Evaluation of the Cohesiometer Test for Asphaltic Concrete

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The investigation reported herein is a supporting study to a larger project concerned with the modification of the AASHO Road Test findings for use under conditions found in Texas. The objective of this special study was to determine whether cohesiometer test results are significantly related to factors known to affect the performance of asphaltic concrete, to modify the equipment or procedure if necessary, and to evaluate the test for use in the parent project.

The cohesiometer used by and available to the Texas Highway Department was modified slightly and a load-deflection recorder was attached to the unit. The data obtained from the evaluation program have shown that the cohesiometer test results are affected by and are sensitive to mixture variables that exist in asphaltic concrete pavements. An equation defining the cohesiometer's response to a test specimen was derived and verified by test data. Also for use in the parent project a specimen height correction chart was established.

•SINCE THE completion and reporting of the AASHO Road Test, highway engineers have recognized the necessity of translating the findings for local conditions. It is primarily for this reason that project HPS-1-(27) E was initiated in Texas. A special phase of this program is concerned with the determination of the surfacing coefficient for use in the Road Test performance equation and with the cohesiometer test for arriving at a value for this coefficient.

The cohesiometer test was developed by the California Highway Department for use in designing asphaltic mixtures and pavements; however, this test has not been used as a specification requirement for asphaltic surfacings. Several districts of the Texas Highway Department employ a cohesiometer of Texas design for evaluation of pavement materials. This type was selected for use in the study (Fig. 1); however, certain modifications to the standard apparatus were made.

A major modification was the addition of a load-deflection recorder. The recorder is a mechanical one in which a paper tape moves at a rate of 18 in./min and a pen attachment linked to the cohesiometer beam traces a curve on the tape as the beam deflects under load. Other changes from the standard are slight ones, such as (a) the beam is allowed to deflect up to 1½ in., and (b) the variation in the gap distance between the clamp-down plates has been reduced from that of previous models.

Before performing some preliminary testing with the new cohesiometer, several machine characteristics were noted and considered in the testing procedure, as follows:

1. On the specimen deck of the cohesiometer a circle 4 in. in diameter was inscribed for aid in centering the test specimens.
2. Specifications for the cohesiometer required that the gap variability between the specimen clamping plates be restricted to close tolerances.

Paper sponsored by Committee on Mechanical Properties of Bituminous Paving Mixtures.

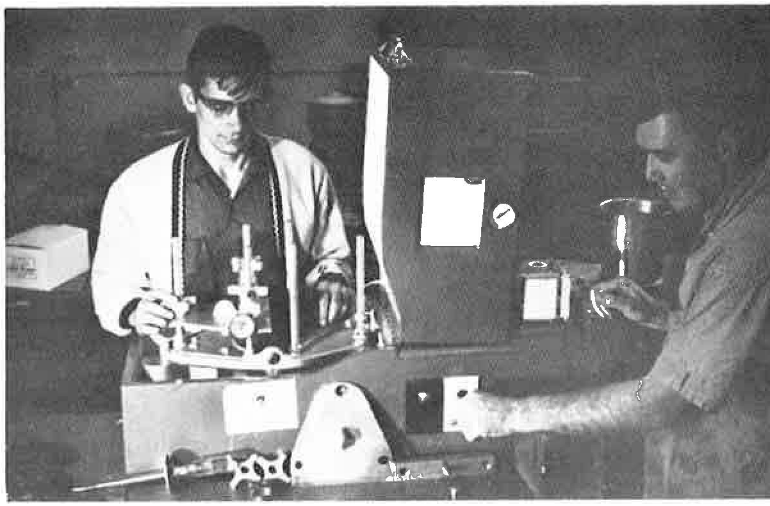

Figure 1. Photograph of cohesiometer.

3. The manufacturer's recommended torque of 25 in.-lb for securing the specimen was found to be excessive for asphaltic concrete specimens. The maximum torque used was 20 in.-lb, and, in some instances, lower torque values were found to be necessary to avoid damaging test specimens.

4. The fixed location of the thermometer for determining cabinet temperature is not considered to be proper. Generally, during use the test temperature is reached sooner at the elevation of the fixed thermometer than at the elevation of the test specimen. For this reason it was necessary to place a thermometer on the fixed-side clamping plate (Fig. 1) for determining and controlling the test temperature.

5. The present design of the cohesiometer utilizes a cam for supporting the loaded end of the cohesiometer beam. The beam deflection recorder responds to the bending of the beam because of its own weight when the end cam support is released. Future designs should eliminate this type of deflection from the load-deflection graph. A typical curve is shown in Figure 2.

6. A sturdier or more rigid construction of the cohesiometer is preferred.

The available literature on this test is limited to procedure and to values obtained for different mixture studies. The common procedure calls for testing a specimen generally 4 in. in diameter, 2 to 2½ in. high, at a temperature of 140 F, and using a rate of loading of 1,800 gm/min. The loading is stopped when the end of the beam deflects ½ in. The load corresponding to the ½-in. deflection is corrected for specimen height to obtain the cohesiometer value.

