FINAL REPORT

AN INVESTIGATION OF THE EFFECTS OF ELEVATED MIXING TEMPERATURES ON THE PROPERTIES OF ASPHALT CEMENT

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SUMMARY

This laboratory investigation was instituted to determine the feasibility of increasing the design mixing temperature for hot-mix asphaltic concrete. Based on data obtained from modified thin film oven tests, it appears that the upper design limit could be increased to 300°F without appreciably affecting the durability of the asphalts studied. The data also indicate that softer grade asphalts (120-150 penetration) remain considerably higher in penetration value than harder asphalts (50-60 and 60-70) after the modified thin film test.

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INTRODUCTION

The paving specifications of the Virginia Department of Highways place limits on the temperatures to which the aggregate and asphalt cement for a mix may be heated. The maximum allowable design mix temperature at the plant is 280°F with a tolerance of ± 20°. The highest temperature, therefore, that could be attained within the specification is 300°F.

In cold weather, the base temperature at the job site determines the lowest allowable mix temperature. If the specification could be changed to allow higher mix temperatures at the plant then paving could take place on lower base temperatures and the end result would be a longer paving season.

PURPOSE AND SCOPE

The primary goal of this project was to determine the feasibility of raising the mixing temperature for hot-mix asphaltic concrete. Consequently, the main concern was that of detecting any harmful effects from raising the temperature — effects that might result in a loss in the durability of the pavement. The project involved two processes: (1) the production of asphalt samples corresponding to identifiable mix temperatures; and (2) the analysis of each sample to determine its acceptability for use as binder in bituminous concrete.

The project involved testing of only the penetration graded asphalts with emphasis on the AP-3 grade (85-100 penetration), since it is the type most commonly used in Virginia. The time factor limited the work to laboratory methods of simulating the mixing process rather than actual plant mixing, which would have been more desirable. Standard testing procedures were used to evaluate and categorize the asphalt samples. Two tests — penetration and viscosity — were used to determine asphalt consistency.

PROCEDURE

Materials

Table I gives a listing of the asphalts used in this study. All samples were obtained directly from the companies and were shipped in 5-gallon sample cans.

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TABLE I

ASPHALTS USED IN STUDY

Company	Penetration Grades			
	50-60	60-70	85-100	120-150
Chevron	X	X	X	X
Esso		X	X	X
Shell			X	
American		X	X	X

Original Asphalt Properties

The first stage of lab work involved the simple determination of the consistency of each asphalt sample, as stated above, by means of the two consistency tests: penetration and viscosity.

Samples were cut from each 5-gallon can with a hot sampling spoon and placed in a copper beaker. The asphalt was then heated to approximately 275°F and poured into three 3-ounce sample tins, allowed to cool, and then covered. One sample was analysed for penetration at 77°F (ASTM D5-65) with a standard penetrometer and 100-gram total weight. The next was tested for viscosity at 140°F (ASTM D 2171-66) using a constant temperature water bath and Cannon-Manning viscometers. The last sample was used for a viscosity determination at 275°F (ASTM D 2170-67) in a constant temperature oil bath with Zeitfuchs Cross-Arm type viscometers. At least five penetration tests were run on each sample and two viscosity determinations were made at each temperature.

Heat Treatment

The heat treatment portion of the study was intended to simulate the asphalt hardening which occurs during mixing operations . For each 5-gallon sample of asphalt, a sample was cut with a hot spoon and placed in a copper beaker. The sample was then heated to approximately 275°F and then exactly 300 grams were weighed into another beaker. This sample was reheated to 275°F and poured into a 12" by 12" galvanized pan to give a film thickness of 1/8", the thickness used in the "Test for Effect of Heat and Air on Asphaltic Materials" (ASTM D 1754-69, Thin Film Oven Test). The sample was then subjected to heating in a Thelco Model 27 oven set at 300°F for five hours. The temperature was monitored by means of a thermocouple with the five-hour period beginning when the temperature reached 300°F. At the end of five hours the sample was removed from the oven and poured into a clean copper beaker. The bottom and sides of the pan were scraped so that a maximum amount of the sample was recovered. The sample was placed on a hot plate and thoroughly mixed at 275°F, and poured into three 3-ounce tins, allowed to cool, and covered. Each of these 3-ounce samples was then used for one of the viscosity or penetration tests as performed on the original asphalt samples.

