BENDING STRENGTH OF ASPHALTIC CONCRETE

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SYNOPSIS

The general methods and findings of the AASHO Road Test are being used to determine the extent to which observed variations in flexible pavement performance in Texas can be explained by variations in the strength of the different layers in the structure. The specific concern of the work reported herein was directed towards the value of the surfacing coefficient, a_1, which appears in the equation for the structural number, SN, developed by AASHO engineers. Variations in the value of the coefficient a_1 were assumed to be primarily dependent on the viscosity of the asphalt and a measure of a mixture's property directly related to a_1 was considered to be its resistance to bending as determined by a modified cohesiometer test. Since a pavement is subjected to repeated loads, a comparison was made between the resistance to a "static" bending and to "repeated" or "dynamic" bending for several paving mixtures. From laboratory prepared specimens, it was found that the data showed definite and reasonably good correlations in (1) asphalt viscosity versus a characterizing number, A_O, obtained from the cohesionmeter test and in (2) A_O versus I_O, an identifying mixture strength determined from a repeated load test.

Pavements are being examined for application of the AASHO findings to Texas conditions. In this program samples of surfacing were taken for laboratory measurements in order to assign or determine values of a_1. Several sections in the study were sampled for evaluation with both static (cohesiometer) and repeated (deflectometer) test procedures. Variability between specimens within a test site and limited information on the paving materials resulted in a lower coefficient of determination, r^2, between the factors A_O and I_O as compared for the laboratory specimens.

Additional data secured from pavement samples obtained from the parent project (2-8-62-32) and also from a Texas project (2-8-59-9) are presented to show variations in (1) permeability of new paving surfaces, (2) viscosity of asphalt in pavement, and (3) micro-ductility values for asphalts recovered from old pavements.

INTRODUCTION

The interest in performing the study of bending strength of asphaltic concrete stems from the need of estimating the value of the coefficient, a_1, for the surface course appearing in the equation for the structural number of a pavement as suggested by the AASHO Road Test findings. It was taken for granted that the value of the surfacing coefficient depends upon the resistance to cracking and to deformation of the asphaltic concrete under traffic and other forces.

Regardless of intent, highway paving mixtures are generally designed to prevent plastic flow or deformation of the surface and no definite requirement is specified to attain a specific resistance to tensile or bending stresses which exist in pavements. Texas and most other states have experienced surface failure from cracking more commonly than from plastic flow or shoving. Perhaps surface failure by cracking should be expected since it is considerably easier to remedy through maintenance and to tolerate than failure resulting from surface deformation. It is for this reason that the value of a_1 will be associated with the bending strength of asphaltic concrete. The susceptibility to cracking or low resistance to flexural stresses of a paving mixture is dependent on more than one property of the material; however, one factor, if not the most important one, is the asphalt with regard to quantity and viscosity.

It is known that there is a considerable variability in the viscosities of asphalt samples classified under a specific grade and also that the greatest changes that will occur within a particular paving mixture during and after construction will be with respect to the viscosity of the asphalt. Therefore, in consideration of the above conditions, it appears that if only one mixture variable is desired for assessing the tensile strength of asphaltic concrete, then this one should be asphalt viscosity.

In California the cohesiometer test[1,2] was developed for the specific purpose of obtaining a measure of the cohesive or tensile strength of paving materials. Recently, this testing equipment was investigated by the Texas Transportation Institute to determine its response to mixture and specimen variables and as a consequence of this study a mathematical model for the response was obtained.[3] On the premise that the cohesiometer test will indicate a relatively good measure of the coefficient a_1, it has been used to evaluate pavement samples taken from roads in the Texas study for application of the AASHO findings. Cohesiometer tests performed on road samples and also for various laboratory prepared specimens can be used to compare the resistance to bending of these materials but the comparison would be valid only at the time of evaluation since the relative strengths would change depending to a great extent on the relative change of asphalt viscosity occurring to or from some other age or period of testing. In order to compare the performance of one pavement to another it would be required that the surfacing materials be compared on a common basis. This datum could be the age at which asphalts in pavements appear to reach a limiting or upper viscosity.

There are no satisfactory mathematical theories presenting a clear description of the stress conditions in an asphalt pavement surfacing subjected to traffic loads. It then becomes apparent that, in order to evaluate the resistance to cracking of such pavement surfaces subjected to repeated loads, a test model simulating actual load conditions would be required. At the present, it is believed that the "deflectometer"[4] is a rational testing device which approximates actual field conditions better than any other laboratory apparatus. In a normal test, that is when total failure is not caused by punching shear, the distress of a specimen is similar to that occurring in a cracked pavement and referred to as "alligatoring." The crack pattern developed from a deflectometer test is shown in Figure 1.

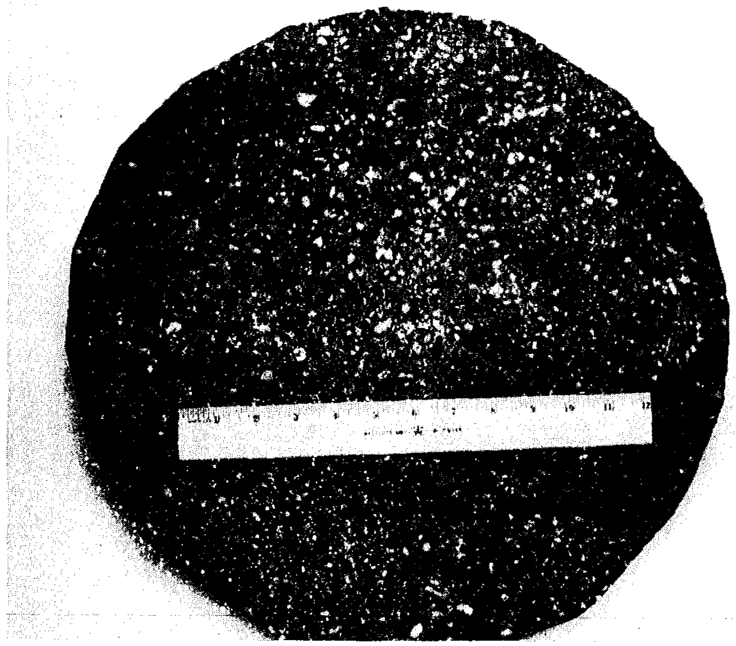
It has been stated earlier in this report that in the over-all pavement research program, one objective is that of determining the character of the surfacing coefficient a_1; however, it must be remembered that the equation for the structural number of flexible pavement also includes coefficients for the other layers in order to determine the total "strength" of the pavement system. The pavement serviceability concept developed at the AASHO Road test takes into account the strength of the layers in the system, the magnitude of loads, and the number of load applications, which would involve the effects of time or age on the pavement. In view of these facts several questions were posed at the outset of this study which will need answers to achieve the objectives aimed at the coefficient a_1; the questions are listed below but not necessarily in order of importance.

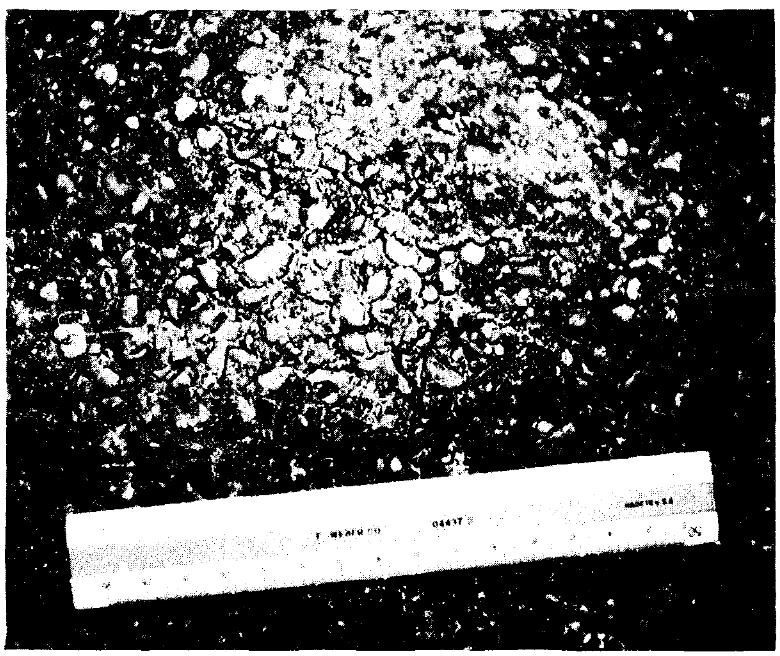
1. Can asphalt viscosity by itself be utilized to determine the effects of time or age on the bending strength of asphaltic concrete?

2. How will asphalt viscosity change with time?

3. Can the change in asphalt viscosity be predicted from some original property?

4. Is there a practical limiting viscosity that asphalts in a pavement will reach and, if so, how long a period of time will it take to reach it?





Crack Pattern of a Road Sample Tested in the Deflectometer

Figure 1.

5. Can a practical measure of the resistance to cracking of asphaltic concrete be obtained from a static-load test such as used in the cohesiometer?

6. Is there a good correlation between a static-load test and repeated-load test for determining the resistance to cracking of asphaltic concrete? In this study the tests are concerned with the cohesiometer and deflectometer.

We are fully aware that at least one of the above questions will not have an answer in the immediate future.

TESTING PROGRAM

The following paragraphs describe the materials and procedures employed in the testing program which was divided into phases of laboratory and road samples.

Laboratory Samples

Materials. - The aggregate used for the preparation of laboratory specimens was selected on the basis of uniformity of composition and availability. The aggregate blend was of limestone with the physical characteristics shown in Table 1. It can be seen that the gradation is one suitable for a surface course mixture and that the absorption obtained by the Centrifuge Kerosene Equivalent (CKE) test[2] was fairly high; however, the quality of the stone was considered to be good. The high absorption value was attributed to the coarse surface texture of the aggregate particles. The asphalt content estimated by the CKE test was 5.5% by weight of total mixture. It has been our experience that the CKE test establishes fairly accurately the optimum asphalt demand of an aggregate blend with reference to the Hveem stability value but that it underestimates the amount of asphalt required for maximum cohesiometer value. The particles retained on the number 8 sieve were somewhat elongated in shape and resulted in a slight problem of workability for the mixtures.

The asphalts used for preparing the test specimens were obtained from two different sources and were essentially of three different grades. The selection of these asphalts was based on the desire to have a set of three grades of asphalts that were produced from the same stock and manufacturing procedure; however, the production methods of the asphalts from the two sources were quite different. Penetration at 77°F and viscosity values at three temperatures for these asphalts are shown in Table 2. Although no other properties of these asphalts were evaluated, they would be expected to meet the specifications of the Texas Highway Department.

