources. Regarding the results of extraction tests carried out on the material obtained from the uncompacted mix, it must be assumed that the sampling procedure (with a small amount of the batch being sampled immediately after spreading, without quenching in water) must have resulted in premature hardening of the asphalt.

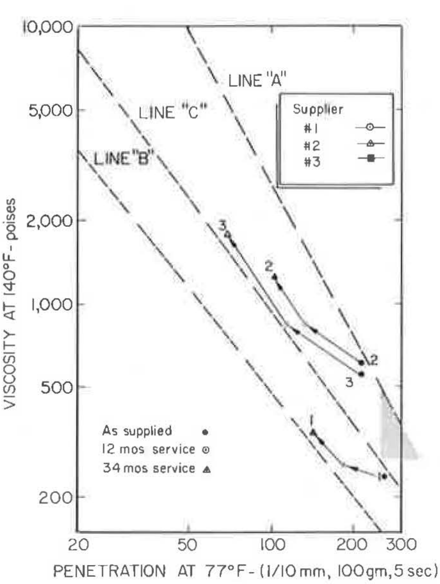

Figure 5. Penetration at 77 F versus viscosity at 140 F for various service ages.

Considerable differences exist between densities determined after final rolling (sampled within 1 or 2 days) and those obtained at subsequent service periods. Calculations were made that indicated that densification by traffic after 2 years should have resulted in apparent rut depths of the order of 0.2 in., assuming uniaxial consolidation. However, rut depths measured at the end of the second year of service were only in the order of 0.06 to 0.10 in. (in other words between one-third and one-half the apparent densification as indicated by unit weight differences). As-compacted densities were determined from the average of three 4-in. diameter cores taken at each production unit location. Six-in. diameter cores were obtained at each sampling period in 1967 and 1968. All sets of cores were measured by identical procedures (uncoated immersion) in one laboratory so that the apparent density difference noted cannot be attributed solely to differences in measurement techniques. It is recognized that data obtained in service are from a relatively small sample, though all coring locations were randomized to avoid bias. For all 3 test sections, there is a significant difference between the as-constructed unit weight and the unit weight obtained from outer wheelpath samples after 24 months of service. There is no statistically significant difference between field densities obtained at 12 months and at 24 months of service. The largest increase in outer wheelpath density occurred with supplier 1, the low viscosity asphalt cement; and after 24 months, average air voids have been reduced to approximately 1.7 percent. An independent check on these changes in density is afforded by utilizing results of density measurements taken on the cores used for tensile splitting tests. Average densities in pcf at the time of construction and comparable values given in Table 3 (shown in brackets) are 138.6 (138.2), 137.0 (136.7), and 134.0 (134.2) for suppliers 1, 2 and 3 respectively. Average densities for cores taken at 32 and 34 months compared to the values given in Table 3 at 24 months (again shown in brackets) are 147.0 (146.6), 142.0 (143.1), and 141.4 (141.6).

Traffic during this period could be described as relatively light. The AADT in 1966 was 3,830 vehicles in both directions. This has increased to an AADT of 4,150 in 1969, with an estimated 15 percent or fewer trucks in the traffic stream.

RESULTS OF THE TENSILE SPLITTING TEST PROGRAM

Use of the tensile splitting test method for evaluating the response of asphalt concrete mixtures at low temperatures has been described in detail (3) and has formed a part of one of the specialized test programs in conjunction with this project. The slightly modified test method along with the computer analysis techniques available has been presented by Christianson (4) and illustrates how changes in low temperature properties can be observed.

A summary of tensile splitting test data at 0 F available for this project together with cracking frequencies is given in Table 4. Asphalt supplier 1, the low viscosity source, exhibits the greatest change in failure stress at the test temperature of 0 F. There is a 60 percent increase in failure stress over the period of time considered, compared to 6 and 30 percent for suppliers 2 and 3.

Failure strain, considered to be the most significant parameter of the tensile splitting test, also shows differing values for the 3 suppliers. The low viscosity asphalt cement, supplier 1, has the lowest failure strain at the time of construction as well as the 34-month service period. Supplier 3, the intermediate viscosity asphalt supplier, has the highest failure strain at the time of construction and at the 34-month age.