A special series of tests were run on the Chevron 85-100 samples. The 300-gram samples were used to obtain the 1/8" films and the exposure period in the oven was still five hours. The only difference was that the samples were run at 300°F, 325°F and 350°F to study the variation of consistency with temperature. Each sample was then divided into three samples and the viscosity and penetration tests run.

To correlate these laboratory tests with actual mixing operations, data were obtained from the Central Office on jobs performed in the past year. For each job, data were collected on the penetration of the original asphalt, the mix temperatures taken at the plant, and the penetration of the residue from Abson recoveries on pavement samples. With this information it was hoped that a correlation could be established between the laboratory heat treatment and the hardening processes which take place during mixing. It should be noted that this phase of the study was performed with only the AP-3 asphalts, which are the ones most widely used in Virginia.

RESULTS

Penetration

Effects of Mixing Temperature

Even though the standard apparatus for the penetration test (AASHO T 49) was used, the penetration values for all the original asphalts seemed to be consistently low. This could possibly have been due to improper functioning of the testing equipment or may have been caused by the heating process involved in obtaining the samples from the cans and pouring them into the 3-ounce sample containers. To minimize any error in the absolute penetration values, the asphalts are compared on the basis of retained penetration, which is a relative measure defined as the ratio of the penetration of the residue to the penetration of the original asphalt. This procedure was necessary so that the results of tests in the Council's laboratory could be compared to the results of tests performed in other laboratories.

Initially, the 5-hour, 300°F oven test used must be correlated with field data since it is supposed to simulate the hardening of the asphalt which takes place during mixing and placement of the hot-mix bituminous concrete. Shown in Table II is a summary of the results of laboratory tests on samples taken immediately after placement on five different jobs completed during 1970 and 1971 in the Richmond, Fredericksburg, and Lynchburg Districts.

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TABLE II

PENETRATION DATA FROM SELECTED JOBS

	JOB					
	A	B	C	D	E	Avg.
Penetration (Original)	91.5	92	92	90	94.3	92.0
Penetration (Abson Recovery)	58	58	73	56	70	63
% Retained Penetration	63.4	68.0	79.3	62.2	74.2	69.4
Mixing Temperature (°F)	288.6	277.2	289.0	284.7	282.3	284.4

Since AP-3 asphalt (85-100 penetration) was used in all the jobs listed, the retained penetration should compare favorably with the values for the 85-100 penetration asphalts tested in the lab. The asphalts from the lab showed an average retained penetration of 63% compared to 69.4% for the field values, so it is apparent from these limited data that the laboratory test, 5-hours at 300°F, produced more severe hardening of the asphalt than did the actual mixing operations at 285°F. Assuming that the laboratory aging approximates mixing at 300°F, this is a very good agreement, and the artificial aging process can be said to closely approximate the actual hardening of the asphalt.

Figures 1 and 2 show the variation of penetration and percent retained penetration with the temperature of the oven, while the time in the oven is held constant at five hours, for one AP-3 asphalt. The Virginia specifications limit the retained penetration for an AP-3 asphalt to a minimum of fifty percent of the original penetration. From the graph of retained penetration versus oven temperature (Figure 2) it is evident that this critical point is somewhere between 300°F and 325°F for Chevron asphalt. The fact that the oven test at 300°F closely approximated mixing at 285°F indicates that the mix temperature could be raised above the present limit of 280°F, before reaching the critical point for retained penetration for this one asphalt. Also shown in Figure 2 is the projected line for the average of all the 85-100 penetration asphalts tested. If the same criterion of 50 percent minimum retained penetration is applied, a maximum temperature of about 330°F is indicated, which would mean that a maximum design temperature of 310°F (with a ± 20°F tolerance) would be possible.

Effects of Penetration Grade

The data showing the results of the heat treatment on penetration are contained in Table III. These data depicted graphically by penetration grade are shown in Figure 3. Although the data are limited, the trend appears toward a lower percent retained penetration with an increase in penetration grade. This was not unexpected and corresponds very well with the specification values of Table III. However, referring again to Table III, it is obvious that an appreciably higher retained absolute penetration is provided by the lower or softer grade asphalts. Therefore, even though less percent penetration is retained in the softer grade asphalts more penetration points are retained.