The asphaltic mixture characteristic evaluated by the cohesiometer may be related to flexural strength of the material and, therefore, information on this property is required for mixture design and evaluation. Use of the cohesiometer under existing procedure has shown that for normal asphaltic concrete there is no visual evidence of failure of the specimen and that the available height correction factors are not adequate for thin specimens. An objective of this study was to determine a method for transforming the test value of specimens of different heights to that value of a specified height.

Because of the lack of information on the theory originally hypothesized for the response of the cohesiometer to test conditions, an hypothesis was stated for the present study and a model equation for cohesiometer response was obtained for verification. The hypothesis is based on the flexural nature of the test. Test conditions are shown in Figure 3. The external moment due to W is given by

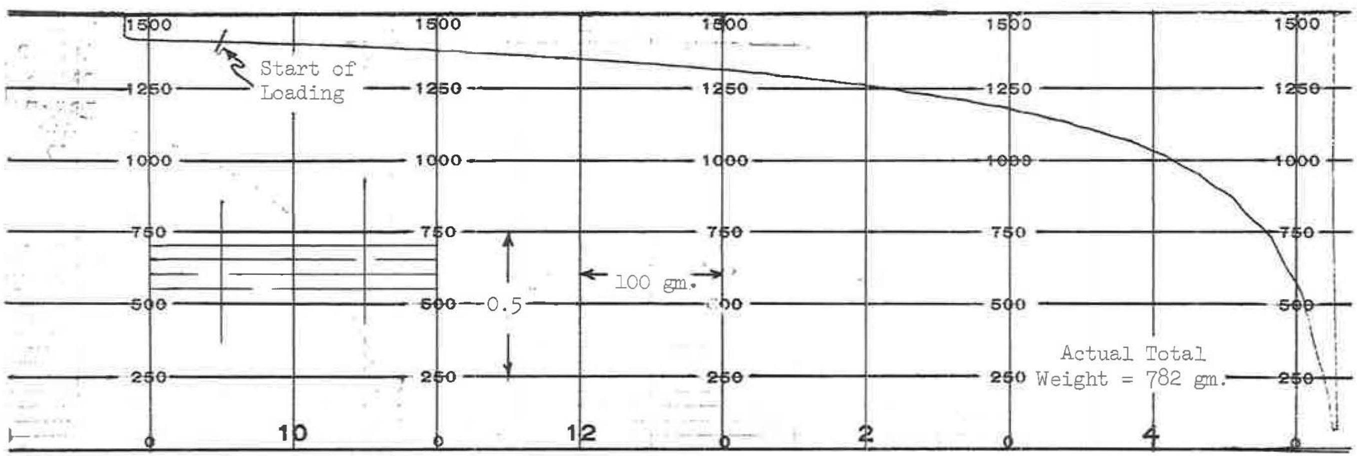

Figure 2. Typical load-deflection curve from cohesiometer test.

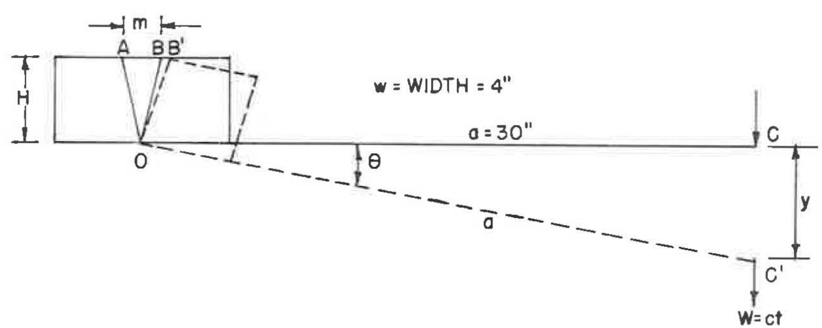

Figure 3. Conditions of cohesiometer test.

$$M_W = a c t \cos\theta \tag{1}$$

in which c is the rate of loading in gm/sec and t is the period of loading in sec. The resistance to the external moment comes from the material in the wedge OAB and is taken to be some function of the original wedge dimensions, H, m, w, of some parameter, K, representing all properties of the material, and also of the instantaneous angular velocity, $d\theta/dt$ at which the deformation occurs in order to account for rate of loading effects. This resistance is represented by

$$M_r = f(H, m, w, K, d\theta/dt) \tag{2}$$

As a first approximation it is assumed that the resisting moment is directly proportional to the instantaneous angular velocity and that dimensions m and w (w = 4 in.) will not be varied for the present; also the length a (a = 30 in.) will be a constant. Under these conditions Eq. 2 becomes

$$M_r = f(H, K)\, d\theta/dt \tag{2a}$$

Neglecting the momentum of moving parts, the external and resisting moments are equated in

$$M_W = M_r;\ a c t \cos\theta = f(H, K)\, d\theta/dt \tag{3a}$$

Separation of variables yields

$$\frac{d\theta}{\cos\theta} = \frac{a c t\, dt}{f(H, K)} \tag{3b}$$

With integration Eq. 3b becomes

$$\log_e \frac{(1 + \sin\theta)}{(1 - \sin\theta)} = \frac{a c t^2}{f(H, K)} \tag{4}$$

