ROAD AND LABORATORY TESTS ON HOT-MIX ASPHALTIC CONCRETE

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Synopsis

The work reported in this presentation is related to a six-year study of materials, tests, and evaluation of asphaltic concrete in Texas. The investigation of asphaltic mixtures was divided into two main phases. The first was concerned with the evaluation of the materials used in twelve pavements built in different parts of the State and the sampling and rating of these roads. The second phase dealt with special testing and experimentation for the design and evaluation of asphaltic concrete; however, only general findings in this phase are included in this report. The purpose of this study was to advance the knowledge of asphalt paving technology in order to meet the demands for more durable pavements required by the increase of traffic volume and loads and by the decrease of source of good paving materials.

This report also contains the initial data collected for a study to investigate the fatigue resistance of pavements in service.

Introduction

The investigation was initiated in 1957 under sponsorship by the Texas Highway Department subsequently in 1959, and since then, the work has been done in cooperation with the Bureau of Public Roads under HPS projects. The title given to this program of study is a misnomer since the greater portion of the work has been involved with laboratory procedures for the design of asphaltic concrete.

The primary reasons for the investigation was to examine present laboratory methods for the design of asphaltic concrete and to modify and expand these or devise new methods to help in obtaining a better product. In the mid 1950's it was noticed that the same or different paving materials were giving completely different serviceability over the state of Texas, even though these mixtures had been designed under the same specifications. Such performances are not limited to the state of Texas nor are they expected to be eliminated in the near future because of the many variables involved in the production of asphaltic concrete and the construction of flexible pavements. A question posed was why should one area produce asphaltic mixtures of good serviceability and other areas build pavements that require sealing within a relatively short period of time after construction. In fairness to all concerned with the construction of asphaltic pavements in Texas, it should be stated that most design and construction engineers are aware that many of the asphaltic concrete mixtures that were and are utilized are not of premium quality and that a 10-year life is not expected of such surfacings. The inadequacies of these surface courses are, in addition to other factors, related to the quality of the materials used, the thickness of the surface course placed, and the relatively low initial cost. In consideration of the various aspects that must be accounted for in the design of asphaltic concrete pavements, it appears that in reality many of these new pavements may be considered phases in "stage construction." The construction of a lower type surfacing in place of a higher type may be justified by the seemingly unpredictable extrapolation of traffic volume and weight for design.

One must recognize that because of construction variables the design of asphaltic concrete meeting most specifications does not insure a product of good performance in service. For this reason specifications must be examined and re-evaluated from time to time so as to give consideration to the new materials - good and not so good - available for construction and to new concepts in the field of pavement and mixture design.

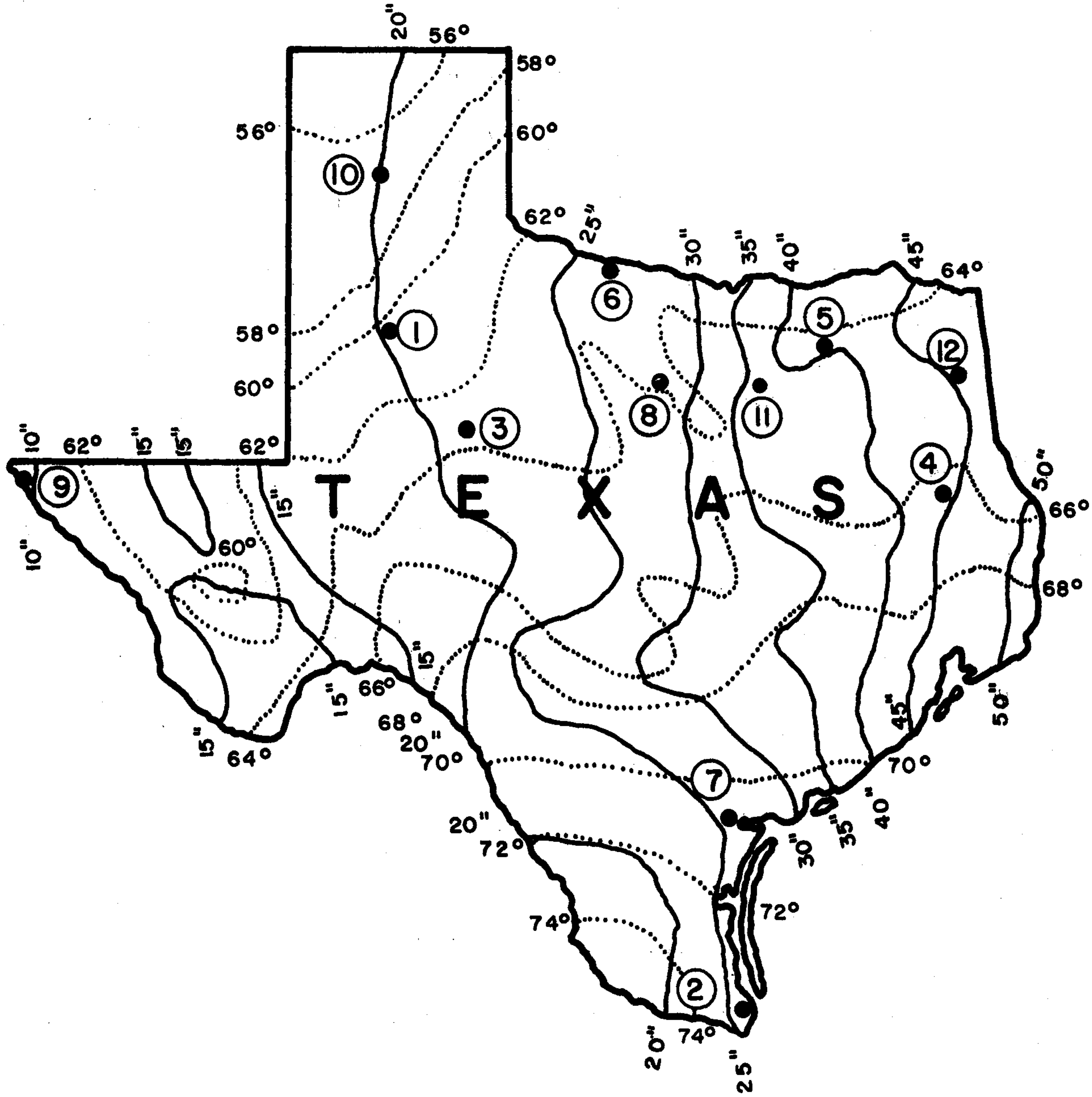
The body of this report will be concerned with history and material evaluation of twelve test sections which may be called Case Studies.