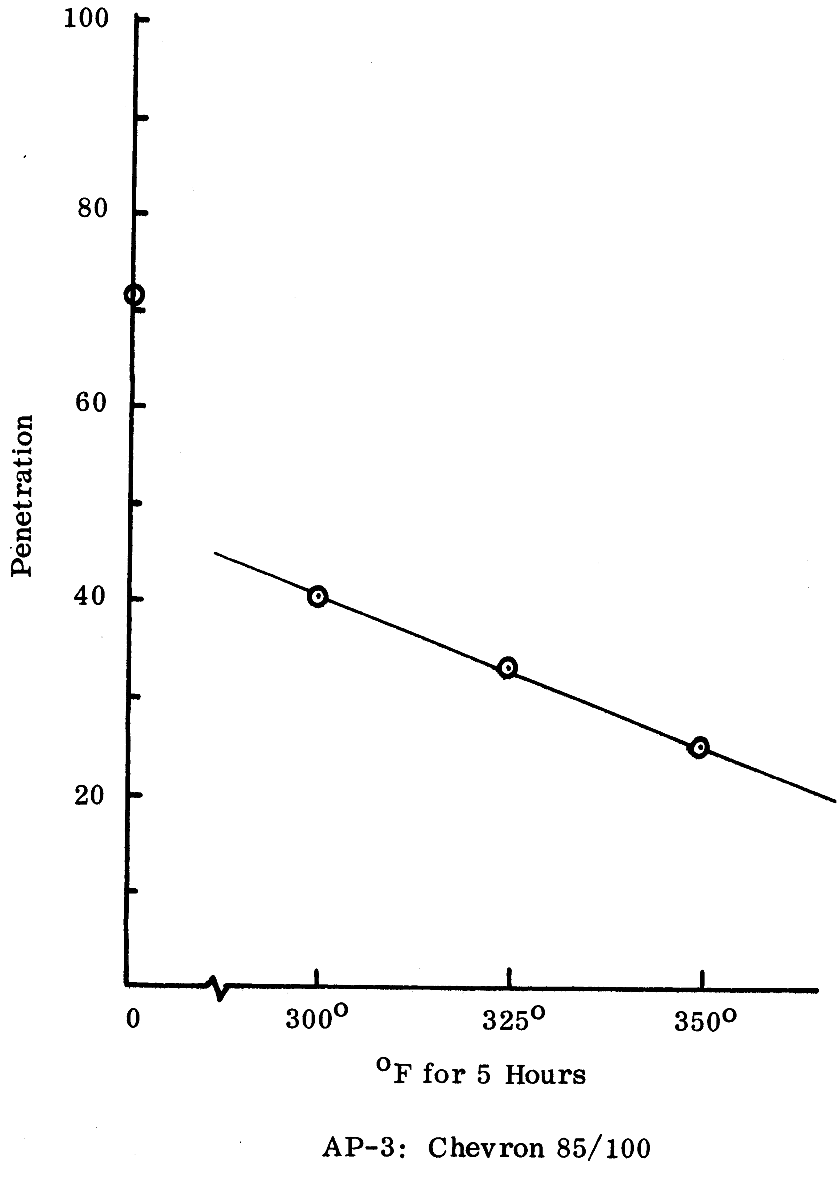

Figure 1. Penetration results after 5-hour oven test.