Substitution of y/a for $\sin\theta$, and W/c for t results in

$$\log_e \frac{(a + y)}{(a - y)} = \frac{a W^2}{c f(H, K)} \tag{5}$$

which can then be written

$$\log \frac{(a + y)}{(a - y)} = AW^2;\ A = \frac{n a}{c f(H, K)} \tag{6}$$

by changing the base of the logarithm and collecting terms. Eq. 6 indicates that its graph on coordinates of $\log [(a + y)/(a - y)]$ vs W^2 should be a straight line of slope A. Preliminary test data have shown the inital portion of this graph to be a straight line (Fig. 4) and, therefore, there is agreement between the test data and the model equation presented. In Figure 4 the deflection value y is used instead of $\log [(a + y)/(a - y)]$ to simplify the plotting operation and yet still show the general shape of the graph for Eq. 6. For the values of y considered, a practical linear relationship exists between log [(30 + y)/(30 - y)] and y. Failure of the model and the specimen is assumed to occur when the plotted data cease to lie on the initial straight line of the graph. It is interesting to note that the apparent failure of specimens represented in Figure 4 is occurring at a deflection of 0.25 in. as opposed to the original procedure in which 0.50-in. deflection is the failure criterion.

Preliminary testing with the cohesiometer was done on specimens of three different heights and at three different rates of loading. A regression analysis of these data indicated a reliable relationship, $r^2 = 0.915$, between the logarithm of specimen height, H, and that of the product of the slope of the straight line of the proposed model, A, and the rate of loading, c (Table A). This relationship suggests that:

$$cA = F(H, K) = H^b f(K) \tag{7}$$

by assuming $F(H, K) = H^b f(K)$

which in turn yields the relationships

$$\log(cA) = \log f(K) + b \log H \tag{8}$$

and

$$\log(cA) = \log a_o + b \log H \tag{9}$$

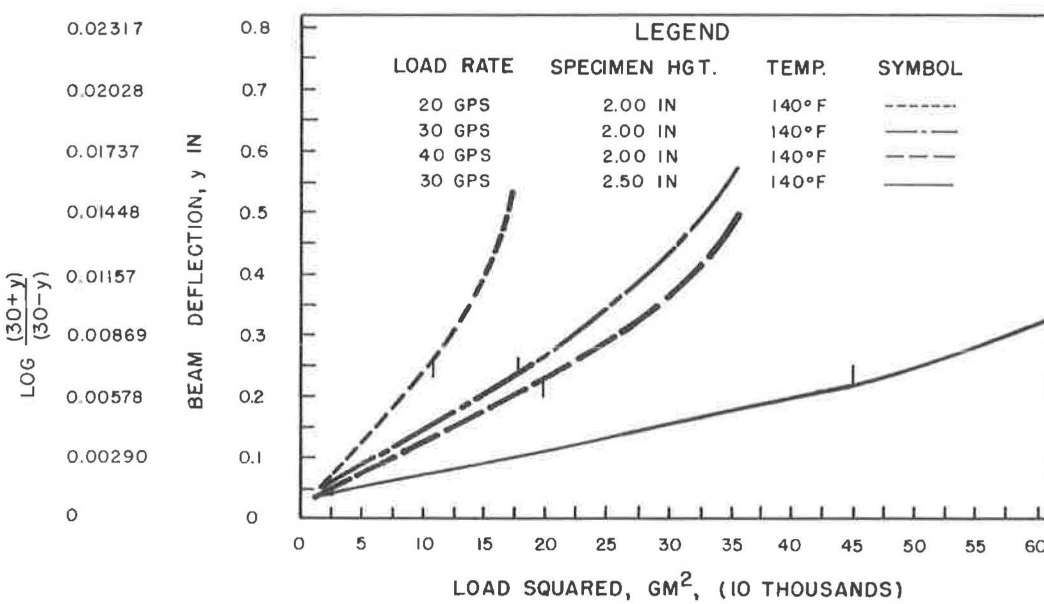

Figure 4. Load-deflection relationship for cohesiometer test.

TABLE 1

GRADATION FOR AGGREGATE BLENDS

Comb. No.	Percent Passing Sieve											
	½ In.	⅜ In.	No. 4	No. 8	No. 10	No. 16	No. 30	No. 40	No. 50	No. 80	No. 100	No. 200
1	100.0	98.4	65.3	50.0	47.5	40.0	25.0	20.0	14.4	11.0	9.5	3.5
2	100.0	98.0	58.0	40.0	38.2	38.0	35.0	28.5	20.0	12.0	10.5	5.0
3	100.0	98.4	65.3	50.0	47.3	38.8	25.0	20.4	17.0	12.0	10.4	3.2
4	100.0	98.0	58.0	40.0	38.6	37.7	35.0	29.0	20.7	12.3	10.9	3.3

Equation 9 is taken as the basic equation for representing a specimen's strength in terms of mixture characteristics, log a_0, and specimen height, H.

This preliminary work was done on specimens made from an actual construction paving mixture in which component variables could not be controlled.

In planning the experiments, it was deemed desirable to investigate the effects of the following factors which are believed to exist and influence the performance of asphaltic concrete surfacings:

1. Aggregate gradation: (a) dense graded, and (b) gap graded;
2. Surface texture of aggregate (- No. 8 sieve size): (a) rough, and (b) smooth;
3. Asphalt content (80 to 100 penetration); and
4. Specimen height and density.