Case Studies

For this general study of asphaltic concrete in Texas it was deemed desirable to investigate mixtures from areas of known good and not so good service records; test sites were also selected to furnish variability in the aggregates utilized in paving mixtures.

The course of work in this phase can be divided into the following headings, (1) location of test site, (2) sampling of materials, (3) laboratory evaluation of materials, and (4) observations of changes in the pavement condition and materials.

Location of test sites -- As can be seen from Figure 1 the distribution and location of test sites are such that extremes in the four cardinal directions are included. These offer variability with respect to climatic conditions and types of materials used in the construction of these pavements.



SAMPLE LOCATIONS ; ISOHYETAL & ISOTHERMIC LINES

Figure 1

Table 1 shows the listing of the materials used for the construction of these pavements. The asphalt source varied as would be expected for these mixtures but the type was predominantly of the penetration grade of 85-100. The aggregates for these mixtures represented general types used such as rounded gravel, crushed stone, and shell. These asphaltic mixtures were placed as overlays on portland cement concrete, asphaltic concrete, or brick and on new bases classified as flexible or stabilized.

Tables 2 and 3 show additional information with respect to traffic and construction conditions.

Sampling of Materials -- No attempts were made to effect any changes in the construction procedures common to the locality. Representatives from the Texas Highway Department obtained samples of aggregate from each of the cold and hot bins at the plant. Also some of the asphalt and asphalt-aggregate mixture were obtained for laboratory evaluation. Each field laboratory made an extra set of three specimens for testing by the Texas Transportation Institute (TTI).

The only deviation from standard construction procedures was the placing of aluminum foil strips 18 inches wide and three feet long on the prepared base prior to passage of the paver. The placing of the aluminum foil was for the purpose of facilitating the isolation of the asphaltic surfacing in future sampling of the pavement.

Testing and Evaluation of Materials -- The materials used in all construction projects were evaluated by the Texas Highway Department and satisfied the requirements as set forth by the controlling specifications.[1*] Similar and additional tests were performed on the materials by the Texas Transportation Institute for amplification of the analyses of those components making up the asphaltic concrete. Such data, it was reasoned, would be of assistance in predicting or explaining future behavior of the pavement under study.

Asphalts -- For the twelve test sites established, nine different asphalt producers were represented. Many of these same producers had supplied the asphalts evaluated for a study (RP-3) on the durability of asphalts in surface treatments; and it was deemed desirable to study the

* Number pertains to reference listed at end of report.

TABLE 1

Description of Test Roads

Sample No.	Asphalt Producer	County	Asphalt Cement Pen. Grade	Aggregate Type	Base	Remarks
1c	A	Lubbock	OA-135	Gravel & Crushed Limestone & Field Sand	Concrete Pavement	Binder
1d	A	Lubbock	OA-135	Gravel & Crushed Limestone & Field Sand	Concrete Pavement	Surface
2	B	Cameron	OA-90	Crushed Gravel & Sand	Concrete Pavement	
3	A	Mitchell	OA-90	Crushed Limestone & Field Sand	Flex. Base	
4	C	Angelina	OA-90	Gravel & Irone ore sand	8" Concrete 10" Flex. Base	
5	D	Hunt	OA-90	Crushed Limestone, Concrete sand & Field Sand	9" Flex. Base 4" Salv. Base	Binder and Surface
6	E	Wilbarger	OA-135	Crushed Limestone & Field Sand	10" Mineral Agg. Lime Stab.	Widening
7	B	Nueces	OA-90	Shell & Field Sand	Flex.	
8	F	Parker	OA-90	Crushed Limestone & Sand	Brick, Bed Sand, Concrete slab	
9	G	El Paso	OA-90	Crushed Basalt	Asphaltic Concrete Over 9" flex.	Overlay
10	H	Randall	OA-90	Gravel & River Sand	16" Caliche	
11	I	Dallas	OA-90	Crushed Limestone & Field Sand	Concrete Pavement	
12	I	Harrison	OA-90	Gravel and sand	Concrete Pavement	