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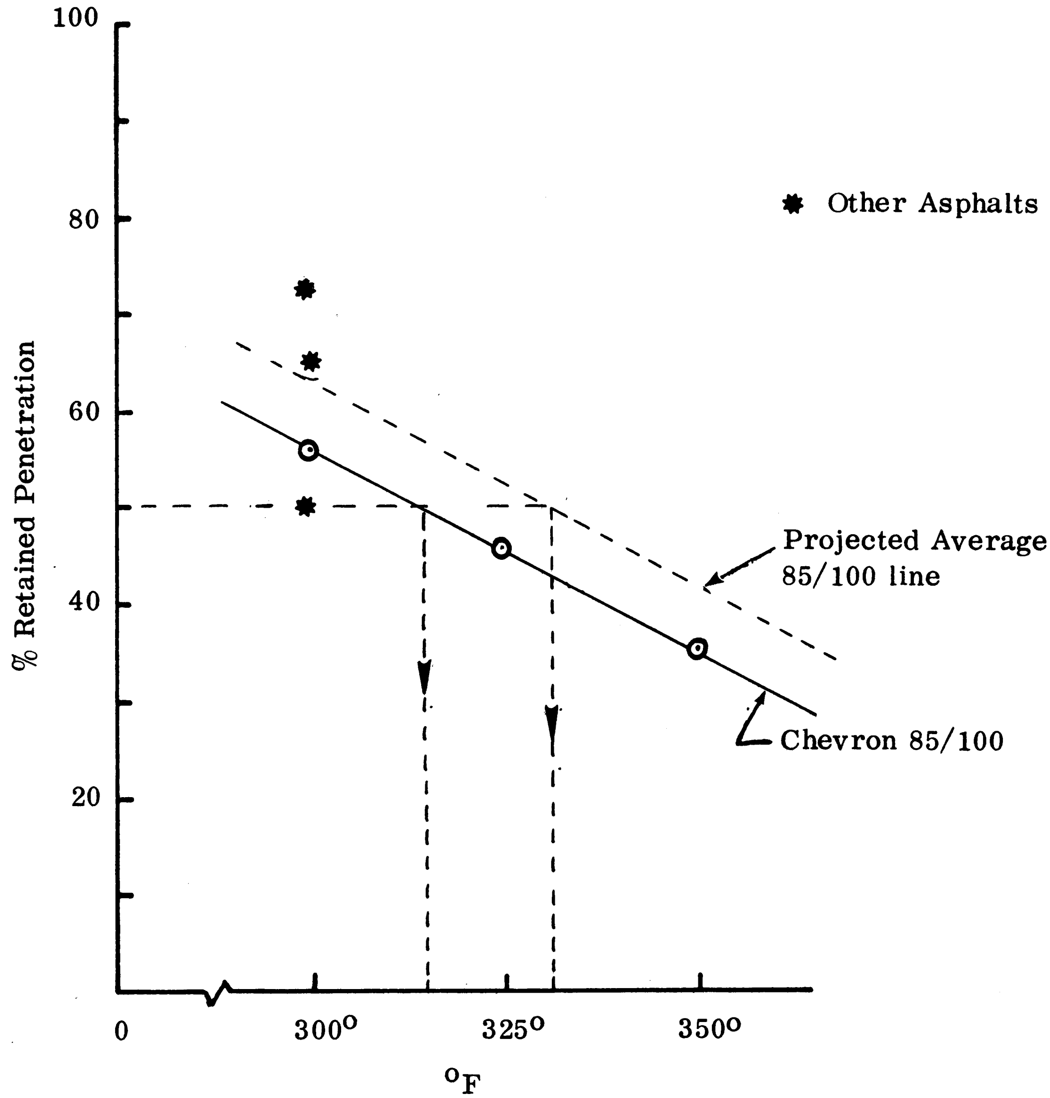

For 5 Hours

AP-3: Chevron 85/100

Figure 2. % retained penetration results after 5-hour oven test.