Mixtures - Mixture design characteristics were determined for the aggregate blend containing 6, 7, and 8 percent asphalt. The asphalt used was of 85-100 penetration grade and of one source. Data obtained from these tests are listed in Table 3. It is to be noted that specimens were compacted by two methods. The development of the vibratory-kneading compaction is described in Reference 4. The data of Table 3 indicate an optimum asphalt content of about 6 to 7 percent for the mixtures compacted by the new method; however, for the specimens densified by the Texas gyratory-shear procedure the optimum asphalt content would be approximately 5 percent. These data are presented to show that specimens of different characteristics were formed by the two compaction procedures. The differences are attributed to variation

TABLE 1

Aggregate Characteristics

Gradation - Crushed Limestone 30% (1/2" - #4), 25% (#4 - #16)
Limestone Screenings 25% (#4 - #30), 20% (- #30)

Sieve Size	Total Percent Passing
1/2"	100
3/8"	95
#4	70
#8	41
#16	28
#30	20
#50	17
#100	12
#200	9

Apparent Sp. Gr. - +#4 = 2.708, -#4 = 2.661, AVG. = 2.675

CKE - Absorption of -#4 = 5.0%, of +#4 = 3.25%
Asphalt (81 Pen.) content by total weight = 5.5%

TABLE 2

Asphalt Characteristics

Source	Penetration Grade	Penetration @ 77°F	Viscosity, Poise 77°F[1]	140°F[2]	275°F[2]
H	50-60	52	1.74×10^6	2162	3.7
	85-100	93	0.54×10^6	1168	3.4
	120-150	131	0.30×10^6	809	2.4
T	50-60	59	2.95×10^6	5440	4.5
	85-100	81	1.30×10^6	1817	2.8
	120-150	125	0.45×10^6	1043	2.5

[1]Evaluated with sliding plate micro-film viscometer at shear rate of 5×10^{-2} sec.$^{-1}$

[2]Determined with capillary tube viscometer.

TABLE 3

Design Characteristics of Mixtures
(81 Pen. Asphalt of Source T)

	Vibratory-Kneading Compaction			Gyratory-Shear Compaction		
Asphalt Content, %	6.0	7.0	8.0	6.0	6.5	7.0
*Theor. Sp. Gr. gm/cc	2.436	2.401	2.366	2.436	2.419	2.401
Spec. Density gm/cc	2.309	2.344	2.336	2.380	2.376	2.365
Hveem Stability, %	63	54	39	30	18	15
Cohesiometer Value gm/in. W./3 in. H.	647	632	499			
Void Content, %	5.2	2.4	1.3	2.3	1.8	1.5

*Computed using the apparent specific gravity of the aggregate.

of the compactive effort imparted by the gyratory-shear method to mixtures with diverse asphalt contents and to differences in particle orientation resulting from the compaction procedures.

Standard methods were used to assure uniformity of gradation and asphalt content in preparing the asphalt-aggregate blends. After mixing, the blend was allowed to cool and then placed uncovered in a 140° F forced-draft oven for a period of 15 hours. Compaction of a mixture was performed at 250° ± 5° F for the gyratory-shear method and at 300° ± 5° F for the vibratory-kneading procedure. (These temperatures are standard for the two methods.)

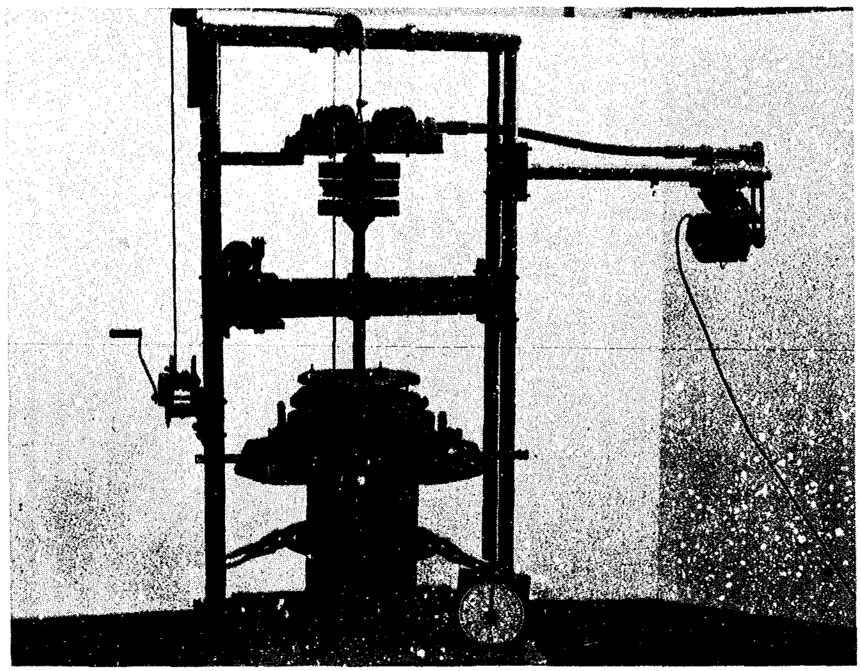
In view of the different viscosity values of the asphalts to be used in the study and in consideration of void content, asphalt contents for the various mixtures were set at 5, 6, and 7 percent.

<u>Deflectometer</u> - Mixtures were prepared and over-cured as described previously. The specimens were densified in the vibratory-kneading compactor illustrated in the photograph of Figure 2. The principle of compaction was essentially as described in Reference 4; however, certain improvements were made in constructing the pictured compactor. The two major improvements were:

(1) Tilting of the compaction table by rotating the upper portion with respect to the bottom on the slanted plates shown clamped with vise-grips and

(2) Complete rotation of the specimen mold which was achieved and simplified by placing a disc of perforated masonite board holding approximately 400-3/16" - diameter ball bearings between the steel compaction plate and the table.

Compaction of a mixture was effected by dynamic impact obtained by counter rotating eccentrics cycling at 1200 revolutions per minute. During the period of compaction, the tilted mold (3/16" in 18") was manually rotated at 15 revolutions per minute. Since the impact forces were not normal to the diametral plane of the mold and the mold was being rotated during impact, the effects of these conditions joined to impart three-dimensional or kneading forces for tumbling the aggregate particles and obtaining what is considered good particle orientation comparable to that existing in an actual pavement. The comparison made between the orientation of particles existing in a pavement and that obtained by vibratory-kneading compaction is based on a limited study[5] in which fatigue characteristics of road samples were compared with those of specimens made from the same road paving mixtures. At the end of a definite period of kneading, compaction, the compaction table was counter rotated and



Vibratory-Kneading Compactor

Figure 2.

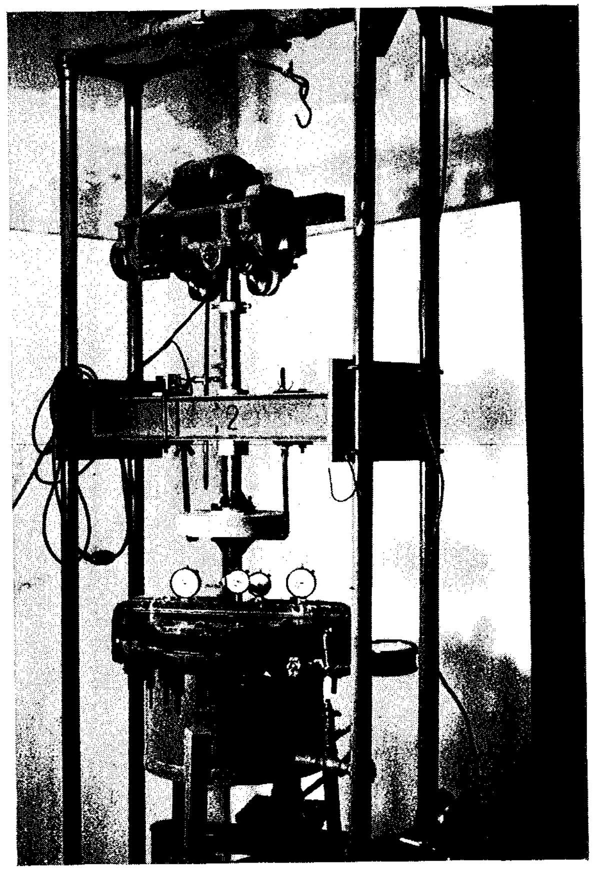
leveled. An additional period (30 seconds) of vibratory compaction was given to a specimen as it was rotated in order to obtain a specimen of constant thickness. Specimens of different thickness were desired so as to develop the fatigue characteristic (S-N curve) of a mixture; this was achieved by using various weights of mixtures and adjusting the compaction period in proportion to the weight of the aggregate. For example, if the mixture contained 10,000 grams of aggregate, the period of vibratory-kneading compaction was two minutes and if the weight of aggregate was 12,000 grams the compaction was for two minutes and 24 seconds; the time was independent of asphalt content. It has been determined that the compaction procedure is adequate for preparing specimens approximately 18 inches in diameter and heights varying from 0.75 inch to 2.5 inches. Specimens of greater thicknesses can be made by compacting successive layers of material.

The deflectometer test procedure has been described in a previous report,[4] but two features of the test have been changed, (a) the test temperature was changed to 77° F and (b) the driving motor was mounted directly on the loading system as shown in the photograph of Figure 3.

Since the construction of the original deflectometer, two more testing units have been built for evaluation of pavements in the parent project. Although there exist some differences among the three machines, calibration or comparisons of the deflectometers show that on a given mixture each one yields the same stress vs. repetition (S-N) curve.

Cohesiometer - The cohesiometer test and interpretation of the load-deflection data have been reported in Reference 3. This test was performed at temperatures of 140° F and 77° F. In the analysis of the data obtained from laboratory prepared specimens and tested at 77° F, it was found that the linear portion of the curves resulting from point plots of deflection (y) versus load squared (w^2), extended past deflection values of 0.5 inch. It is felt that the strains induced in a specimen at 0.5 inch deflection are too great for design purposes; however, in keeping with the mathematical model derived for the response of the cohesiometer, failure or strength of the specimens was established at the upper end of the linear portion of the y vs. w^2 plot.

Since a relationship between the cohesiometer and deflectometer responses was desired, specimens for the cohesiometer test were obtained from the deflectometer specimens after these had been subjected to repeated load. Four to six 4" x 4" samples were sawed from the outer portions of the deflectometer specimens; one-half of these were tested at 140° F and the other at 77° F.



Deflectometer

Figure 3.

Recovered Asphalt - A purpose of the study was to investigate the effect of asphalt viscosity on the cohesiometer test; accordingly, asphalt was recovered from deflectometer specimens by the modified Abson method. Viscosity determinations on the recovered asphalts were made at 77°F with a sliding plate micro-film viscometer and also at 140°F with a capillary tube viscometer.

Field Samples

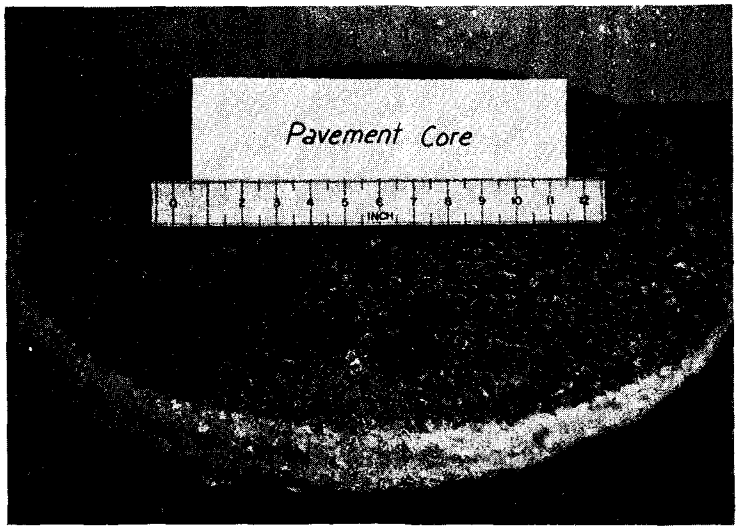
Project 2-8-62-32 - An objective of the parent project is to determine the extent to which observed variations in flexible pavement performance in Texas can be explained by variations in the strength of the constituent layers. This supporting study was proposed as a means for acquiring certain laboratory data expected to be useful in the search for a relationship between the strength of surfacing materials and the contribution they make to the over-all performance of flexible pavements. To this end, over 200 sections of test pavements were sampled for testing and evaluation of the surface course materials. As can be visualized the variations of the surfaces were large in terms of (a) age, (b) composition as to aggregate and asphalt, (c) number and types of layers, and (d) other general factors such as condition of roughness.