TABLE 2

Traffic and Climatological
Data for Test Sections

Sample No.	Traffic ADT 1957	Traffic ADT 1961	Location Section of State	Type Terrain	Avg. Annual Rainfall (in.)	Mean Annual Temp. (°F)
1c	4,230	4,330	Northwest	Plains	21	60
1d	4,230	4,330	Northwest	Plains	21	60
2	520	730	South	Coastal Plains	27	73
3	4,220	4,550	West Central	Plains	22	63
4	5,410	5,510	East	Wooded & Rolling	44	66
5	1,990	2,290	Northeast	Wooded & Rolling	40	64
6	960	1,140	North Central	Plains	27	63
7	6,040	6,830	Southeast	Flat	27	71
8	6,690	4,450	North Central	Rolling	28	64
9	20,000	15,390	West	Flat	10	62
10	15,000	8,160	North	Plains	20	57
11	17,500	13,670	Northeast	Rolling	35	65
12	5,710	6,190	Northeast	Wooded & Rolling	46	65

TABLE 3

Spreading Weights, Thicknesses, and
Rolling Information on Test Roads

Sample No.	Amount Surfacing Used lb/sq. yd.	Thickness (in)	Rolling Temp. °F	Roller Type
1c	100	1	310	10-ton, 3-wheel 10-ton, 2-wheel
1d	110	3/4		light pneumatic
2	125	1-3/8		
3	200	2	310	10-ton, 3-wheel 15-ton, 2-wheel 20-ton, pneumatic
4	150	1-3/8	300	10-ton, 3-wheel 8-ton, 2-wheel
5*	110	7/8	275	10-ton, 3-wheel 10-ton, 2-wheel
5**	105	7/8	275	10-ton, 3-wheel 10-ton, 2-wheel
6	210	1-3/4	300	10-ton, 3-wheel 8-ton, 2-wheel
7	150	1-1/2		10-ton, 2-wheel 10-ton, 2-wheel
8	150	1-1/4	250	10-ton, 3-wheel 10-ton, 2-wheel
9	110	1/2	260	10-ton, 2-wheel Pneumatic 260# lin 8-ton, 2-wheel
10	200	1-1/2	310	10-ton, 3-wheel 8-ton, 2-wheel 25-ton pneumatic
11	160	1	300	10-ton, 3-wheel 8-ton, 2-wheel
12	205	1-5/8	275	10-ton, 3-wheel 8-ton, 2-wheel

* Binder Course
** Surface Course

changes that occur in asphalts used in hot-mix hot-lay asphaltic concrete in much the same manner as in the previous work.

Presented in Table 4 are the results of fractionation of the asphalts by the Traxler-Schweyer[2] method. In this report the original component names of asphaltics, cyclics, and paraffinics are referred to as Fractions I, II, and III respectively. Asphalt H stands out as being radically different from the others for these determinations.

The samples of asphalt taken from the plant at the time of construction were evaluated in the laboratory for viscosity and artificial weathering characteristics. The viscosity data were obtained for the original asphalts by the sliding plate method using microfilms of asphalt. The initial work utilized a shop made viscometer which has been described by Gallaway.[3] Later, viscosity determinations were obtained utilizing a microfilm viscometer manufactured by Hallikainen Instruments.

Three "aging" methods were employed for the laboratory weathering of the asphalt samples. One method was patterned after the Ebberts[3,4] procedure for oxidizing with potassium permanganate. In the second method a thin film (15-20μ) of asphalt between two glass plates was exposed to light from a sunlamp (275W Ken-Rad Sunlamp Type RS) and heat (180-185^{o}F) for a period of 24 hours. A third procedure for aging the asphalts was the "Shell Method"[5] of Griffin, Miles, and Penther. The weathering elements of these three procedures are (1) oxidation, (2) heat and light, and (3) heat and air, respectively. The effects of these exposure atmospheres on the asphalts were shown by the change in viscosity caused by hardening. The increases in viscosity due to these various exposures are listed in Table 5 and typical rheological diagrams are shown in Figure 2. As can be seen the exposure to heat and light was the least severe towards aging the asphalts tested.

<u>Aggregates</u> -- As mentioned previously, samples of aggregates were obtained from both the cold and hot bins. These were tested for specific gravity and gradation and were combined to produce a blend meeting the specifications for each asphaltic concrete mixture. For the various aggregate combinations the sand equivalent test[6] and the centrifuge kerosene equivalent [6,7] were performed.

The evaluation of the aggregate combinations was limited to general acceptance tests and a study of some physical characteristics. However, for some tests minor variations to standard test procedures were made.