Failure stiffness reflects the combined effect of changes in the failure stress and strain and affords the use of a single term to denote changes with time. The low viscosity asphalt cement, supplier 1, exhibits a 185 percent increase in stiffness over the observed time period. Supplier 2 shows a corresponding increase of 33 percent, and supplier 3 shows an increase of 95 percent. The majority of the increase in stiffness may be attributed to the changes in density previously described.

The marked increase in cracking in all 3 asphalt supply sections during the third winter, 1968-69, may be explained by the fact that this was considered to be the most severe in central and northern Alberta for the period of record of 75 years, while the previous 2 winters were considered to be equivalent to the long-term average.

In reviewing the data presented, one can note that for this particular project observations to date indicate a definite correlation between the amount of low temperature

TABLE 4

SUMMARY OF TENSILE SPLITTING TEST INFORMATION ON HIGHWAY SECTIONS 2-D-2/1 AND 2/2 AT TEST TEMPERATURE 0 F

Supplier	Condition	Failure Stress (psi)	Failure Strain (in./in.)	Failure Stiffness (psi)	Pavement Performance (cracks/mile)
1	Design value	490	0.00074		
	At construction	302	0.00082	699,000	
	At 32 months	460	0.00056	1,679,000	
	At 34 months	505	0.00047	2,296,000	
	After first winter				4
	After second winter				87
	After third winter				187
2	Design value	480	0.00151		
	At construction	289	0.00105	599,000	
	At 32 months	305	0.00102	579,000	
	At 34 months	310	0.00061	1,071,000	
	After first winter				nil
	After second winter				nil
	After third winter				126
3	Design value	490	0.00165		
	At construction	194	0.00138	336,000	
	At 32 months	270	0.00083	623,000	
	At 34 months	263	0.00082	704,000	
	After first winter				nil
	After second winter				4
	After third winter				84

transverse cracking of asphalt pavements and failure stress, failure strain, and failure stiffness as measured by the tensile splitting test at 0 F. Comparing the sections constructed with the 3 sources of 200 to 300 penetration grade asphalt cement, we have made the following conclusions:

1. An increase in cracking frequency is accompanied by a decrease in failure strain and an increase in failure stress and failure stiffness;
2. An increase in density with service life is accompanied by a decrease in failure strain and an increase in failure stress, failure stiffness, and cracking frequency;
3. In terms of relative comparisons, the pavement section with the highest crack frequency also has the lowest failure strain and the highest failure stress and failure stiffness; and
4. In terms of service life, the low viscosity asphalt cement exhibits the greatest change in density, failure stress, failure strain, and failure stiffness and the highest cracking frequency per mile.

The previous observations were based on tensile splitting tests performed on core specimens. Therefore, construction variability must be considered in attempting to explain the low temperature response obtained. Subsequent to developing the method as a potential design procedure, information has been collected on a variety of mixtures using asphalt cements of varying penetration grades and viscosities. Figure 6 shows results based on laboratory specimens tested at 0 F and indicates failure strain values to be expected for various asphalt cements of differing penetration at 77 F and viscosity at 140 F. The contour lines have been drawn in tentatively on the basis of approximately 15 various mix designs and may have to be revised as more information becomes available. In the meantime, a basic point concerning the low temperature behavior of asphalt cements may be stated following an examination of data shown in Figure 6.

An increase in penetration value at 77 F, while maintaining the same relative viscosity at 140 F by paralleling lines A, B, or C, generally results in increased failure strain at 0 F. This is consistent with experience gained with the use of softer grades of asphalt cement in cold climates. It may be further noted that, for a particular penetration at 77 F, an increase in viscosity at 140 F can be expected to produce large increases in failure strain at 0 F. This also reflects experience gained with low and high viscosity asphalt cements, but is not readily deduced from conventional asphalt tests at higher temperatures. Although a definite limiting failure strain cannot be stated at this time, indications are that values below 10×10^{-4} in./in. can be expected to indicate mixes having high potential for cracking under the climatic conditions of western Canada.