The primary test for evaluation of these surface courses made use of the cohesiometer; however, several sections were selected for a more thorough evaluation of the samples. These select pavement surfaces were examined for the following characteristics: (1) air permeability, (2) resistance to repeated loading, (3) Hveem stability, (4) aggregate gradation, (5) asphalt viscosity, and (6) asphalt ductility.

The problems of sampling road specimens were variable and their solutions were different for each case. For this reason no attempt will be made to describe procedures of sampling other than to state that extreme care was taken to prevent damaging the specimen during the cutting and transportation of the material. The photographs of Figure 4 show deflectometer specimens as received from the field and also after trimming the base and excess asphaltic concrete in preparation for testing. For the large cores, it was impossible to remove the base material and obtain a perfectly smooth surface on the bottom of asphaltic course and as can be seen from two of the photographs in Figure 4 the upper surface of a specimen can be fairly rough or textured. The smaller size of specimens tested for stability and cohesiometer value was such that the base material could be removed by slicing the bottom off the sample with a diamond tipped masonry saw.

The method used to remove the base material from the deflectometer specimens generally did not give as smooth a surface as desired. Because of

A.



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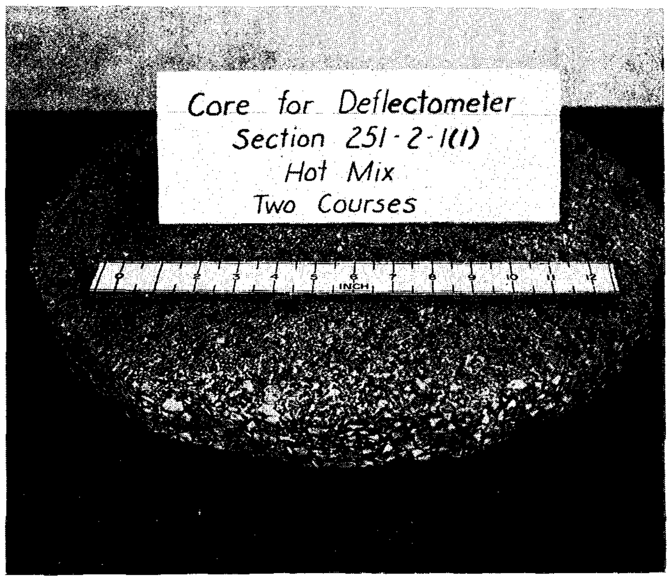


C.

Typical Road Samples

Figure 4.

this surface condition the specimens were loaded on the bottom side of the surface course and supported on the upper side by the thin rubber membrane of the reaction unit of the deflectometer. In this position the traffic-side of the pavement sample was subjected to the greatest tensile stresses during the repeated load test and would also correspond to the side or surface on which cracking distress would be visible and manifest itself for a subjective rating of a pavement. For comparing the cohesionmeter test value with the deflectometer results it was desirable to subject the same side of a pavement sample to maximum tensile stress under both devices.

The testing of samples with either the cohesiometer or deflectometer was limited by the dimensions of the testing equipment to specimens not over two inches in thickness. For those sections in which the thickness of the asphaltic concrete was over two inches only the cohesiometer test was performed on specimens cut from the top two inches and also on the successive layer so that if a core had a thickness between 3-1/2 and 5-1/2 inches only two cohesiometer values were obtained for the sample. Following this procedure often resulted in testing a specimen of two or even three layers of different asphaltic materials. The results of the cohesiometer tests performed on the road surfacing material are presented in Figures B-1, B-2 and B-3 of Appendix B.

Evaluation of road samples with the cohesiometer was started a year before the study of laboratory specimens of this report. At that time failure of a cohesiometer specimen obtained from a test site generally occurred at a beam deflection of less than 0.5-inch; however, there were several samples in which failure, as defined by the limit of the linear portion of the Y vs. w^2 plot, occurred at beam deflections greater than 0.5-inch. For these materials it was assumed that the pavement surface could not tolerate such a large strain and for such tests, the failure load was established at the beam deflection value of 0.5-inch. The distinction should be noted between the cohesiometer failure load of the laboratory specimens which will be used to characterize the material and the failure load of the road samples which was arbitrarily restricted to some limiting strain.

Project 2-8-59-9 - This study is being conducted by the Asphalt Technology Department of the Texas Transportation Institute under the direction of Dr. R. N. Traxler. A portion of this project is concerned with the changes in asphalt viscosity occurring during mixing, placing and service of asphaltic concrete. It was expected that data from this study could be used to establish a general relationship between pavement age and asphalt viscosity for asphalts of different aging characteristics. In this program road samples were taken and measurements were made to determine the air permeability and density of the surface course and also viscosity of the recovered asphalt. Several deflectometer tests were performed on road samples taken at one year of age. Data of interest to the investigations of Project 2-8-62-32 are presented in Table C-1 and Figure C-1 of Appendix C.

TEST RESULTS AND DISCUSSION

The analysis and discussion of the data obtained will be primarily directed towards the objectives of seeking general relationships between bending strength and asphalt viscosity and also between static and repeated load bending strength.

Laboratory Specimens

Deflectometer - Data on the results obtained with the deflectometer test performed at 77° are given in Tables A-1 to A-3 of Appendix A. The values for specimen density appear to indicate that perhaps factors of operator and "learning" variables were present in the molding of these specimens. However, it is not believed that these factors would have any appreciable effects in the development of the S-N curves since they could not readily be separated from inherent reproduciibility variations.

The effect of stress on the resistance to repetitive loading was determined on the basis of logarithm equivalencies, and from previous investigations[4,6] it appears that the following expression is warranted -

$$\text{Log } S = \text{Log } I + b \text{ Log } N$$

where: S = central radial tensile stress, psi

I = a constant

b = slope

N = number of repetitions at failure

The stress and repetitions data listed in Appendix A were examined for regression and correlation coefficients which are shown in Table 4. The high values of the coefficient of determination, r^2, reaffirm the above equation expressing the ralationship between stress and fatigue resistance for asphaltic concrete. The differences in slope, b, were considered to result from random variation so that an average slope of -0.1946 was obtained for this study. References [4,6,7] show that for finer mixtures the value of slope b was reported as being about -0.165. In Reference 7, Professor Monismith states that fatigue data plotted as log strain versus log cycles to failure for the work done by Pell, Jimenez and Gallaway, and by himself, will show these plot as approximately parallel lines. This comparison is interesting in view of the three

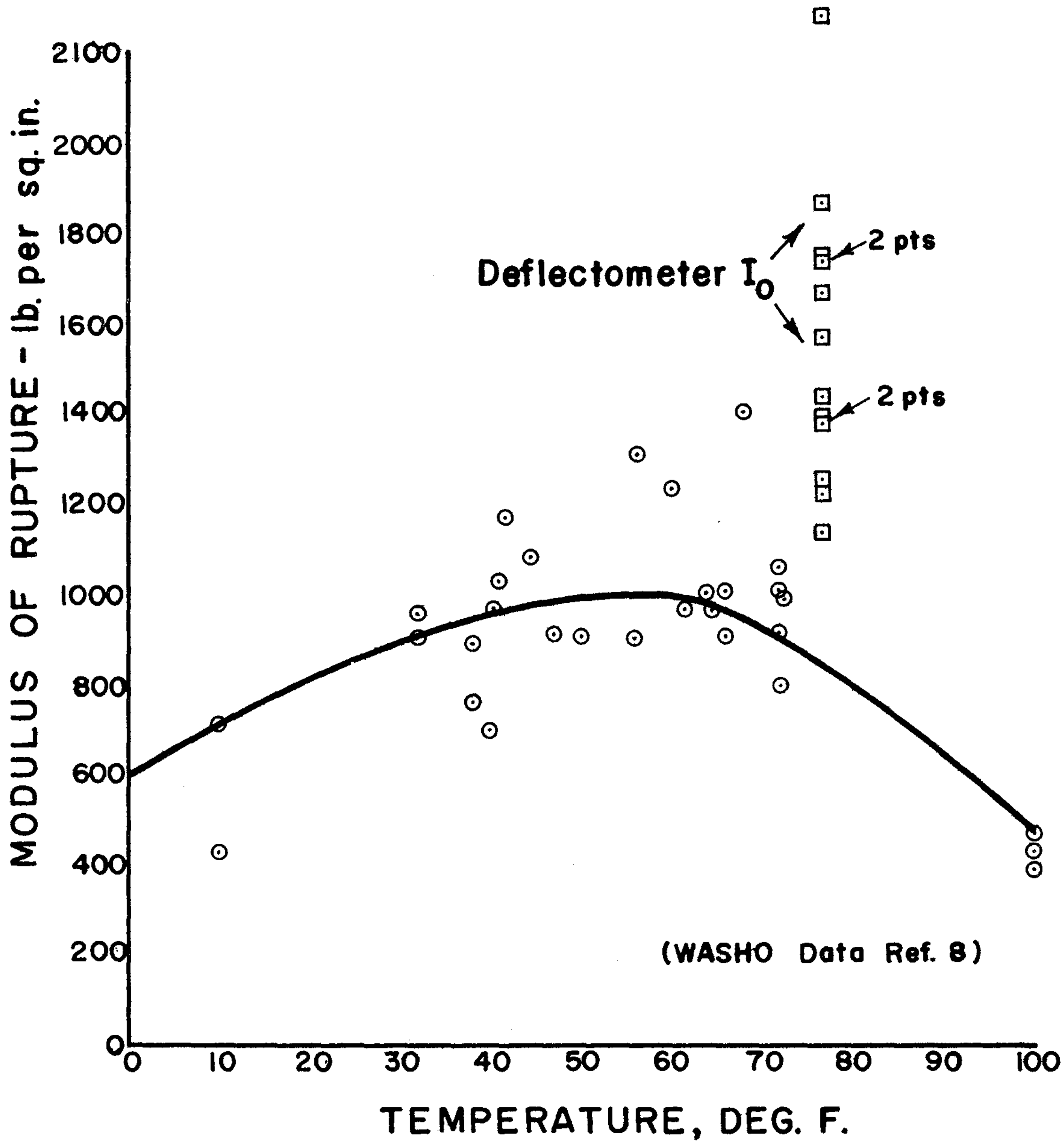
TABLE 4

COEFFICIENTS FOR STRESS-REPETITION RELATIONSHIP ON DEFLECTOMETER

$$\text{Log } S = \text{Log } I - b \text{ Log } N$$

Source	Asphalt Grade & Viscosity 77° F Poise	Asphalt Content, %	b	Number of Observations	Coefficient of Determination r^2	I* psi	I_o** psi
		5	0.1479	3	.8889	1006	1757
	120-150	6	0.1934	6	.9953	1360	1379
	0.45 x 10^6	7	0.1192	4	.9243	517	1140
		5	0.1808	6	.9978	1367	1569
T	85-100	6	0.1700	6	.9967	1123	1446
	1.30 x 10^6	7	0.2686	5	.9990	2574	1233
		5	--	--	--	--	2285
	50-60	5	0.2318	6	.9799	2504	1676
	2.95 x 10^6	7	0.2072	4	.9732	2184	1869
		Average	0.1899				
	120-150 0.30 x 10^6	6	0.2031	4	.9388	1369	1252
		5	0.1714	6	.9942	1358	1760
H	85-100	6	0.1896	5	.9940	1317	1388
	0.54 x 10^6	7	0.2109	6	.9358	1571	1364
	50-60 1.74 x 10^6	6	0.2356	5	.9895	2806	1740
		Average	0.2021				
	GRAND AVERAGE		0.1946				