TABLE 4

Component Analysis

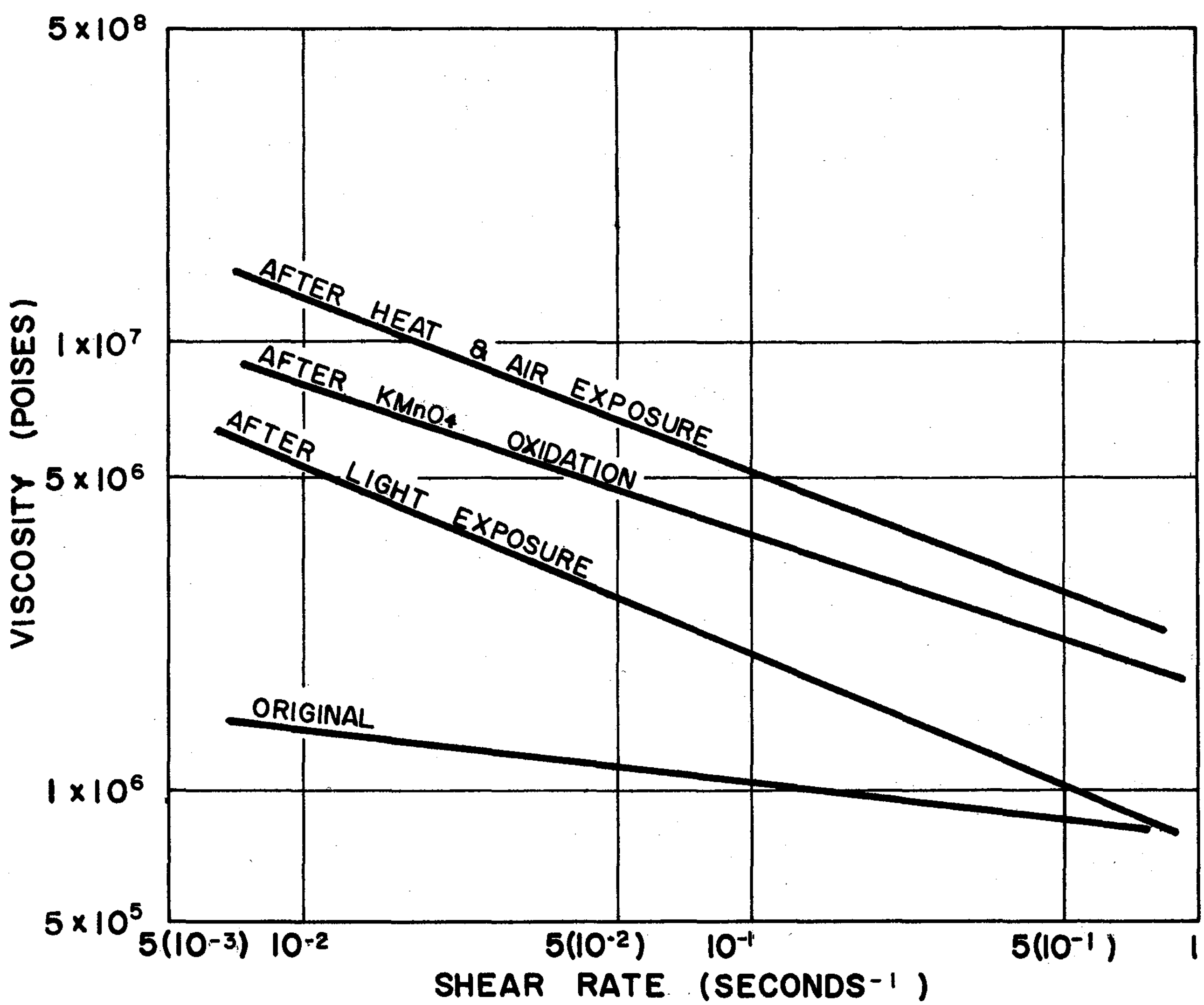
Sample No.	Asphalt Producer	Percent of Total: Asphaltic Fraction I	Cyclics Fraction II	Paraffinics Fraction III
1c	A	28	25	47
1d	A	28	25	47
2	B	30	25	45
3	A	31	22	47
4	C	38	18	44
5	D	45	18	37
6	E	38	10	52
7	B	35	23	42
8	F	42	13	45
9	G	40	21	39
10	H	75	5	20
11	I	50	14	36
12	I		Not received	

TABLE 5

Viscosity and Aging Data

Sample	Original Viscosity Megapoise	After KM_nO_4[1] Viscosity Megapoise	After KM_nO_4[1] Oxidation Value	After Light[2] Viscosity Megapoise	After Heat[3] Viscosity Megapoise	Relative Viscosity[4]
1A	0.56	2.42	1.54	1.27	3.60	4.0
2B	1.10	4.65	1.14	2.65	6.70	3.1
3A	0.86	4.25	1.28	2.77	5.80	7.7
4C	1.19	2.55	1.15	3.00	6.00	3.5
5D	1.10	5.45	0.85	3.30	8.80	5.1
6E	0.74	2.98	1.45	2.06	3.55	---
7B	1.08	3.95	0.83	2.70	5.70	3.1
8F	1.16	5.05	1.00	2.05	6.05	---
9G	0.96	6.90	1.05	----	6.00	4.1
10H	0.88	6.45	1.26	----	4.05	5.1
11I	1.95	5.15	1.48	----	9.90	---

1. Ebberts.
2. Light (ultraviolet) 15-20μ, 180-185°F. for 24 hrs., covered.
3. Exposed films 5μ in thickness stored for 2 hrs. at 225°F.
4. 1962 samples direct from manufacturer exposed 2 hrs. at 225°F in 15-micron films. Data after Traxler.[14] The relative viscosity is obtained by dividing the viscosity after exposure by the viscosity of the unexposed material.



RHEOLOGICAL DIAGRAM

Figure 2

The specific gravity of an aggregate blend was computed from separate determinations made on the fractions retained on and the fraction passing the No. 4 sieve. The method employed utilized a pycnometer, a weak aerosol solution, and vacuum. This procedure yielded a value comparable to the apparent specific gravity of the samples. There was no plan to obtain water absorption values for the aggregates, since the maximum theoretical specific gravity of the asphalt-aggregate mixtures was to be determined by use of the vacuum-saturation method [8,9] on the composite loose material.