The basic aggregate blends, identified as Combinations 1, 2, 3 or 4 are:

1. Combination 1—dense graded and rough surface texture;
2. Combination 2—gap graded and rough surface texture;
3. Combination 3—dense graded and smooth surface texture; and
4. Combination 4—gap graded and smooth surface texture.

The rough-textured aggregate blends were obtained by combining a rounded gravel and hard limestone screening. The limestone screening furnished most of the minus No. 8 size particles.

The smooth-textured aggregate blends were made by blending the same gravel as in the previous aggregate mixture, concrete sand and field sand. To facilitate the duplication of gradations for both rough- and smooth-textured aggregates, it was thought that the use of the gravel for the plus No. 8 size for all combinations would not greatly minimize the surface texture effect on test values. Table 1 gives the gradations of the various blends obtained by computation for blending the different aggregates, and Figure 5 shows graphically the size distribution obtained after actual blending for the dense- and gap-graded combinations of rough-textured aggregates.

Evaluation of the different asphalt aggregate combinations was made according to the Texas Highway Department method in which specimens are formed by gyratory shear compaction. The results of these tests are presented in Table 2. The cohesiom-

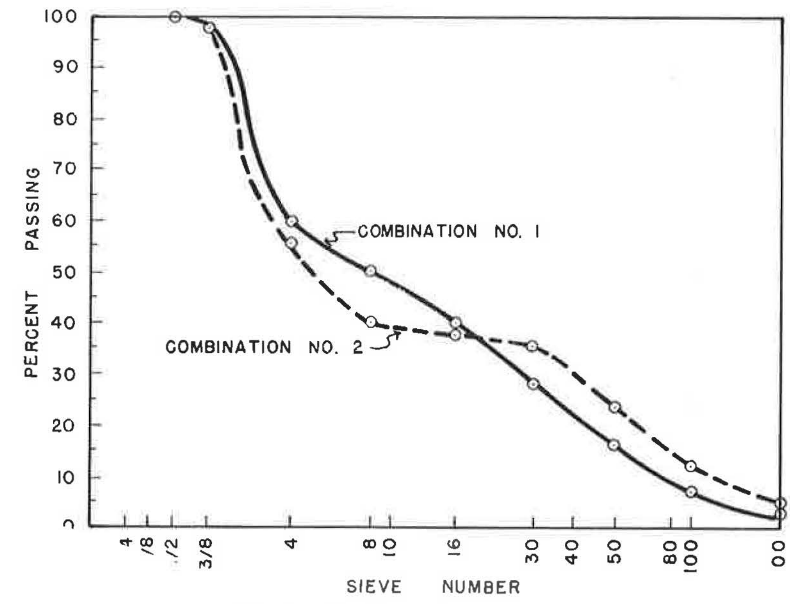

Figure 5. Gradation curves.

eter values were obtained by the original method of testing. All asphaltic mixtures contained an 85 to 100 penetration grade asphalt which met the State's specifications.

TABLE 2

DESIGN CHARACTERISTICS OF ASPHALTIC CONCRETE MIXTURES WITH OA-90 ASPHALT

Combination No.	Asphalt Content (%)	Air Content (%)	Hveem Stability	Cohesiometer Value (gm/in. width/3-in. height)
1	4.5	5.6	61	212
	5.0	3.4	51	293
	5.5	2.5	40	303
2	4.5	6.4	57	177
	5.0	4.3	51	249
	5.5	3.5	33	254
3	4.25	4.2	44	127
	4.5	3.8	43	150
	4.75	3.3	35	114
4	4.6	4.7	36	103
	4.85	3.5	38	133
	5.10	2.9	38	157

EXPERIMENTAL WORK

Three experiments were set up for studying the response of the new cohesiometer to the different variables considered.

Experiment 1 involved primarily the effects of temperature on the strength of test specimens. The variables in this testing program were:

1. Temperature—74, 90, 105, 120 and 140 F;
2. Asphalt content—5.0 and 5.5 percent; and
3. Specimen height—1.5 and 2.0 in.

For these specimens, aggregate Combination 1 was used, and the rate of loading with the cohesiometer was the standard 30 gm/sec.

Experiment 2 included the variables:

1. Aggregate—4 combinations;
2. Asphalt content—4.5, 5.0 and 5.5 percent; and
3. Compactive effort—3 levels.

In view of background experience with the cohesiometer test and study of the first experiment, testing conditions were standardized to a test temperature of 140 F and a loading rate of 30 gm/sec.

The objective of Experiment 3 was to determine a relationship between a value representing the strength of a specimen and the height of the test sample. The establishment of this relationship is necessary to allow comparison of cohesiometer values for different mixtures. Because one curve of these variables of strength and height would not satisfy the needs, the following variables were incorporated:

1. Specimen height—1.50, 1.75, 2.00 and 2.25 in.;
2. Compactive effort—2 levels;
3. Asphalt content—2 levels; and
4. Aggregate—Combinations 1, 2, 3 and 4.

In effect, these variables represented 16 different pavement mixtures with differences other than thickness.