*Intercept of stress axis for 1 repetition for individual values of slope b.
**Average intercept of stress axis for 1 repetition assuming slope b =-0.1946



INFLUENCE OF TEMPERATURE UPON MODULUS OF RUPTURE OF ASPHALTIC CONCRETE

Figure 5

different testing devices used on different asphaltic mixtures. An unreported study conducted by the Texas Transportation Institute showed that certain modifications of a mixture resulted in S-N slopes ranging from -0.164 to -0.275. Although that range of slopes is not as large as the one found from the present study, the value of the slope appeared to be influenced by the aggregate variable. At high stress the mixture with the greater absolute value of slope had better resistance to repeated loads; however, the reverse occurred at low values of stress.

Using the average slope value of -0.1946, the data points were extrapolated to determine the stress that would presumably cause failure if applied once. The stress intercept, I_o, was assumed to characterize the mixture and the values obtained for the mixtures studied are shown in Table 4. Examination of the values for I_o indicates that for any one grade, the asphalt content of 5 percent was the optimum value and that the value of I_o tended to increase as the viscosity of the asphalt increased for mixtures containing the same amount of asphalt. A comparison of the initial viscosities at 77° F of the asphalts from the two sources shows that the viscosities of asphalts T were higher and this effect was generally shown in values of I_o as indicated in Table 4 at asphalt content of 6 percent but not for the other mixtures.

The number of load repetitions resulting in failure ranged between 1,000 and 1,000,000, so it is with acknowledged reservations that the S-N curves were extrapolated to obtain the failure stresses corresponding to one application of load. As mentioned before a characterizing measure of fatigue resistance was desired and it is presently believed that the values of I_o and slope b are adequate for this purpose. Figure 5 presents data obtained at the WASHO Road Test[8] and also the range of values for I_o resulting from this study. The differences in strength are attributed to method of testing and rate of loading. The WASHO results were obtained by third-point loading of simple beams with the maximum load applied in about 0.25 second. The deflectometer stresses a diaphragm at a repeated rate of about 12 cycles per second (0.04 second from low to maximum load).

Cohesiometer - Since the cohesiometer specimens were obtained from the slab compacted for the deflectometer test, the same variables of asphalt content, grade, and source were present at the test temperatures of 77° F and 140° F. Evaluation of the cohesiometer test as performed by the Institute has indicated that a logarithmic relationship exists between specimen height and failure load. The failure load was determined at the upper limit of the straight line portion of the plot of $\text{Log} \frac{30 + y}{30 - y}$ vs. W^2. The effect of height of a specimen on the failure load is expressed by the following equation-

$$\text{Log } W_f = A_o + 1.67 \text{ Log } H$$

where: W_f = failure load, gm.

A_o = constant, for a given mixture

H = specimen height, in.

The previous study[3] showed that for the different mixtures the effect of specimen height was consistent (see Figure A-1, Appendix A) so that each material could be characterized by the value of A_o which corresponds to the failure load for a specimen thickness of one inch; however, the units of A_o turn out to be force divided by length to the 1.67 power ($F/L^{1.67}$). Table A-4 in Appendix A presents the values of A_o obtained from testing specimens cut after performing the repeated load test on the various mixtures.

It would appear desirable to express the cohesiometer strength in terms of stress. In order to do this, it was assumed that the stress varied linearly from zero at the bottom of the specimen to a maximum value at the top. Neglecting momentum of the moving parts of the cohesiometer during a test, a static condition of equilibrium was assumed for computing the maximum stresses, S_f, corresponding to the failure load, W_f. The chart of Figure A-2 in Appendix A shows a relationship between failure load and maximum stress, and also the effects of specimen height. It can be seen that height effects are different for W_f than for maximum stress; however, this difference appears to be constant for different mixtures. Since there was not a linear relationship between W_f and S_f no further efforts were made at the time to analyze cohesiometer data on the basis of stress.

<u>Recovered Asphalt</u> - The effect of asphalt viscosity on the bending strength of a mixture was desired. It was not considered sufficiently accurate to make a comparison on the basis of the original viscosities of the asphalts particularly since the temperature susceptibility of the asphalts from the two sources were different and also there was no assurance that the effects of temperature on viscosity would remain the same for any one asphalt after being exposed to heat and air during the mixing with the aggregate. In view of the above, asphalt was recovered from deflectometer specimens containing different amounts of asphalt to determine if the quanitity of asphalt in a mixutre affected the degree of hardening and the viscosity-temperature relationship resulting from the mixing procedure.

Viscosity measurements were made on recovered asphalts from specimens containing all grades of asphalt and the three asphalt contents. The viscosities determined at 77° F were obtained by use of a microfilm sliding plate viscometer and for asphalt films either 25 or 100 microns in thickness. The data obtained did not establish if asphalt content or film thickness affected the value of viscosity for the recovered asphalts. Since it appeared that asphalt content had no effect on the viscosity value obtained at 77° F, viscosity determinations were made at 140° F for asphalts recovered from specimens containing 6 percent binder. A plot of viscosity versus temperature for the original and recovered asphalts did show that the temperature susceptibility of the asphalt was decreased after being heated and mixed with the aggregate. A listing of the viscosity values obtained for the recovered asphalts is presented in Table A-5 of Appendix A.

Viscosity Effects on Strength - The effects of asphalt viscosity on the characterizing numbers of the different mixtures as determined with the cohesiometer and deflectometer are summarized in Table 5. These data show the results of regression analysis made for relating the logarithm of recovered asphalt viscosity η_r and the logarithms of the strength numbers A_o and I_o. The analysis for the cohesiometer strength A_o shows a good or predictable relationship with η_r. The data points used included values obtained at both testing temperatures of 77° and 140° F. The value of slope b appears to be affected by asphalt content; however, in view of the amount of data involved, it is possible that the variations are random in nature.

The standard cohesiometer test value has been compared and correlated with the Marshall Stability[9] and some technologists are of the opinion that both tests determine the same property of a specimen. Various relationships have been established between test temperature and strength of asphaltic concrete. Pignataro[10] has done this using semi-logarithmic coordinates with Marshall stability. The engineers of the AASHO Road Test [11] have used the model obtained from work done at Purdue[12] to compare the log of Marshall stability with test temperature. The equation used on the AASHO data was of the following form

$$\text{Log Log } S = aT + b$$

where: S = Marshall stability, lb

T = test temperature, °F

This equation was tested by substituting recovered asphalt viscosity for temperature, and using cohesiometer value A_o for the Marshall stability. It was found that the Purdue Model did not fit the data as well as relating the logarithm of A_o to the logarithm of the recovered asphalt viscosity in the form of

$$\text{Log } A_o = \text{constant} + b \text{ Log } \eta_r$$

The upper part of Table 5 shows that the Coefficient of Determination, r^2 was in order of 0.99. For the same set of data the Purdue model yielded r^2

TABLE 5

RESULTS OF CORRELATION STUDY OF COHESIOMETER VALUE, A_o, AND DEFLECTOMETER NUMBER, I_o, WITH RECOVERED ASPHALT VISCOSITY, η_r

Mixture	Test Temperature °F	Slope b	Number of Observations	Coefficient of Determination r^2
		$\text{Log } A_o = \text{constant} + b \text{ Log } \eta_r$		
T - 5%	77 & 140	0.2685	5	0.9951
T - 6%	77 & 140	0.2455	6	0.9965
T - 7%	77 & 140	0.2426	6	0.9968
H - 6%	77 & 140	0.2569	6	0.9895
		$\text{Log } I_o = \text{constant} + b \text{ Log } \eta_r$		
T - 5%	77	0.1057	3	0.4046
T - 6%	77	0.0830	3	0.8748
T - 7%	77	0.2092	3	0.8135
H - 6%	77	0.1535	3	0.9992

ranging from 0.42 to 0.72. From these comparisons, it appears that the value of A_o as determined by the modified cohesiometer is not necessarily equivalent to the Marshall stability.

The lower portion of Table 5 presents information on the effects of recovered asphalt viscosity on the deflectometer number I_o. The number of data points for this part of the study was much more limited than for the cohesiometer test particularly since the test was performed at one temperature. The low value of r^2 for the T-5% mixture is apparently due in part to the irregular values of I_o as is shown in Table 4, and also to some extent upon the poor workability of the mixture as this factor affects the uniformity within a specimen and from one to another.

$\underline{A_o \text{ vs. } I_o}$ - One of the objectives of this study was to determine if an acceptable relationship exists between the bending strength of asphaltic concrete subjected to "static" loading and that established by repetitive loading, that is, the fatigue strength.

A direct relation between the cohesiometer number, A_o, obtained at a test temperature of 77° F and the deflectometer values of I_o indicated that the slope on logarithmic coordinates was 0.6221 but the coefficient of determination had a value of 0.5982. It was noticed that the absolute values of variations in A_o determined at 77° F were much greater than for those obtained at 140° F. Since the data analysis indicated a very good correlation between A_o and the viscosity of asphalt (Table 5), the values of A_o found at 140° F were used to calculate the bending strength of these specimens at 77° F. For these calculations the individual slope associated with each asphalt content was used rather than assuming an average value of slope for the effect of asphalt viscosity on the value of A_o. A comparison of the calculated with the observed values of A_o at 77° F showed a slope of 1.1025 and the value for r^2 was 0.8369. In this analysis the values obtained from testing the specimens T-135-5% were not used since a plot indicated that these were considerably out of line.

The regression analysis in logarithmic from of the computed values of A_o at 77° F with the deflectometer number I_o yielded a slope of 0.6326 which is quite in agreement with the above value of 0.6221; however, an improved fit with r^2=0.7028 was obtained. At the present there appears to be no information published with which to compare the above relationship found for relating the resistance to bending of asphaltic concrete under static and repetitive loadings. For the mixtures tested the equation for the comparison takes the form of

$$\text{Log } I_o = \text{constant} + 0.6326 \text{ Log } A_o$$

Field Specimens

Parent project (2-8-62-32) - In previous sections mention was made of sampling the surface course from many of the test sections of the parent project. As can be visualized there were considerable variations in these different surface materials. In addition, there were also differences in the specimen tested for resistance to bending in both the cohesiometer and deflectometer.