At the time (1957-58) of determining aggregate combinations to meet gradation requirements, an attempt was made to express the Texas Highway Department's specifications in terms of "total percent" passing (or retained). Figure 3 illustrates the limits computed for Type D gradation. Also shown in this figure, as dotted lines, are tentative limits that were used as guides by this laboratory for describing other aggregate gradations not directly connected with the parent study. It can be seen that these dotted limit curves are similar to maximum-density curves expressed by Fuller's[10] equation and that Hveem's[11] "density point", M/32, is on a limit line. This point is located by the coordinates of 31 percent passing and 1/32 times the maximum particle size. Experience has shown that maximum density gradation curves for aggregates used in asphalt concrete contain too much of the larger particle sizes and result in mixtures that are lacking in workability. Hveem[11] described the effect of gradation on mixture characteristics and this is shown in Figure 4. More recently Goode and Lufsey [12] reported on a new type of gradation chart which is illustrated in Figure 5. Their analyses indicate that gradings that plot a hump at or near the No. 30 sieve size often contribute to tenderness during field compaction.

It would appear to the inexperienced that the listed specification limits for aggregate gradation (see Table 6) are not restrictive. However, a study of the aggregate gradations found in these field mixtures will show that there were no great differences in gradation. The one possible shortcoming of the specification limits that might be presented to some engineers is that of allowing gap graded aggregate blends.

Appendix A presents the gradations of the road surfacing aggregates. Figure 6 shows a band established by five individual gradings of Type D aggregates represented in the test sections. Although it is not the purpose of this report to go into great detail concerning the interesting study of aggregate gradation, it is desirable to show typical data of actual construction