DISCUSSION OF RESULTS

In the basic strength equation for the cohesiometer test (Eq. 9), cA can be simplified by the elimination of c if a standard rate of loading is specified for the test. Also, Figure 4 indicates that the load at the end of the straight-line portion (representing failure of a specimen) might be correlated with the slope of that line and this suggests the direct use of the failure load instead of the slope of the line in Eq. 9. Figure 6 shows that a correlation between failure load, W_f, and slope, A, does exist; that is, that specimens having different failure loads are not likely to have the same value for slope A. The constants of the equation $W_f \cong (8000)/(A^{0.600})$ were determined directly from the graph and do not represent "best-fit" values. The term c is kept in Eq. 9 for flexibility, should variations in loading rate be desired in future work. For the present, the value of slope A, instead of failure load W_f, will be used because the evaluation of A is felt to be more exact than establishing the location of the end of the straight-line portion of curves such as shown in Figure 4. However, it is possible that testing variations may be larger than differences obtained in the use of A or W_f in Eq. 9.

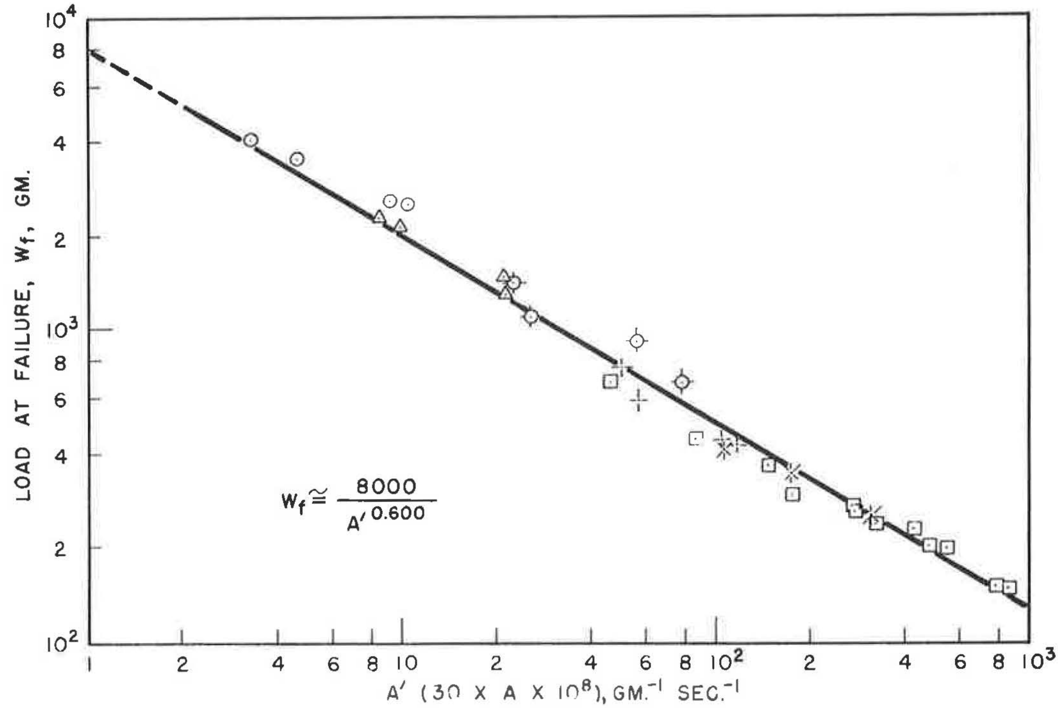

Figure 6. Relationship between load at failure, W_f and A'.

The results obtained in the preliminary testing with the cohesiometer are presented in Table A. These data have indicated the relationship

$$\log (cA \times 10^8) = 3.349 - 4.473 \log H \qquad (10)$$

in which

A = slope of the initial straight-line portion of a log [(30 + y)/(30 - y)] vs W^2 plot;
y = deflection in in. at the end of the cohesiometer beam corresponding to the load W in gm;
c = rate of loading in gm/sec; and
H = height of specimen in in.

As shown, the correlation coefficient, r^2, had a value of 0.915.

The basic data for Experiment 1 are given in Tables B1 and B2. For ease in tabulating and use, the symbol A' has been substituted for $30 \times A \times 10^8$. The analysis of variance for these data shows that temperature, specimen height, interaction between asphalt content and height, and interaction between asphalt content and temperature had significant effects on the cohesiometer response represented by the value of A'. The lack of significant effect by asphalt content alone can be explained by the fact that in regular testing with the cohesiometer, it has been observed that the strength of specimens increases as asphalt content increases, but only to an optimum amount of asphalt. Increasing the amount of asphalt above such an optimum value results in a decrease of cohesiometer value. Further, for most asphaltic concrete specimens containing asphalt near the optimum amount, the cohesiometer value is not affected to a significant extent by slight variations of asphalt content. This behavior is illustrated by the cohesiometer values presented in Table 2.

As mentioned in discussing Experiment 1, the effect of temperature was significant;

however, a limited study of the comparison between A′ and temperature did not show a distinct discontinuity near the softening point temperature of 115 F for the asphalt used. Also a study of the standard deviations for the different A′ values did not indicate differences within these values that could be attributed to test temperatures. Perhaps a more meaningful way of expressing the variations of values is by the coefficient of variation which is the standard deviation divided by the mean value and is usually expressed in terms of percent. The coefficients of variation for A′ of specimens 2.00 in. high and containing 5.0 and 5.5 percent asphalt averaged 11.7 and 8.5, respectively, for the test temperature range from 74 to 140 F; these values for the temperature of 140 F were 11.4 and 8.7. For these reasons and because of experience in this area of testing, a temperature of 140 F was chosen for a standard test.