Table B-1 in Appendix B presents data obtained from testing samples taken from test sites designated at E-sections. In these sections, samples were taken for determinations with the Hveem stabilometer, modified cohesiometer, and the deflectometer. In addition other evaluations were made of the paving mixtures as indicated in the table.

The samples taken for the deflectometer tests were used for evaluation of air permeability with an Asphalt Paving Meter, Model AP-400 purchased from Soiltest, Inc. It was found that all specimens appeared to be impermeable under the pressures available with the testing device. However, additional data obtained with the Asphalt Paving Meter will be presented later in this report.

Based on a maximum theoretical specific gravity obtained by Rice's method of vacuum saturation,[13] the air void content varied from 0.8 to 7.6 percent.

The cohesiometer tests were evaluated by the modified method except that maximum deflection corresponding to the failure load was limited to 0.5 inch.

During the course of the deflectometer test the translation of the loading system increases and also the supporting pressure to the specimen increases. These actions contribute to the stresses given to a specimen but since they are of opposite direction they cancel out as shown in Table B-1 for stresses at 1.5 pounds per square inch support pressure and at failure. For the computations of central radial stress and dynamic modulus of elasticity indicate that these values determined at a support pressure of 1.5 pounds per square inch and at failure are essentially of the same magnitude. However, stresses were compared at the values obtained at the support pressure of 1.5 pounds per square inch, which followed the established procedure (Ref. 4).

Micro-ductility tests on asphalts were performed utilizing the equipment manufactured by Cox & Son which meets the specifications of the California Highway Department.[14]

A plot of viscosity (77° F) and micro-ductility on logarithmic coordinates showed a linear relation in that the ductility decreased as viscosity increased at a slope of -0.8250. The value of r^2 for these data was 0.7197.

The relationship between I_o and A_o determined from the laboratory specimens was tested with the results obtained from the field samples. The transformation of A_o determined at 140° F to its corresponding value at 77° F was performed by interpolating for the recovered asphalt viscosity at 140° F and assuming a slope of 0.2575 for the effects of viscosity on A_o. The form of the calculation is shown as follows:

$$\text{Log } A_{o_{77^\circ}} = \text{Log } A_{o_{140^\circ}} + 0.2575 \, (\text{Log } \eta_{77^\circ} - \text{Log } \eta_{140^\circ})$$

It is questionable that the same value of slope was applicable to all specimens tested since the laboratory study indicated that it may have been affected by asphalt content. However, the use of the single value of slope was justified on the basis that greater variability would be introduced into the comparison by the fact that most road samples consisted of layers of different asphaltic materials in which the layers had different viscosity as opposed to the combined viscosity found for the recovered asphalt. Road samples containing asphaltic rock were not used for the comparison of I_o and A_o nor were those values which were found to be outside of the two standard deviation (2σ) band established from the laboratory specimens. The regression analysis of the field specimens of Log A_o on Log I_o yielded a slope of 0.6375 and an r^2 value of 0.6041. It is noticed that the data from the field add weight to the relationship between I_o and A_o that was determined from the laboratory samples and gave a slope of 0.6326.

In the introduction of this report it was stated that the modified cohesiometer value could serve as an indicator of the magnitude of the surfacing coefficient a_1 in the equation for the structural number (SN) of a pavement. For the parent project over 230 test sections of asphaltic pavements were sampled for the cohesiometer test. The results of this evaluation are summarized in Figure B-1 to B-3 of Appendix B.

SUMMARY AND CONCLUSIONS

The following paragraphs summarize the findings of this study on the bending strength of asphaltic concrete. Also data from other investigations have been considered to expand the utility of results obtained. It should be recognized that the area investigated and reported is a relatively new one and as a consequence future work must attempt a correlation between laboratory results and field performance.

1. There is a linear relationship between the logarithm of stress and the logarithm of number of stress applications for asphaltic concrete. For a constant aggregate and variations in asphalt content and also asphalt viscosity, the slope was -0.1946. Fatigue properties of asphaltic concrete have been characterized with a stress value that can be withstood only once (I_o) and the slope of the S-N curve. These findings are based on tests performed with the deflectometer.

2. The response of the modified cohesiometer test indicated that asphalt content might have affected the influence of asphalt viscosity on the static bending strength identified by the value A_o. The data presented indicated a logarithmic relationship between cohesiometer value, A_o, and viscosity η_r of the asphalt of test specimens. The slopes of such plots had values around 0.25 and r^2 values of 0.99 were obtained.

3. Cohesiometer (Static loading) values (A_o) determined at 140° F and then converted to the temperature (77° F) of the deflectometer (repeated loading) test were compared with the deflectometer value of I_o. On logarithmic coordinates the slope was 0.6326 with an r^2 value of 0.7028 for laboratory prepared specimens and for field samples the slope was 0.6375 with an r^2 value of 0.6041. There are no published data attempting to establish a relationship between the resistance to static bending load and the resistance to repeated flexure load of asphaltic concrete.

4. Presently, there appears to be no acceptable or tested method to predict the viscosity of the asphalt in a pavement from evaluation made of the original asphalt. Such an acceptable method would be useful for predicting bending strength characteristics of asphaltic concrete surfaces at various periods of service.

5. The modified cohesiometer value, A_o, may be a reasonable measure of the bending strength of asphaltic concrete as required for a pavement subjected to repeated loads. The use of A_o in the determination of the surfacing coefficient of the structural number (SN) equation should be in such a form that as the value of A_o increases SN increases but at a decreasing rate, more or less, in an exponential form.

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

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APPENDIX A

This appendix contains data obtained from measurements of laboratory prepared specimens for testing in the deflectometer and cohesiometer. Also included are charts for use with the modified cohesiometer test.

TABLE A-1

DENSITY OF DEFLECTOMETER SPECIMENS COMPACTED BY VIBRATORY-KNEADING

Aggregate Weight gm.	Density, gm/cc — Asphalt Grade and Content, Percent								
	120-150 Pen			85-100 Pen			50-60 Pen		
	5	6	7	5	6	7	5	6	7
				Asphalt - T					
8,000 ± 1.0"		2.225 2.236 2.230		2.305 2.249 2.277	2.217 2.235 2.226	2.224 2.216 2.220		2.253 2.235 2.244	
10,000 ± 1.25"	2.300 2.291 2.295	2.243 2.232 2.237	2.258 2.267 2.263	2.274 2.237 2.255	2.228 2.228 2.228	2.261 2.267 2.264	2.286 2.289 2.287	2.239 2.224 2.231	2.298 2.293 2.296
12,000 ± 1.50"	2.274 2.289 2.281	2.241 2.252 2.246	2.292 2.341 2.317	2.257 2.243 2.250	2.267 2.254 2.260	2.326 2.319 2.323	2.287 2.300 2.293	2.269 2.261 2.265	2.280 2.310 2.295
				Asphalt - H					
8,000 ± 1.0"				2.281 2.280 2.280	2.222 2.217 2.219	2.264 2.238 2.251		2.223 2.243 2.233	
10,000 ± 1.25"		2.260 2.275 2.267		2.235 2.250 2.242	2.246 2.234 2.240	2.262 2.217 2.239		2.244 2.218 2.231	
12,000 ± 1.50"		2.276 2.234 2.255		2.258 2.253 2.255	2.264 2.242 2.253	2.293 2.328 2.310		2.240 2.233 2.236	

TABLE A-2

REPETITIONS TO FAILURE OF DEFLECTOMETER SPECIMENS TESTED AT 77° F

Aggregate Weight gm.	Repetitions, in Thousands — Asphalt Grade and Content, Percent: 120-150 Pen 5	120-150 Pen 6	120-150 Pen 7	85-100 Pen 5	85-100 Pen 6	85-100 Pen 7	50-60 Pen 5	50-60 Pen 6	50-60 Pen 7
Asphalt - T									
8,000		2.0		4.0	3.0	3.7		8.0	
± 1.0"		3.0		3.0	3.0	--		8.0	
10,000	90	28.0	3.8	60.0	60.0	20.0	740	64.0	160
± 1.25"	90	25.0	2.6	60.0	60.0	21.0	700	80.0	120
12,000	300	100.0	19.0	190.0	150.0	50.0	610	200.0	370
± 1.50"	300	90.0	23.0	200.0	120.0	50.0	500	200.0	500
Asphalt - H									
8,000				7.0	--	3.2		--	
± 1.0"				9.0	4.0	4.0		16.0	
10,000		20.0		84.0	31.0	23.0		120.0	
± 1.25"		23.0		140.0	32.0	22.0		86.0	
12,000		66.0		400.0	100.0	60.0		300.0	
± 1.50"		66.0		430.0	110.0	125.0		400.0	

TABLE A-3

CENTRAL RADIAL STRESS AT SUPPORT PRESSURE OF 1.5 PSI IN DEFLECTOMETER TEST

Aggregate Weight gm.	Stress, psi — Asphalt Grade and Content, Percent: 120-150 Pen			85-100 Pen			50-60 Pen		
	5	6	7	5	6	7	5	6	7
Asphalt - T									
8,000		310		307	285	282		335	
±1.0"		294		318	289	--		293	
10,000	202	181	187	189	174	181	187	190	185
±1.25"	188	195	207	188	178	180	194	178	190
12,000	135	146	167	154	148	141	152	154	157
±1.50"	163	153	151	147	150	139	158	145	141
Asphalt - H									
8,000				286	--	308		--	
±1.0"				302	274	276		294	
10,000		180		186	188	172		173	
±1.25"		181		178	180	178		187	
12,000		149		151	152	150		143	
±1.50"		138		149	143	148		139	

TABLE A-4

Values of A_o Obtained From the Cohesiometer Test

Aggregate Weight gm.	Temp. °F	A_o Asphalt Grade and Content, Percent: 120-150 Pen 5	120-150 Pen 6	120-150 Pen 7	85-100 Pen 5	85-100 Pen 6	85-100 Pen 7	50-60 Pen 5	50-60 Pen 6	50-60 Pen 7
Asphalt - T										
10,000	77		1280	944	1570	1635	1415	1705	2010	1855
		1635	1148	850	1645	1635	1385	1850	2140	1855
12,000		1600	1430	850		1760	1445	1855	1855	1570
		1790	1430	1005		1510	1350	1950	1915	1820
		1675	1322	912	1607	1635	1399	1840	1980	1775
10,000	140	144.8	157	163.5	169.9	281.1	216	214.0	316.5	324
			192	242.0	157.1	275.0	209	182.3	302.0	324
12,000		182.2	248	188.5	195.0	295.5		319.5	431.0	258
		163.5	245	236.0	298.0	267.0	---	314.0	393.5	280
		163	210	207	205	280	213	317	361	297
Asphalt - H										
10,000	77		944		1335	1130	1180		1460	
			1085		1290	1005	960		1509	
12,000			1120		1350	1415	975		1955	
			1075		1290	1290	1163		2020	
			1056		1316	1210	1069		1736	
10,000	140		192.0		173.0	147			236.0	
			188.7		220.0	231			256.0	
12,000			192.0		188.5	230	210.5		261.0	
			270.0		169.7	205	169.8		264.5	
			211		188	203	190		254	