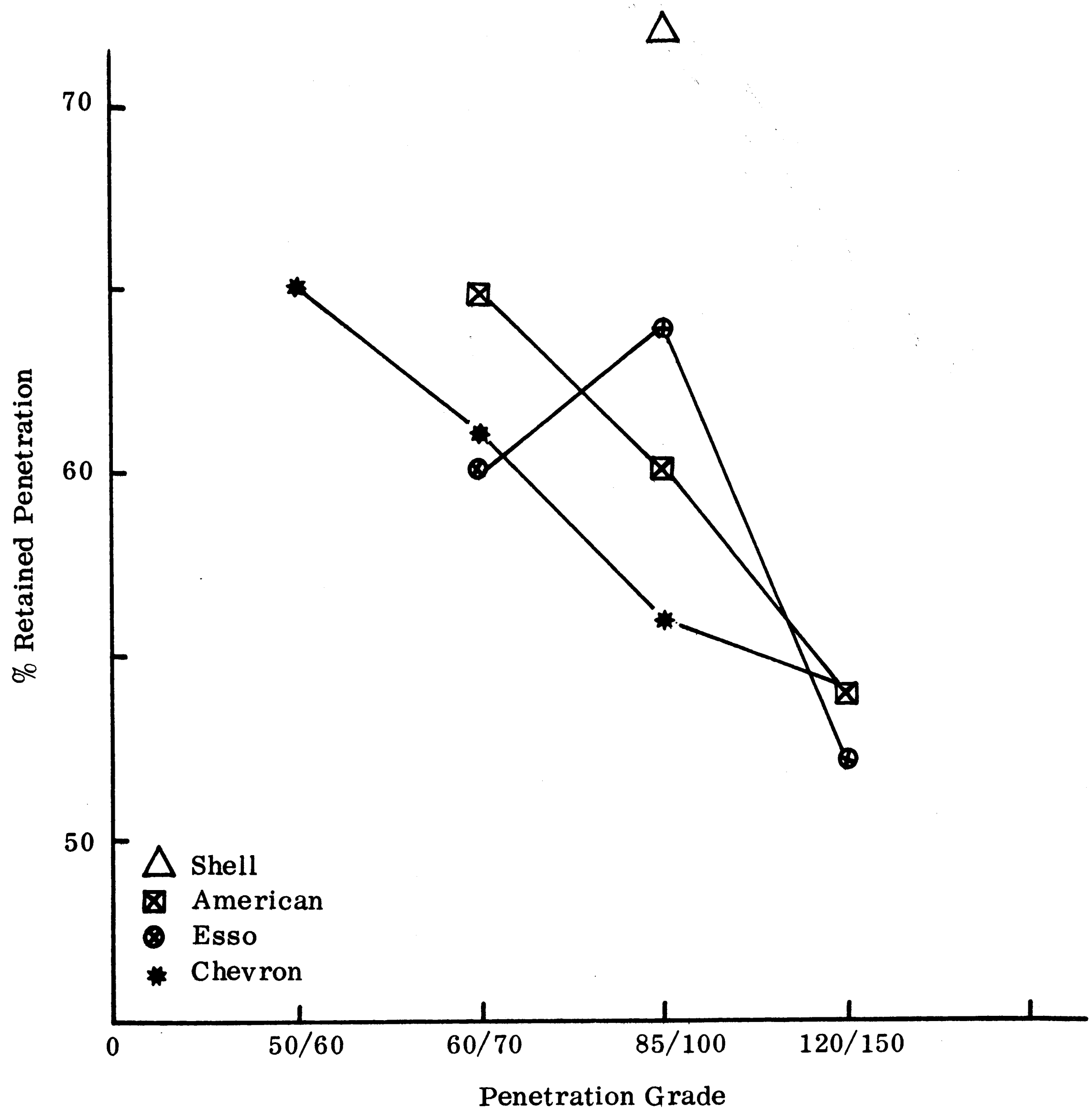

Figure 3. Effect of heat treatment by penetration grade.

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TABLE III

EFFECTS OF HEAT TREATMENT ON PENETRATION

ASPHALT	ORIG. PEN.	PEN. AFTER 5 HR. AT 300°F	% RETAINED PEN.		
American 120-150	127.8	69.6	54	Avg.	Specs.
Chevron 120-150	127.8	69.6	54	53.3	
Esso 120-150	112.8	59.7	52		46
Shell 85-100	70.4	51.0	72		
American 85-100	74.0	45.0	60	Avg.	
Chevron 85-100	71.0	40.4	56	63.0	
Esso 85-100	71.6	46.2	64		50
American 60-70	53.8	35.0	65	Avg.	
Chevron 60-70	54.0	33.4	61	62.0	
Esso 60-70	58.8	35.6	60		54
Chevron 50-60	46.2	30.4	65	Avg. 65	
AP-3 WITH VARYING TEMPERATURE					
Chevron 85-100	71.0				
5 Hr. at 300°F		40.4	56		
5 Hr. at 325°F		33.2	46		
5 Hr. at 350°F		25.0	35		

Viscosity

The viscosity results (Table IV) show one trend which is consistent throughout all four penetration groups. The percent viscosity at 140°F is increased almost twice as much as the percent viscosity at 275°F on heating. This is encouraging because the viscosity of the asphalt at mixing temperatures must be limited to a maximum value to assure proper coating of the aggregate, and higher viscosities at 140°F, which is close to service temperatures, are unfavorable for maximum pavement life since the brittler asphalt binders have been connected with increased pavement cracking.