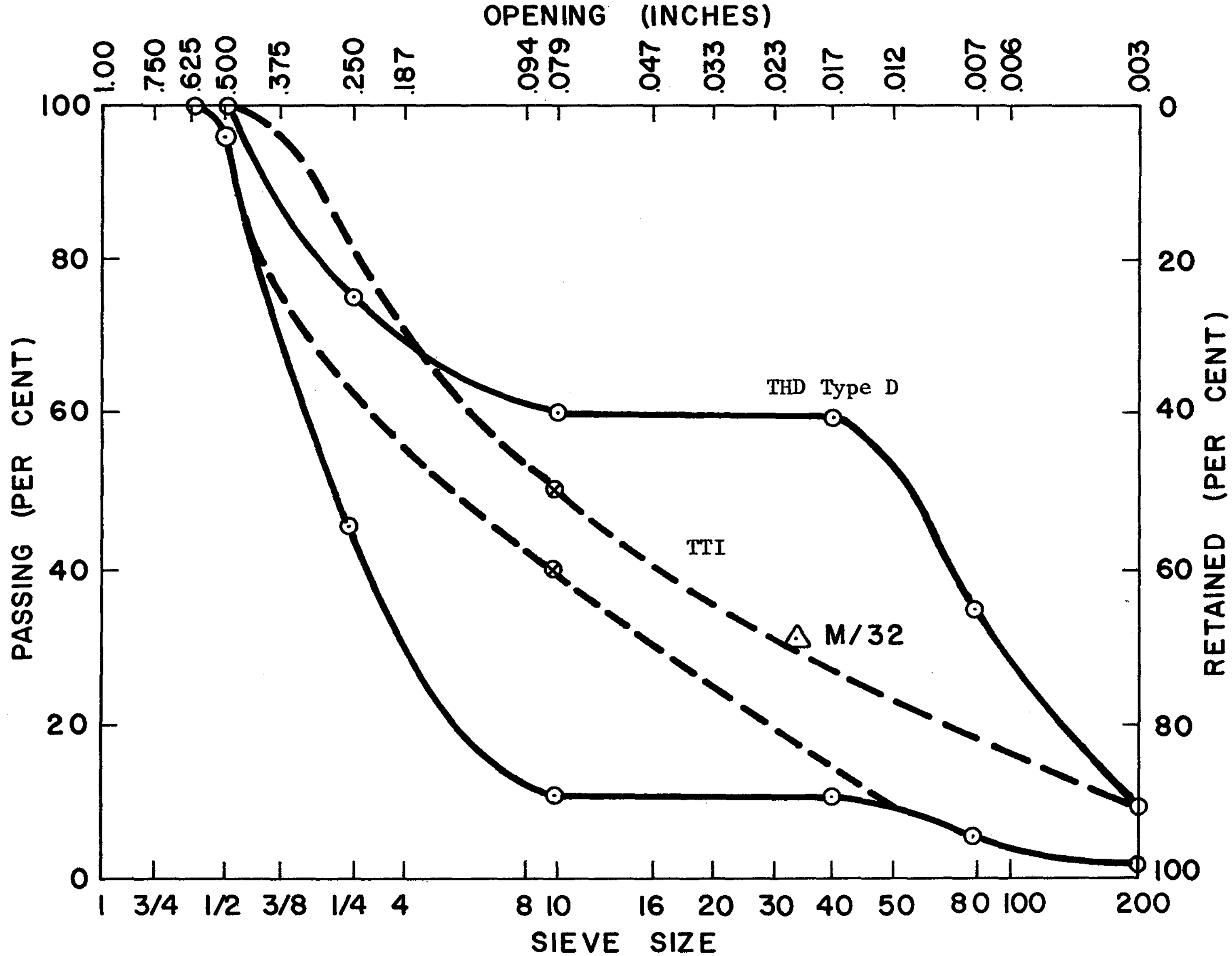


Figure 3 AGGREGATE GRADATION LIMITS

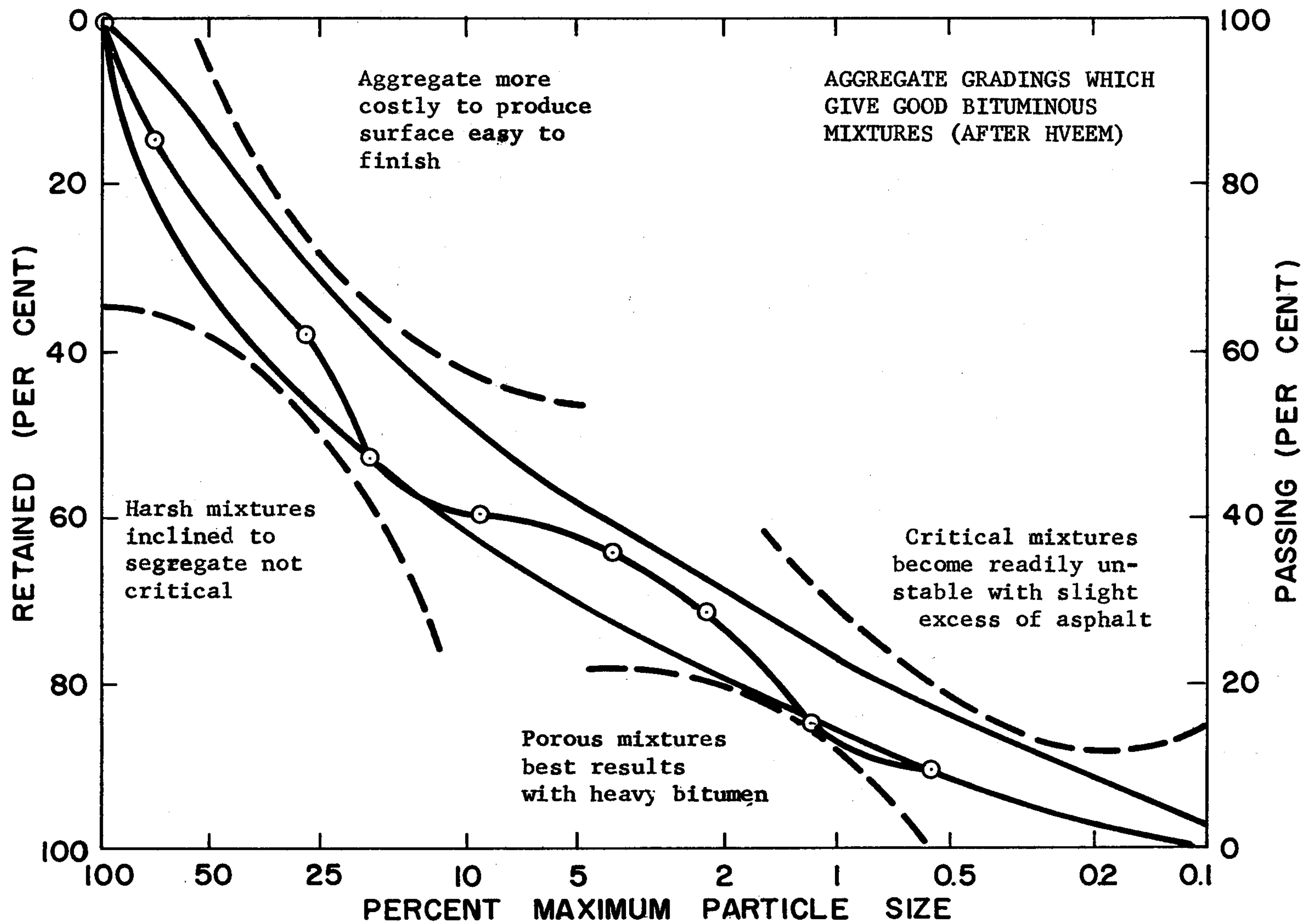


Figure 4 MIXTURE CHARACTERISTICS AFFECTED BY GRADATION

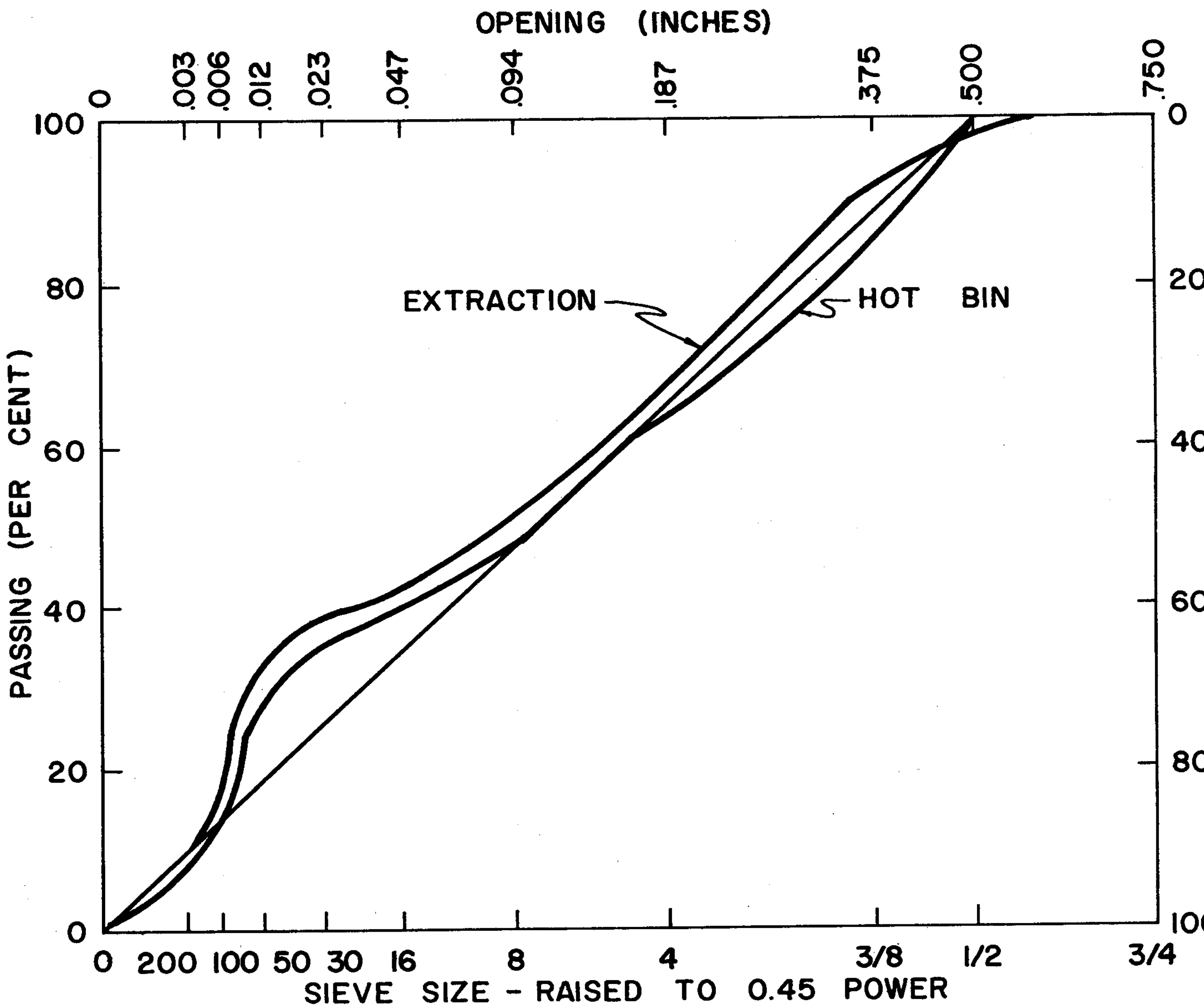


Figure 5 BPR GRADATION CHART

TABLE 6

Specifications for Aggregate Gradation on
Two Types of Paving Mixtures (1951)

Size	Type C Coarse Graded Surface Course		Type D Fine Graded Surface Course
Pass 1 inch screen	100		
Pass 3/4 inch screen	97 - 100	(Pass 5/8 inch)	100
Pass 3/4 inch - Ret. 1/2 inch screen	15 - 40	(Pass 1/2 inch)	97 - 100
Pass 1/2 inch - Ret. 1/4 inch screen	15 - 40		25 - 50
Pass 1/4 inch screen - Ret. No. 10 sieve	10 - 30		15 - 35
Total retained No. 10 sieve	50 - 65		50 - 65
Pass No. 10 - Ret. No. 40 sieve	0 - 25		0 - 25
Pass No. 40 - Ret. No. 80 sieve	5 - 25		5 - 25
Pass No. 80 - Ret. No. 200 sieve	5 - 25		5 - 25
Passing No. 200 sieve	1 - 10		2 - 10