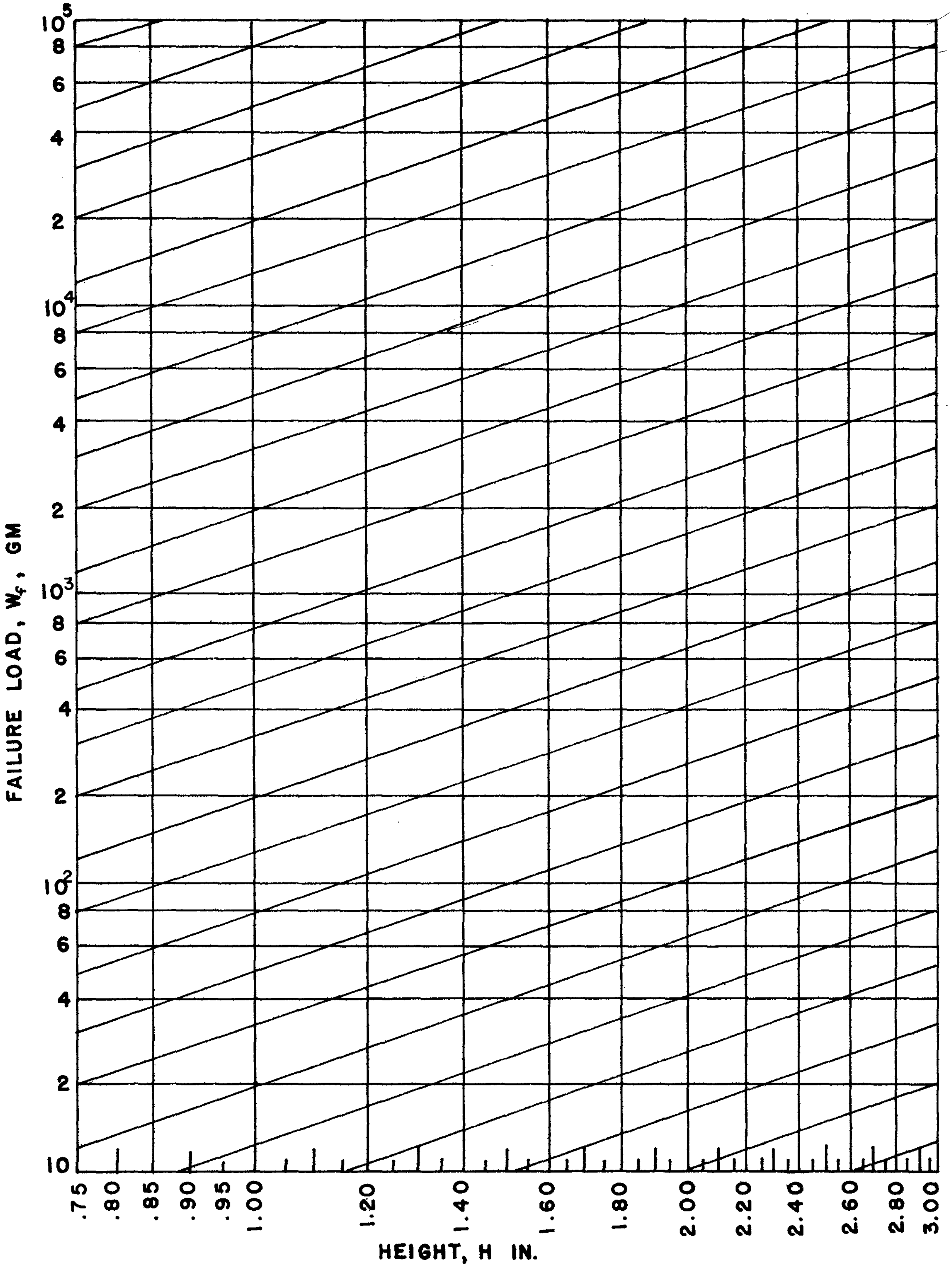
TABLE A-5

VISCOSITY OF ASPHALTS RECOVERED FROM DEFLECTOMETER SPECIMENS

Source	Penetration Grade	Viscosity, Poise $77^\circ F$ [1]	$140^\circ F$ [2]
	50-60	7.50×10^6	6,250
H	85-100	1.80×10^6	2,440
	120-150	0.87×10^6	1,580
	50-60	28.5×10^6	21,300
T	85-100	10.5×10^6	6,240
	120-150	2.90×10^6	3,555

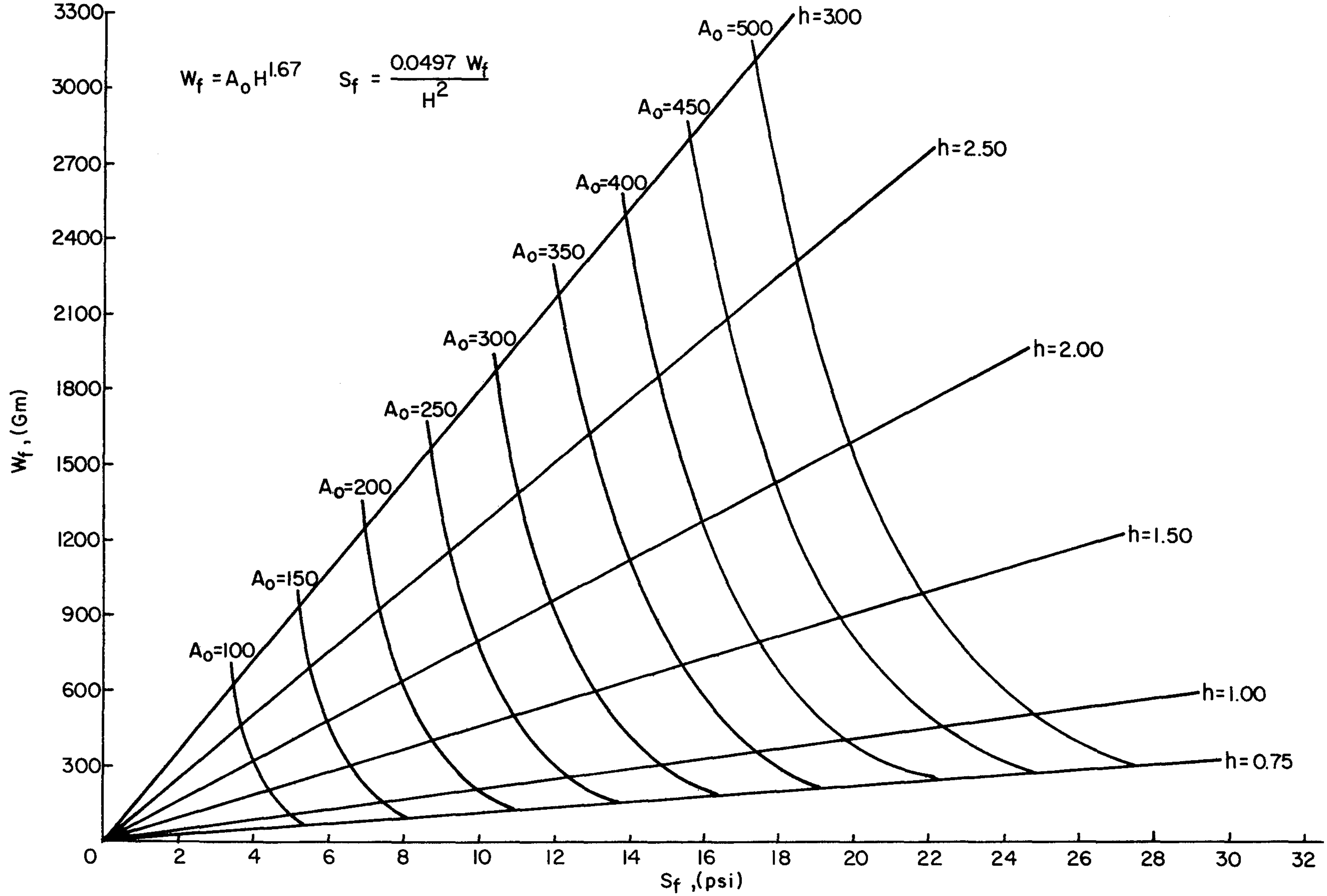
1. Determined with sliding plate micro-film viscometer at a shear rate of 5×10^{-2} $sec.^{-1}$.

2. Determined with capillary tube viscometer.



HEIGHT CORRECTION CHART FOR COHESIOMETER

Figure A-1



SPECIMEN HEIGHT EFFECTS ON COHESIOMETER RESULTS

Figure A-2

APPENDIX B

In this section the data listed are those obtained from the testing of field samples from the parent project, number 2-8-62-32.

Table B-1 contains the measurements made on the samples taken from Section E of Field Tests.

Figures B-1, B-2, and B-3 show the average modified cohesiometer values corrected to a height of specimen equal to 2 inches. These samples were obtained from over 230 sections of asphaltic concrete pavements identified as Section D. The symbols in the bar graphs are identified as follows:

L. S.	is	Limestone
P. G.	is	Pea Gravel
R. A.	is	Rock Asphalt (asphaltic rock)
LWA	is	Lightweight Aggregate

The individual cohesiometer values will be used in the parent project for correlation studies in that program.