In Experiment 2 the variables considered were aggregate, asphalt content, and compactive effort.

The standard Texas Highway Department method of asphaltic concrete laboratory compaction requires that gyratory shear be imparted to the mixture until a particular strength of mixture, or "end point," is obtained. The end point is reached when one stroke of the standard jack handle raises the ram pressure to 100 psi. To achieve a variation in density for different compacted mixtures, the molding procedure was modified by setting 50 and 200 psi as end points.

Table C gives the values of A′ obtained in this program. It can be seen that the range of compactive effort used caused significant changes in strength as indicated by A′ for all mixtures. A review of Figures 4 and 6 shows that a high value of A′ is associated with a weak specimen. An increase in compactive effort may either increase or decrease the value of A′ depending on the amount of asphalt and the aggregate combination contained in the specimen.

The use of compactive effort for showing these effects may be questioned by those who would prefer to make the comparison on the basis of void content or asphalt film thickness; however, the density variations were not made to establish a design criterion but to study the cohesiometer's response to changes in density.

The data also show that the aggregate combinations employed affected the results of the test. The dense-graded mixtures were generally stronger than the gap-graded ones but were more susceptive to decrease in strength at the higher asphalt content with an increase of compactive effort. Rough-textured aggregate produced specimens stronger than those containing smooth-textured aggregate. However, a combination of gradation and texture can be found such that a well-graded smooth-textured aggregate mixture (Combination 3—4.5 percent asphalt, 200 psi end point) can be stronger than a gap-graded rough-textured aggregate mixture (Combination 2—4.5 percent asphalt, 50 psi end point).

The ultimate desire of the research was to establish a means by which different asphaltic concrete surfacing materials can be compared in terms of some characteristic parameter. Inasmuch as asphaltic surfacings are of different thicknesses, the method established should evaluate the mixture's characteristic parameter in relation to thickness. And further, because all asphaltic pavements are not made from the same materials, this same method of evaluation should be responsive to differences in mixtures. These considerations were the basis for choosing the variables of Experiment 3. It is recognized that compositional variations of the specimens tested were not as great as those found in actual pavements; however, the strength variations created by changes in thickness, asphalt content, and density are considered to be as great as those found in practice. The results of evaluations from Experiment 3 are given in Table D.

The molding of mixtures by the Texas Highway Department's method resulted in a simple procedure for obtaining specimens of different height but with equal density. An examination of the slopes, b, obtained from a regression analysis of $\log A' = \log a_o + b \log H$ shows a range of values from -2.6 to -4.2. These extreme values of b occur for mixtures that are comparable in strength characteristics and do not represent extremes of strength. A plot of log A′ vs log H for the 16 sets of specimens showed that variations in the slope, b, were not correlated with any of the variables studied, nor with strength. Thus, a constant slope was suggested by the data in this

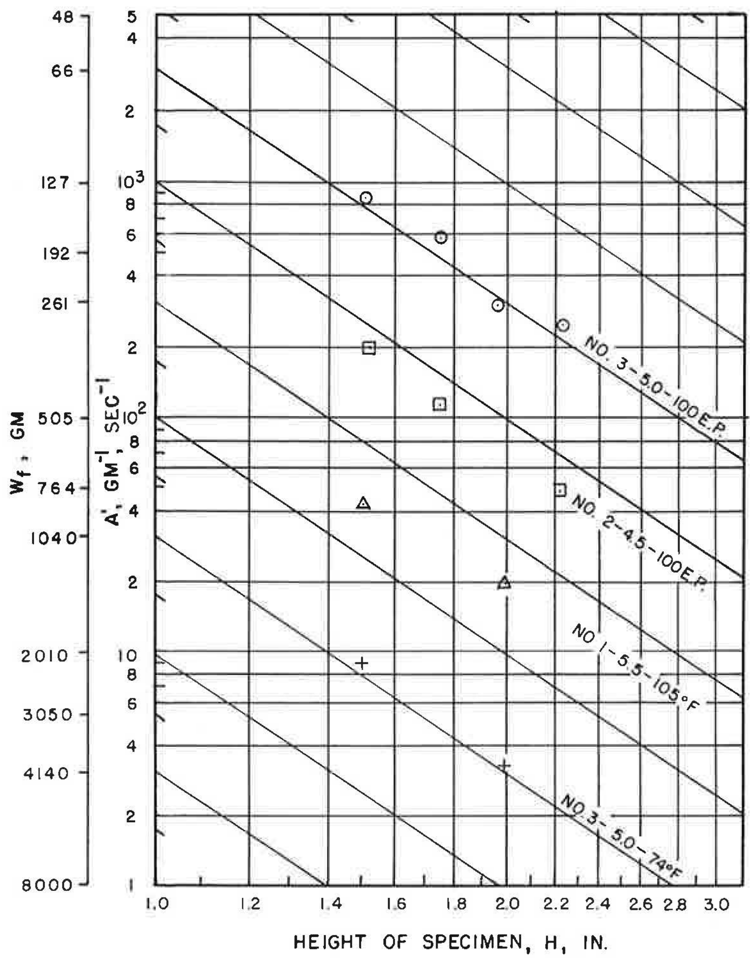

Figure 7. Cohesiometer height correction chart.

experiment and was obtained by averaging the 16 values of b, giving -3.558 with a standard deviation of individual values of 0.698.