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TABLE IV

EFFECTS OF HEAT TREATMENT ON VISCOSITY

Asphalt	Visc. at 140°F Poises	Visc. at 275°F Centistokes	% Increase at 140°F	% Increase at 275°F
American 120-150	852.1	226.9		
American Heated	2351.3	346.0	276	152
Chevron 120-150	1128.4	349.2		
Chevron Heated	3229.2	577.4	286	165
Esso 120-150	1100.7	325.8		
Esso Heated	2742.54	466.1	225	143
American 85-100	1832.4	381.6		
American Heated	No Data	606.7	—	159
Chevron 85-100	2156.5	463.0		
Chevron Heated	6534.9	772.2	303	167
Esso 85-100	1846.8	430.8		
Esso Heated	4076.6	595.9	221	138
Shell 85-100	1269.6	306.7		
Shell Heated	3830.9	380.9	302	124
American 60-70	3817.8	597.2		
American Heated	10326.8	957.0	271	160
Chevron 60-70	3961.1	638.4		
Chevron Heated	10985.4	974.8	277	153
Esso 60-70	3113.8	471.5		
Esso Heated	6579.9	638.0	211	135
Chevron 50-60	4941.8	704.5		
Chevron Heated	12359.3	1110.3	250	158

There appears to be very little correlation between percent increase in viscosity and penetration grade at either 140° or 275°F except that a very slight upward trend exists with an increase in the penetration grades.

Since Virginia does not have viscosity standards at present in the specifications for mix design, it is very difficult to reach any definite conclusions on the basis of the viscosity results from this study. The Maryland State Roads Commission has done work in the area of viscosity specifications for use in determining mixing temperatures. Basically, the mix temperature is specified by projecting the characteristic viscosity versus temperature curve for the asphalt to the temperature which will produce a viscosity of 200 centistokes. This value has been determined to be necessary to produce sufficient coating of aggregate during mixing. The viscosity-temperature line is determined for an asphalt sample by obtaining its viscosity at 140°F and 275°F. A nomograph has been constructed which enables simple determination of the mix temperature from the viscosity at 140°F and 275°F. A copy of this nomograph is contained in the Appendix.

Using the values for viscosity at 140°F and 275°F of the original asphalt samples and the Maryland nomograph, the theoretical mix temperature by the Maryland standards was determined for each asphalt. The results are shown in Table V.

TABLE V

MIX TEMPERATURES AS DETERMINED BY
MARYLAND STATE ROADS COMMISSION NOMOGRAPH

Asphalt	Visc. at 275° cst	Visc. at 140° poises	Mix Temp °F	
			Ind. Val.	Avg.
American 120-150	227	852	290	
Chevron 120-150	349	1128	293	291.0
Esso 120-150	326	1101	290	
American 85-100	382	1832	296	
Chevron 85-100	463	2156	303	
Esso 85-100	431	1847	301	296.7
Shell 85-100	307	1270	287	
American 60-70	597	3818	312	
Chevron 60-70	638	3961	315	310.0
Esso 60-70	471	3114	303	
Chevron 50-60	704	4942	318	318.0

The results show that the viscosity specification allows significantly higher mix temperatures than the present Virginia specifications, especially for the lower penetration asphalts. However, there is very little difference between the mixing temperatures for the various penetration grades. This indicates that a maximum temperature of 300°F ± 20°F would suffice.

CONCLUSIONS

1. On the basis of percent retained penetration, the results showed that for an oven temperature of 300°F the lower penetration asphalts were less affected than the higher penetration asphalts. Therefore, the mix temperature should be graduated from the lowest for 120-150 pen. cements to the highest for 50-60 pen. asphalts.

2. According to the present penetration specifications, the results of this study indicate that a slight increase in the allowable mix temperatures presently specified by Virginia may be possible.

3. Of the four penetration grades tested, the AP-3 cements had the best values of retained penetration relative to the specification and, therefore, show the greatest potential for elevated mix temperatures.

4. The viscosity results indicated that oven aging increased the low temperature viscosity (140°F) of the asphalts far more than the high temperature viscosity (275°F).