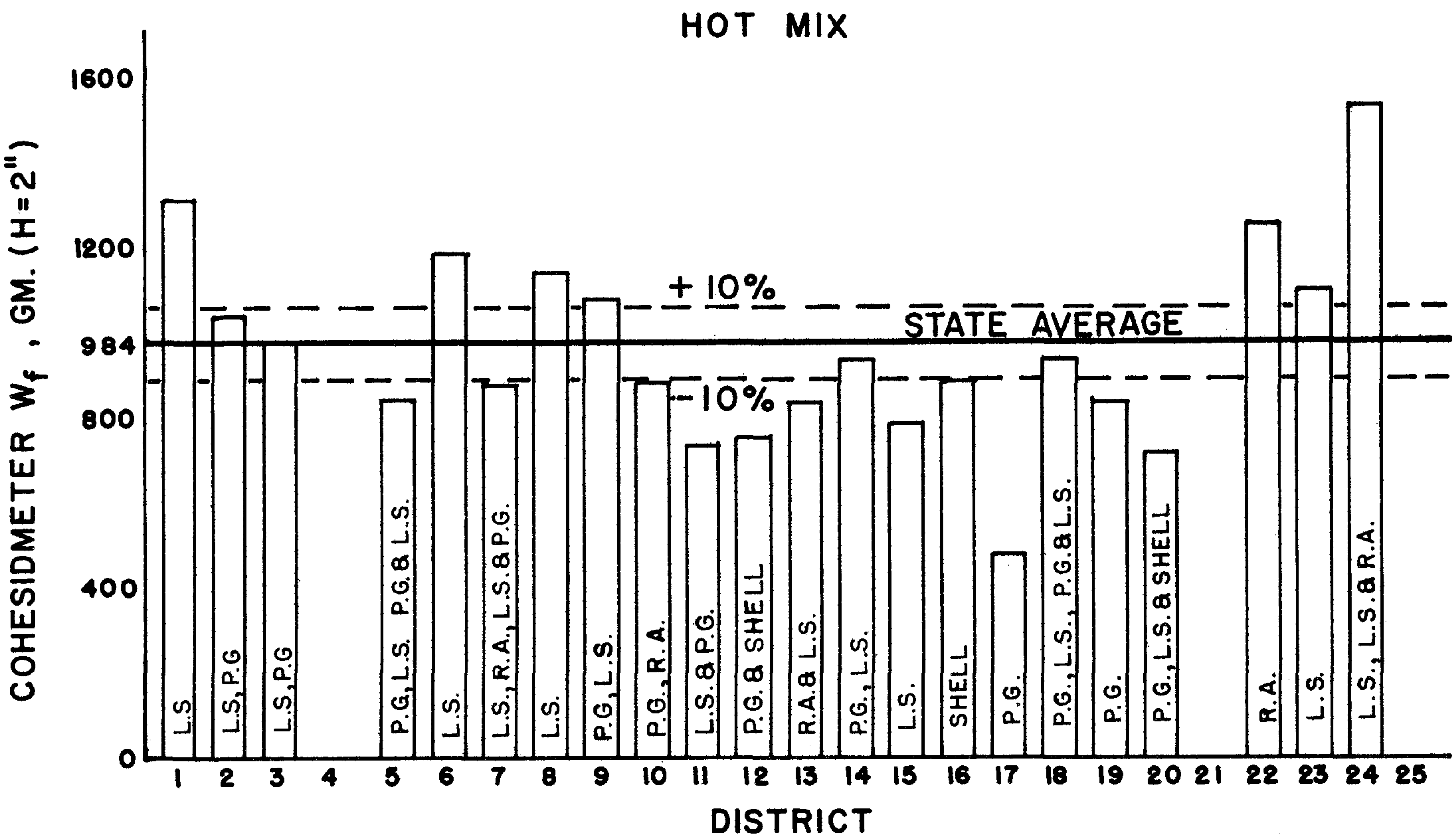
TABLE B-1

DATA FOR DEFLECTOMETER SECTIONS (E) OF FIELD TESTS

District No.	Test Section	Air Permeability ml/in/min	Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Air Void %	Hveem Stability %	Cohesiometer W_f-2"-140^oF gm
1	203-2-1	Imper.	2.431	2.450	0.8	39	1790
5	52-6-1	Imper.	2.144	2.254	4.9	31	1080
	53-5-2	Imper.	2.283	2.328	1.9	too thin	700
	227-3-1	Imper.	2.103	2.252	6.6	26	1083
8	5-5-3	Imper.	2.268	2.385	4.9	35	2600
	5-7-1	Imper.	2.310	2.404	3.9	36	777
	6-2-1	Imper.	2.329	2.438	4.5	-	565
	6-6-1	Imper.	2.329	2.402	-	28	965
9	15-6-1	Imper.	2.430	2.460	1.2	27	963
12	389-12-1	Imper.	2.256	2.396	5.8	20	1137
13	25-7-1	Imper.	2.203	2.323	5.2	too thin	777
15	521-5-1	Imper.	--	--	-	42	689
	613-2-1	Imper.	2.291	2.421	5.4	too thin	787
16	617-1-1	Imper.	2.300	2.345	1.9	too thin	too thin
17	186-6-1	Imper.	2.306	2.439	5.4	25	1173
	210-2-1	Imper.	2.371	2.430	2.4	11	767
18	364-3-1	Imper.	2.398	2.472	3.0	-	540
19	62-1-2	Imper.	2.329	2.460	5.3	51	470
20	305-7-1	Imper.	2.209	2.392	7.6	-	775

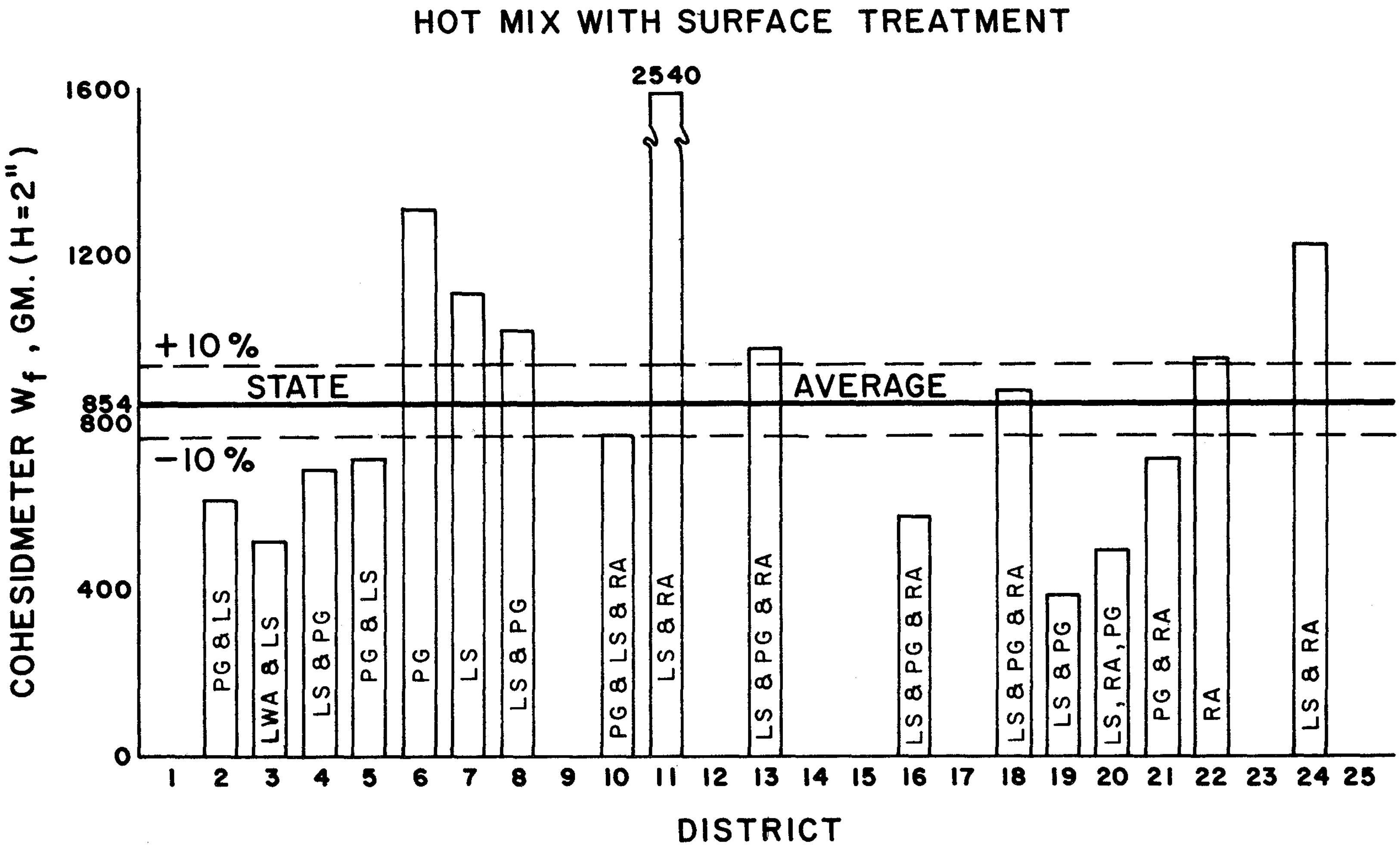
TABLE B-1 (Cont.)

District No.	Test Section	Deflectometer: Fail. Reps. 10^{-3}	Deflectometer: Stress, psi 1.5 psi	Deflectometer: Stress, psi Fail.	Deflectometer: E, psi 1.5 psi 10^{-3}	Deflectometer: E, psi Fail. 10^{-3}	Asphalt: Content %	Asphalt: Micro Ductility 77°F, cm.	Asphalt: Pen. 77°F	Asphalt: Viscosity 77°F megapoise	Asphalt: Viscosity 275°F poise
1	203-2-1	1,580	104	103	120.5	133.0	4.8	0.60	30	27.8	9.62
5	52-6-1	900	129	129	49.1	45.0	6.2	.45	21	58.0	6.87
	53-5-2	107	251	245	265.0	227.1	6.7	3.93	37	9.0	3.66
	227-3-1	345	128	120	53.9	54.1	6.5	.58	25	39.0	7.71
8	5-5-3	880	87	87	35.7	35.1	5.6	.25	15	110.0	3.25
	5-7-1	820	104	105	55.9	44.7	5.0	.53	15	82.0	8.14
	6-2-1	980	120	119	67.5	39.9	5.5	1.40	25	20.4	4.42
	6-6-1	766	89	89	33.8	34.1	5.7	1.53	27	19.8	4.60
9	15-6-1	Too thick					4.5	6.75	35	9.3	7.94
12	389-12-1	1,400	132	114	72.6	59.4	Mix Contained Rock Asphalt				
13	25-7-1	145	163	-	143.1	-	Mix Contained Rock Asphalt				
15	521-5-1	-	-	-	-	-	-	-	-	-	-
	613-2-1	460	170	165	203.5	132.5	4.9	1.00	47	7.5	5.23
16	617-1-1	3.3	300	300	156.8	126.8	5.0	3.34	68	3.36	3.98
17	186-6-1	-	-	-	-	-	4.5	.42	18	52.2	13.64
	210-2-1	777	122	-	140.3	-	5.4	.42	27	46.6	8.69
18	364-3-1	20	-	155	-	65.5	5.0	1.18	29	29.0	8.48
19	62-1-2	225	140	140	48.5	52.7	4.5	too hard	15	78.0	19.49
20	305-7-1	1,550	125	132	134.5	93.9	4.9	.30	14	136.0	17.33