The transformation of a cohesiometer test value, A′, for a specimen of a specific height to a standard height specimen can be done by means of Figure 7 which contains logarithmic coordinates of value A′ and H. Also shown is an axis, W_f, in which the value corresponds to the failure load located at the end of the straight-line portion of the y-W^2 plot (Fig. 4). In addition these are data points for different mixtures. Although the data from Experiment 1 were not used to establish the slope of the guide lines, the two bottom sets do appear to follow the trend presented. The use of this chart involves entering into it with values of H and A′ and assuming a standard height of H of 2.00 in. As an example, if a specimen 4 in. in diameter and 1.40 in. high yields a test value of A′ equal to 200, the strength of a standard specimen of such a mixture is determined by locating on the chart a point described by the two given coordinates. From this point a line is followed parallel to the guide lines and intersecting the vertical line representing H = 2.00 in. The ordinate, A′ = 60, of this junction point then indicates the strength as represented by A′ of a standard specimen.

A similar description for height correction can be made for use of the failure load W_f.

SUMMARY AND CONCLUSIONS

The objectives of this study were primarily to evaluate the cohesiometer test for use in project HPS-1(27)E and secondarily to modify the equipment or procedure to achieve these objectives. It has been found that the modified cohesiometer test as described herein yields results that are affected by variables found in asphaltic concrete and which are believed to affect the performance on such pavements. Modifications to the cohesiometer test involved the following items:

1. A load-deflection recorder was attached to the apparatus to obtain a record of beam deflections and corresponding loads during a test.
2. A 4-in. diameter circle was inscribed on the specimen deck to aid in centering a test specimen.
3. The specimen clamping plates were modified to minimize the variability of gap opening.
4. The torque applied to secure a specimen was limited to 20 in.-lb; however, in some instances this value was reduced to as much as 10 in.-lb to prevent damaging a test specimen.
5. The free end of the cohesiometer beam was allowed to deflect 1½ in.

A study of the mechanics of the cohesiometer test led to the derivation of a model equation for defining the cohesiometer's response. Another equation was found to be suitable for establishing a height-correction chart for reducing test values to strengths of specimens of a standard height:

$$\log A' = \log a_o - 3.558 \log H \qquad (11)$$

It is not the intention of this report to set the standard specimen height at 2.00 in. in the evaluation of pavement surfacing to be tested for the parent project, "Application of AASHO Road Test Results to Texas Conditions." It is believed that the standard height for pavement samples should be set in consideration of the average thickness of road samples to be tested and the average height of specimens used in this study.

The cohesiometer test procedure used in this study has been described in detail in a publication of the Texas Highway Department (1).

ACKNOWLEDGMENT

The research presented in this report was done under sponsorship of the Texas Highway Department and the Bureau of Public Roads. Most of the statistical analysis was done under the guidance of Donald E. Cleveland of the Texas Transportation Institute. The basic model equation proposed for the cohesiometer test response was derived by Frank Scrivner of the Texas Transportation Institute.

REFERENCE

1. "Application of AASHO Road Test Results to Texas Conditions." Texas Highway Department Tech. Rep. 3.

Appendix

TABLE A

RESULTS OF PRELIMINARY TESTING WITH COHESIOMETER OF CONSTRUCTION MIXTURE[a]

Specimen Height, H (in.)	Rate of Loading, c (gm/sec)	Slope A × 10^8 (gm^{-2})
1.5	20	24.2
		11.7
		26.6
1.5	30	13.8
		10.5
		8.99
1.5	40	7.64
		9.09
		9.35
2.0	20	5.06
		6.38
		5.88
2.0	30	2.90
		4.56
		3.24
2.0	40	2.78
		1.44
		4.41
2.5	20	1.55
		2.16
		1.19
2.5	30	0.73
		1.54
		1.29
2.5	40	1.13
		1.12

[a]Test temperature, 140 F.

TABLE B1

VALUES OF A′ OBTAINED FROM EXPERIMENT 1[a]

Temp. (F)	5.0% A.C.		5.5% A.C.	
	1.5 In.	2.0 In.	1.5 In.	2.0 In.
74	12.24	2.94	9.63	5.16
	7.95	3.87	11.37	4.26
	7.26	3.00	10.38	4.53
90	20.13	8.64	20.37	9.39
	20.70	8.79	22.35	9.84
	23.82	8.58	20.28	10.56
105	78.00	25.41	48.90	24.87
	69.00	27.54	64.80	20.94
	87.00	24.06	55.50	22.56
120	126.3	49.20	75.30	52.20
	109.8	57.30	109.2	53.40
	110.4	64.20	130.8	44.40
140	223.2	89.70	173.1	104.1
	309.0	105.0	192.0	123.9
	399.6	112.8	158.1	116.1

[a]Rate of loading of 30 gm/sec, A′ = 30 × A × 10^8/gm-sec.