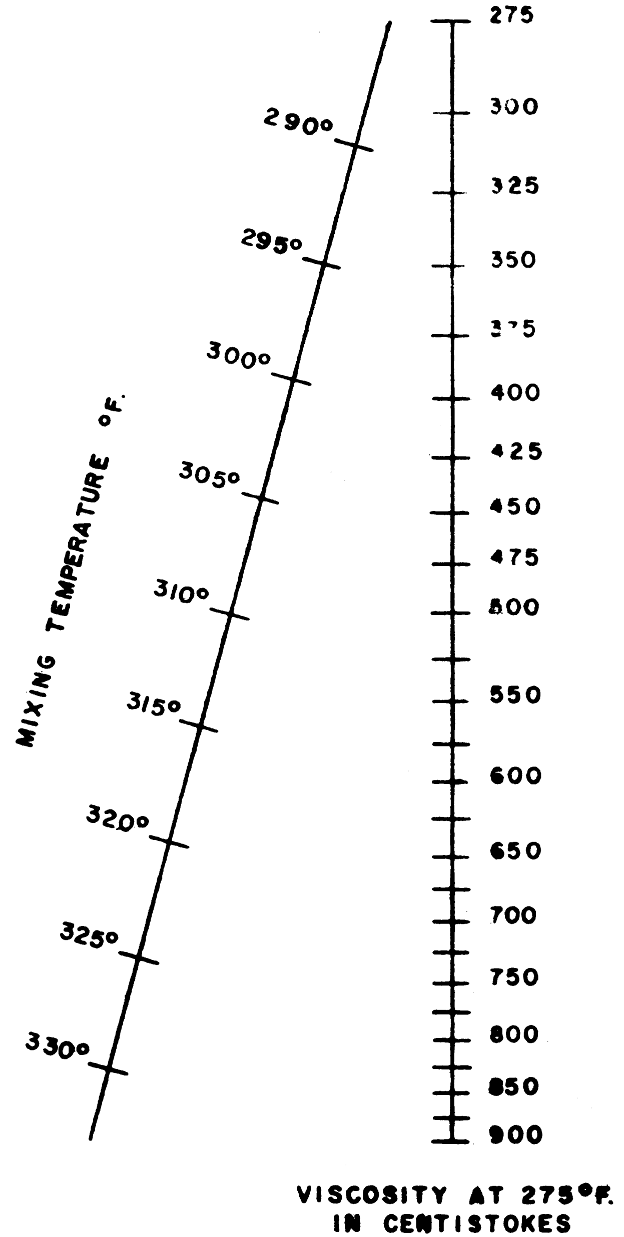
5. The Maryland State Roads Commission nomograph indicated significantly higher mix temperatures than the Virginia specifications for each of the four penetration grades studied. Since the Maryland specification is based on the production of a mixing viscosity without regard to the effect of the higher temperature on the service properties of the asphalt, the higher mixing temperatures should not be accepted without further justification.

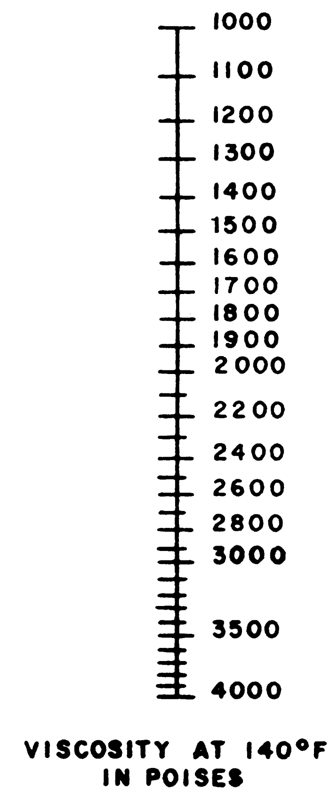
6. More extensive work should be done in the area of elevated mix temperatures using actual plant mixes and control sections to evaluate the effects rather than laboratory work.

MARYLAND STATE ROADS COMMISSION
MATERIALS & RESEARCH

Asphalt Plant Mixing Temperature Chart

1. LOCATE THE VISCOSITY AT 140°F. ON THE RIGHT HAND SCALE.
2. LOCATE THE VISCOSITY AT 275°F. ON THE CENTER SCALE.
3. EXTEND A LINE THROUGH THESE TWO POINTS TO THE LEFT HAND SCALE. THE POINT OF INTERSECTION IS THE MIXING TEMPERATURE.





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