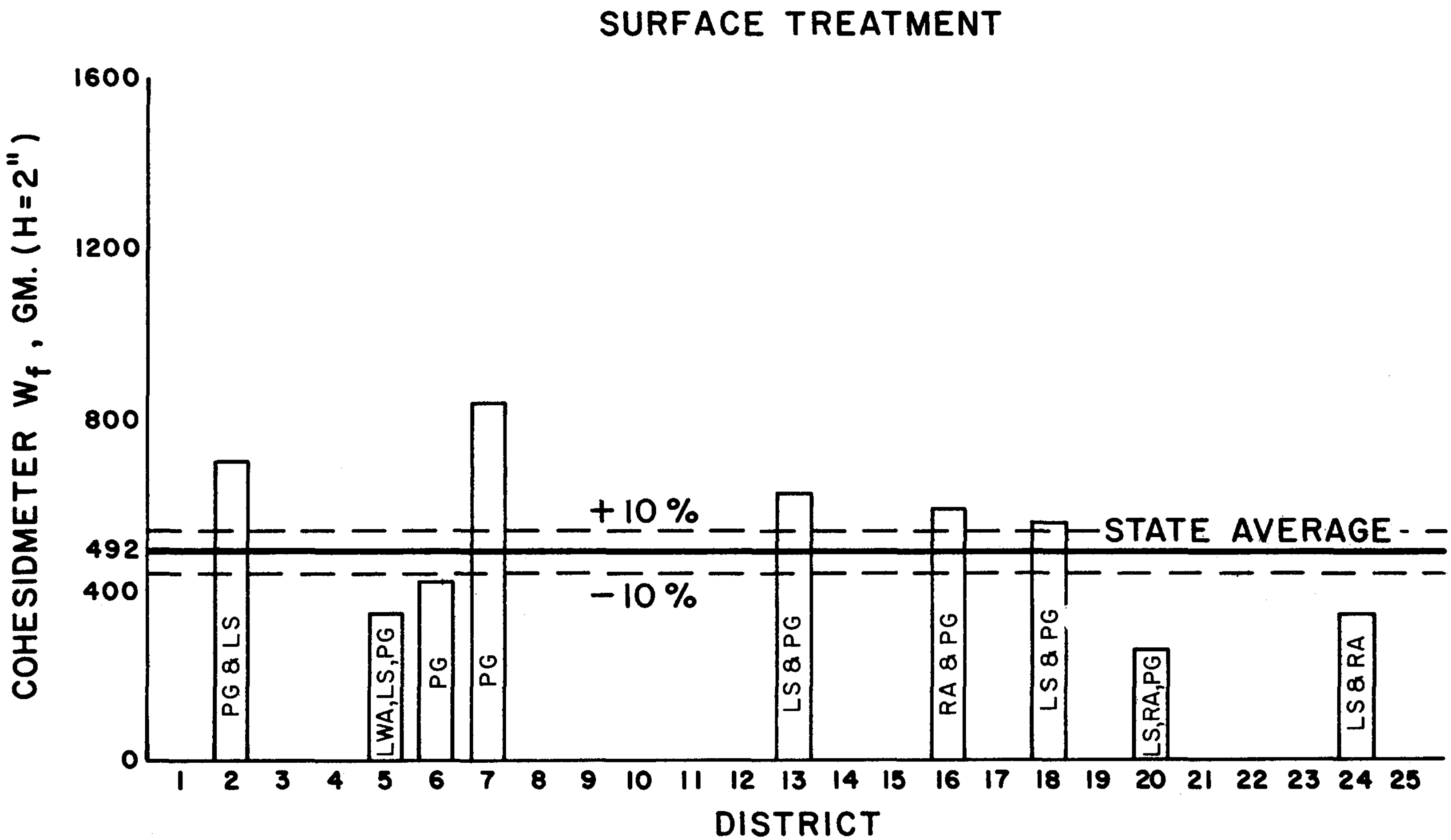
BENDING STRENGTH OF ASPHALTIC SURFACING IN TEXAS

Figure B-1



BENDING STRENGTH OF ASPHALTIC SURFACING IN TEXAS

Figure B-2



BENDING STRENGTH OF ASPHALTIC SURFACING IN TEXAS

Figure B-3

APPENDIX C

The information presented in this appendix is related to the Texas Highway Department Project 2-8-59-9. The road samples tested were not taken from field sections of Project 2-8-62-32. These data are included in this report since they do have a bearing on the change of asphalt viscosity occurring in pavements.

A primary objective of this study was to determine the changes in asphalt viscosity brought about by the processing of asphaltic concrete and by the service exposure in the pavement. The findings of this investigation will be reported to the Texas Highway Department by Dr. R. N. Traxler of the Institute; however, certain data were made available for presentation in this report.

Measurements for the determination of permeability of asphaltic surface slabs included in the AASHO correlation study indicated that those pavements were considered to be impermeable under the test procedure utilizing the Asphalt Paving Meter. It is reasoned that those pavements were of such age that the surfaces were fairly well sealed. The data obtained from Traxler's project indicated that approximately a year was required to seal an asphaltic concrete surface to the pressure provided by the permeability device. Also it was found that the permeability values as determined on slab specimens were not reliable at values below 10 milliliters per inch thickness per minute.

A definite relationship existed between the density and the logarithm of permeability for a mixture. Data on these measurements are shown in Table C-1. The high values of r^2 indicate the feasibility of following or controlling construction compaction of asphaltic concrete with the Asphalt Paving Meter. However, because of the variability in the values of the slope and the materials used it would be required that a calibration curve be developed for each mixture.

Selected data are presented in Figure C-1 to show hardening and rates of hardening of asphalt that can occur in pavements of Texas. The curves of the figure show that a limiting value of viscosity is being approached at the end of one year. Such a trend appears to be reasonable and has been reported in another study[16] of asphaltic concrete pavements in Texas. It is not suggested that the Aging Index will separate the hardening rate of asphalts as definitely as shown in the figure; especially, since the change in viscosity with time was referenced to the mixture after being processed through the plant. The variabilities of hardening of the asphalt caused in producing asphaltic concrete would be difficult to predict without close control of the plant operation. Further, the rate of asphalt hardening in a pavement would be affected by the sealing of the surface obtained during construction and the environment of exposure.

It has been shown that asphalt viscosity has a definite influence on the bending strength of asphaltic concrete. If the future bending strength of a mixture being designed is to be predicted, then, knowledge of a viscosity of the asphalt at the future date must be estimated. It does not appear too idealistic to propose that an acceptable method of evaluating asphalts be developed for predicting the changes in viscosity that will occur in a pavement.

TABLE C-1

DATA AND TEST RESULTS FOR PERMEABILITY OF ROAD SAMPLES OBTAINED FROM PROJECT 2-8-59-9 (Ref. 15)

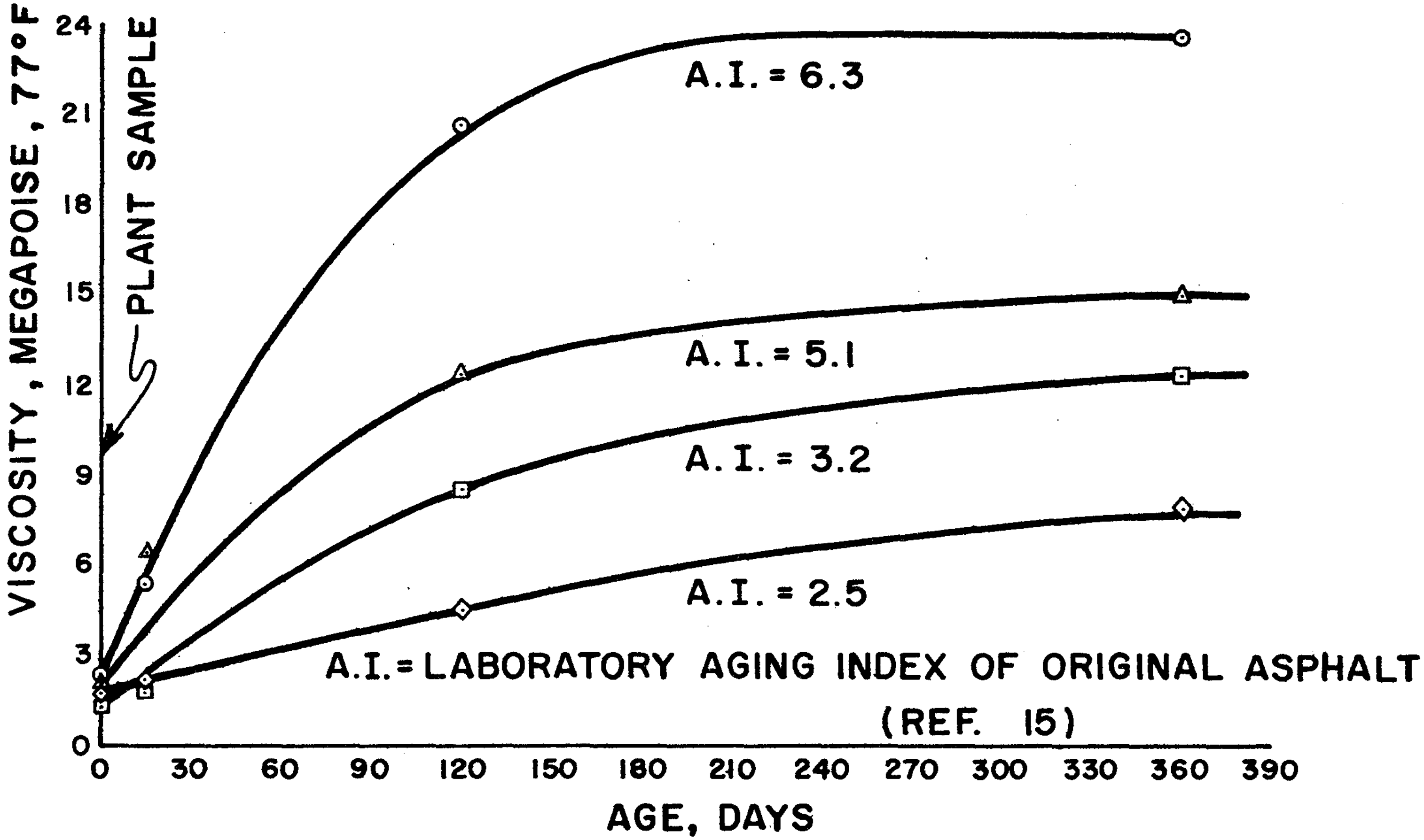
Lot	Age	Density gm/cc	Permeability* ml/in/min	Regression of Density on Log Permeability Slope	r^2	Number of Observations
1	1 day	2.311	103	--	--	-
	2 wks	2.278	169	--	--	-
2	1 day	2.355	36	--	--	-
	2 wks	2.390	2	--	--	-
3	1 day	2.130	200			
	2 wks	2.160	41			
	4 mos	2.231	1	-0.2277	0.9999	3
6	1 day	2.255	160			
	2 wks	2.293	65			
	4 mos	2.325	5	-0.2179	0.8962	3
7	1 day	2.155	1,820			
	2 wks	2.240	272			
	4 mos	2.269	46	-0.1303	0.9356	3
8	1 day	2.172	2,260			
	2 wks	2.206	473			
	4 mos	2.239	49			
	1 yr	2.245	11	-0.1718	0.9074	4
9	1 day	2.300	236			
	2 wks	2.295	164			
	4 mos	2.336	41	-0.1718	0.9074	3
10	1 day	2.282	129			
	2 wks	2.322	61			
	4 mos	2.337	35			
	1 yr	2.327	39	-0.1034	0.9465	4
11	1 day	2.209	158			
	2 wks	2.254	36			
	4 mos	2.271	9	-0.1918	0.9431	3

*Determined at room temperature with Asphalt Paving Meter for a pressure differential of 0.25 inch of water.

TABLE C-1 (Cont.)

Lot	Age	Density gm/cc	Permeability* ml/in/min	Regression of Density on Log Permeability Slope	r^2	Number of Observations
12	1 day	1.951	269			
	2 wks	2.005	132			
	4 mos	2.009	39	-0.1070	0.6701	3
14	1 day	2.128	1,033			
	2 wks	2.144	1,380			
	4 mos	2.159	588	--	--	-
15	1 day	2.287	1,080			
	2 wks	2.303	950	--	--	-

* Determined at room temperature with Asphalt Paving Meter for a pressure differential of 0.25 inch of water.



CHANGES IN ASPHALT VISCOSITY WITH SERVICE TIME

Figure C-1

PUBLICATIONS

Project 2-8-62-32
AASHO Road Test Results

1. Research Report 32-1, "A Report on a Modification of the AASHO Road Test Serviceability Index Formula" by Frank H. Scrivner.

2. Research Report 32-2, "A Study of the Troxler Soil Density and Moisture Gauges" by Robert Lane Freidenwald.

3. Research Report 32-3, "Evaluation of the Cohesiometer Test for Asphaltic Concrete" by R. A. Jimenez.

4. Research Report 32-4, "An Electro-Mechanical System for Measuring the Dynamic Deflection of a Road Surface Caused by an Oscillating Load" by F. H. Scrivner and W. M. Moore.

5. Research Report 32-5, "A Trailer for Transporting the CHLOE Profilometer" by L. E. Stark.