TABLE B2

ANALYSIS OF VARIANCE FOR CODED DATA[a] EXPERIMENT 1[b]

Source of Variation	D. F.	Sum of Squares	Mean Square	Variance Ratio
Percent asphalt, P	1	7,194.15	7,194.15	1.82
Height of specimen, H	1	2,008,242.15	2,008,242.15	507.91[c]
Temperature, T	4	15,265,164.77	3,816,291.19	965.18[c]
P × H	1	42,400.42	42,400.42	10.72[d]
P × T	4	96,064.10	24,016.03	6.07[c]
H × T	4	31,449.10	7,862.28	1.99
P × H × T	4	36,022.49	9,005.62	2.28
Error	39	154,204.67	3,953.97	
Lost observation	1			
Total	59	17,640,696.85		

[a]Coded data = (log 30 × A × 10^8) 1,000 - 400.
[b]Est. variance = 3953.97 = 0.00395397; σ = 0.06288.
[c]Significant at 0.01% level.
[d]Significant at 1% level.

TABLE C

VALUES OF A′ OBTAINED FROM EXPERIMENT 2[a]

Comb. No.	Value of A′								
	50 Psi			100 Psi			200 Psi		
	4.5% A.C.	5.0% A.C.	5.5% A.C.	4.5% A.C.	5.0% A.C.	5.5% A.C.	4.5% A.C.	5.0% A.C.	5.5% A.C.
1	239	200	77	120	90	104	98	86	82
	253	150	87	134	105	124	114	73	78
	333	161	98	103	113	116	117	97	120
2	291	195	155	259	164	155	171	118	132
	420	204	127	280	151	211	160	76	92
	396	217	147	234	107	149	172	97	125
3	666	336	306	-	336	402	266	315	387
	867	669	303	747	280	420	315	315	494
	624	315	354	600	308	504	290	321	526
4	1,245	489	336	672	381	345	912	370	339
	442	342	336	872	687	366	1,050	277	453
	1,026	570	306	-	513	546	645	479	432

[a]Test temperature, 140 F; rate of loading, 30 gm/sec; height, 2.00 in.; A′ = 30 × A × 10^8/gm-sec.

TABLE D

VALUES OF HEIGHT, H, AND A′ FROM EXPERIMENT 3[a]

Comb. No.	50 Psi				100 Psi			
	4.5% A.C.		5.0% A.C.		4.5% A.C.		5.0% A.C.	
	H (in.)	A′	H (in.)	A′	H (in.)	A′	H (in.)	A′
1	1.57	645	1.55	834	1.49	134	1.51	223
		858		834		140		309
		1,008		650		146		400
	1.81	693	1.75	200	1.75	100	1.74	134
		495		230		100		191
		588		220		102		130
	2.01	239	2.01	209	1.97	121	1.96	90
		253		150		134		105
		333		161		103		113
	2.25	348	2.25	129	2.21	31	2.21	57
		180		258		37		59
		182		122		37		59
	b = -3.906		b = -3.940		b = -4.532		b = -4.233	
	r^2 = 0.937		r^2 = 0.759		r^2 = 0.842		r^2 = 0.993	
2	1.54	810	1.54	594	1.52	237	1.51	174
		830		792		172		200
		822		498		214		207
	1.79	327	1.81	439	1.75	103	1.73	174
		514		432		110		124
		420		423		126		172
	2.02	291	2.01	195	1.99	259	1.98	163
		420		204		280		151
		396		217		234		107
	2.26	426	2.22	148	2.22	54	2.22	56
		220		146		40		50
		258		150		44		46
	b = -2.620		b = -4.120		b = -3.949		b = -3.142	
	r^2 = 0.916		r^2 = 0.951		r^2 = 0.994		r^2 = 0.771	
3	1.55	2,140	1.54	1,410	1.53	1,293	1.50	1,293
		2,200		1,410		1,500		537
		2,100		1,460		1,245		933
	1.79	1,540	1.81	1,300	1.79	468	1.75	498
		1,528		1,580		867		696
		1,540		756		936		591
	1.99	666	1.99	336	2.01	1,200	1.96	336
		867		670		747		280
		625		315		600		308
	2.24	360	2.22	177	2.28	379	2.23	205
		528		468		291		252
		730		220		-		312
	b = -4.109		b = -4.932		b = -3.131		b = -3.320	
	r^2 = 0.952		r^2 = 0.882		r^2 = 0.842		r^2 = 0.954	
4	1.54	1,720	1.54	1,850	1.53	1,135	1.52	1,310
		2,500		1,550		1,320		1,400
		2,245		1,720		1,515		1,470
	1.79	1,340	1.79	707	1.78	1,092	1.78	758
		1,340		1,101		864		780
		1,340		431		978		582
	2.01	1,245	2.01	490	1.98	672	1.98	381
		942		342		870		687
		1,003		570		-		513
	2.24	1,420	2.23	342	2.27	420	2.26	357
		417		368		471		357
		657		378		504		513
	b = -2.064		b = -4.228		b = -2.623		b = -3.140	
	r^2 = 0.992		r^2 = 0.959		r^2 = 0.971		r^2 = 0.961	

[a]Test temperature, 140 F; rate of loading, 30 gm/sec; $A' = 30 \times A \times 10^8$/gm-sec; $\log A' = \log a_o + b \log H$.