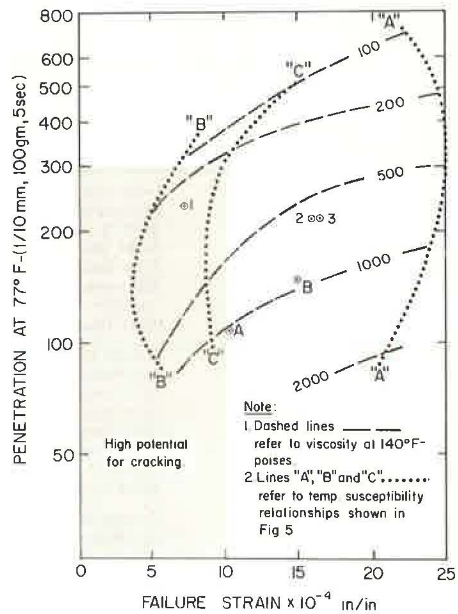

Figure 6. General relationship among tensile failure strain, penetration at 77 F, and viscosity at 140 F.

EXPERIENCE WITH VISCOSITY-GRADED ASPHALT CEMENTS

As noted earlier, in 1967 the Alberta Department of Highways revised its asphalt cement specifications to include a minimum acceptable viscosity at 140 F, basing this on extensive field surveys of low temperature cracking occurrence and the early performance of the test sections described in a preceding section (shown as shaded portion in Figure 5).

The change to specifying asphalt paving cements with a minimum value for viscosity and penetration has yielded some immediate improvements to the mixing and compaction phases of pavement construction. General field observations have shown that greater uniformity in mixing and rolling have been realized because of the smaller range of viscosity of asphalts obtained from various suppliers. This point is illustrated by the fact that contractors do not find it necessary to alter their rolling patterns because of a change in source of asphalt. There has been complete success in eliminating tender mixes that previously were experienced frequently.

These newly specified viscosity-graded asphalts have been in service for only 3 years. Performance during the first normal winter of 1967-68 was encouraging with only slight to no transverse cracking observed on most projects. However, the abnormally severe winter of 1968-69 resulted in large amounts of cracking in all projects constructed by using the new specification asphalt cements. A return to more normal conditions in the winter of 1969-70 again showed little initial crack development in the previous summer's construction.

The department's experience to date suggests that the specified minimum limits of 250 penetration at 77 F and 275-poise absolute viscosity at 140 F provide the softest asphalt that can be used under current surfacing criteria and requirements. The introduction of softer asphalts at this time would require major alterations in gradation to most provincial aggregate sources.

CONCLUSIONS

1. Extensive field surveys and laboratory investigations have shown that low temperature transverse cracking of flexible pavements in Alberta is closely associated with certain asphalt sources. These asphalt cements, penetration grades 150 to 200 and 200 to 300, are identified by a relatively low viscosity at 140 F.

2. A field experiment compared the in-service performance of 3 sources of 200 to 300 penetration grade asphalt cements ranging from low to high viscosity at 140 F. The low viscosity source exhibited the largest variation in conventional physical properties, most rapid densification under traffic, and the earliest and largest amount of low temperature cracking.

3. The tensile splitting test method can be used to measure the low temperature stiffness of asphaltic concrete mixtures; low temperature tensile strain capability increases with increasing viscosity at 140 F for a given penetration grade.

4. A specified minimum viscosity at 140 F for soft penetration grade asphalt cement has resulted in a more uniform product from several distinct sources, the elimination of tender mixes, and an apparent reduction in low temperature transverse cracking, under normal winter conditions.

REFERENCES

1. Anderson, K. O., Shields, B. P., and Dacyszyn, J. M. Cracking of Asphalt Pavements Due to Thermal Effects. Proc. Assn. of Asphalt Paving Technologists, Vol. 35, 1966.
2. Shields, B. P., Anderson, K. O., and Dacyszyn, J. M. An Investigation of Low Temperature Cracking of Flexible Pavements. Proc. Canadian Good Roads Assn., Ottawa, 1969.
3. Anderson, K. O., and Hahn, W. P. Design and Evaluation of Asphalt Concrete With Respect to Thermal Cracking. Proc. Assn. of Asphalt Paving Technologists, Vol. 37, 1968.
4. Christianson, R. H. A. Analysis of the Tensile Splitting Test for Low Temperature Tensile Properties of Asphaltic Concrete. Master of Science thesis, University of Alberta, Edmonton, 1970.