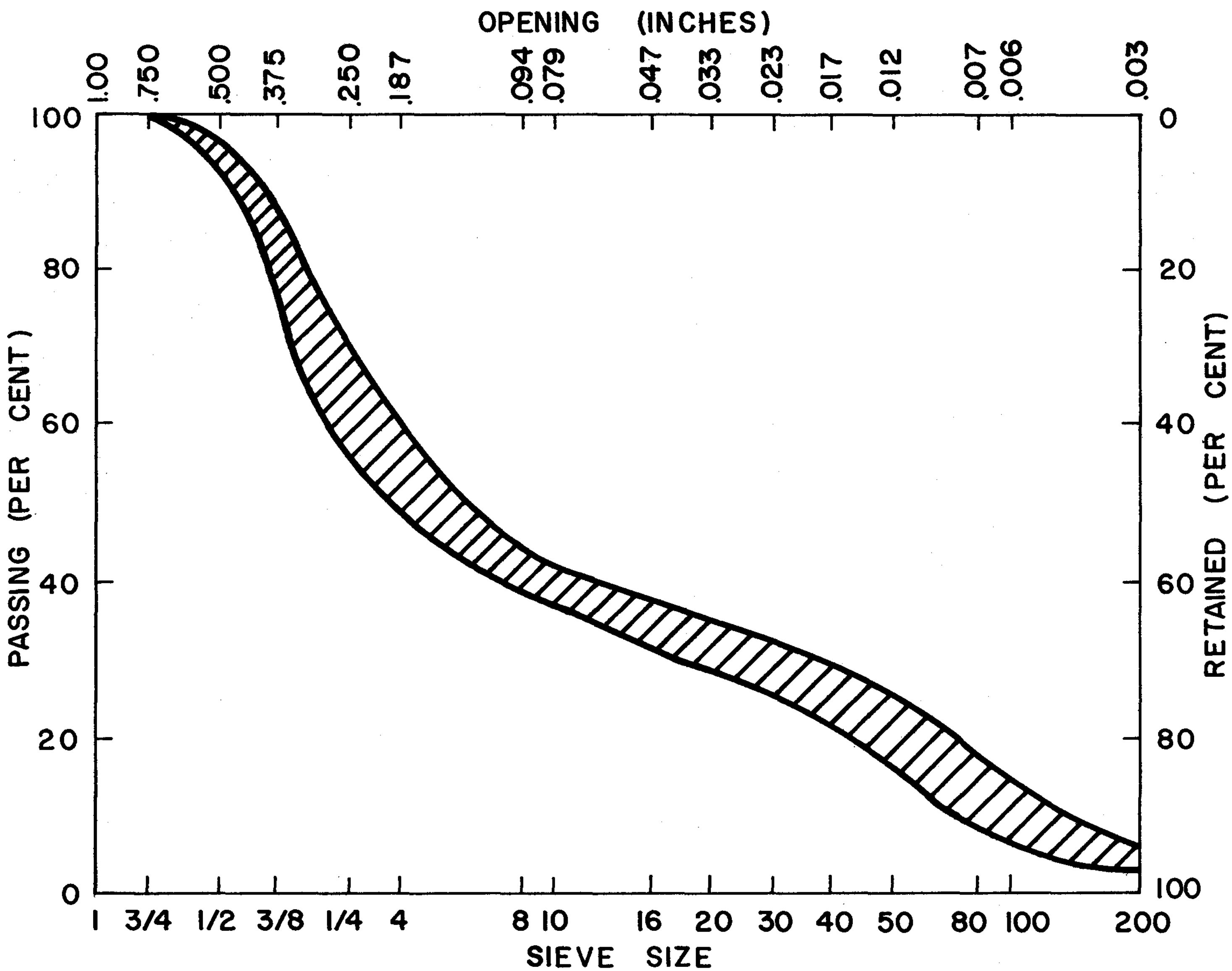


Figure 6 GRADATION BAND OF DIFFERENT MIXTURES

materials for comparison with reported standards.

The combinations derived from the blending of aggregates obtained from both the hot and cold bins were tested for absorption by the CKE test for comparison of the asphalt contents determined by this test and that amount used in the actual construction mixture. The sand equivalent test values were also used for comparison with results obtained from the immersion-compression test (ASTM D-1074 & 1075).

Asphaltic Mixtures -- As previously mentioned, the actual construction mixture was sampled for evaluation by this laboratory. The asphaltic concrete was taken from the paver at the location selected for future sampling by a representative of the Texas Highway Department. Also a duplicate set of three test specimens was made by the field laboratory and these specimens were sent to the Texas Transportation Institute for testing.

The specimens molded by the field laboratories were tested for stability by TTI technicians. Stability and immersion-compression specimens from the construction mixtures were molded and tested. Test values obtained by TTI and the Texas Highway Department are listed in Appendix A.

Discussion on Testing of Materials

Asphalt -- The data presented on the fractionation of the asphalts used in this program show that the method is capable of detecting differences among the test samples. However, a previous report [13] showed that the method of component analysis by itself is not sufficient to predict the service behavior of asphalts used in road surfacings.

The laboratory aging characteristics of the asphalts are shown in Table 5; however, these data only indicate differences in susceptibility to the treatment. It would seem that the asphalts showing the greatest increase in viscosity would be the least durable, but experience[13] has shown that durability of a given asphalt in a pavement is highly dependent on construction controls with special emphasis on the temperature of the asphalt during mixing and compaction of the mixture in the field. These data do show that the asphalts reacted differently to the various types of exposure. A typical rheological diagram is presented in Figure 2 which illustrates the changes in the flow characteristics due to the different aging treatments.

Aggregate --The information presented on aggregate gradation shows that the differences between the gradations obtained by the Institute and those specified by the highway department are comparable to the differences between design values and those obtained from the extraction of field molded specimens. Generally most of the gradations shown met the specifications for the particular type of surfacing.

An example of the data obtained for aggregate and mixture evaluation is shown in Table 7. In this particular mixture the aggregate blend was a combination of marine shell and sand. For this aggregate the gradation specification was modified to account for the breakdown of the shell during manufacture and construction operations. The proportioning of the cold bin and hot bin materials by TTI was done in view of economical use of the materials and in consideration of gradation requirements. As can be seen the cold bin material was degraded in passing through the dryer and screens. The above behavior is an exception rather than the rule for the rest of the aggregates studied.

The amount of minus No. 200 sieve size material determined by washing is shown to be considerably greater than that obtained by dry sieving for many of the aggregates. Sand equivalent values determined for both hot and cold bin combinations did not present a definite relationship with the amount of material passing the No. 200 sieve.

Asphaltic Mixtures -- In comparing test results of the construction mixtures it was generally found that specimen densities produced by the field laboratories were duplicated within acceptable tolerances by this laboratory as were stability values. A report[15] presented to the Texas Highway Department has shown that the reproducibility of compacted specimens by different operators is affected by the type of mixture. This factor explains the random differences in density of specimens compacted at the field and at the laboratory. A divergence in specimen density is also noted between THD and TTI values for specimens molded in the field.

The stability values of field specimens show an average difference of about 3 percentage points between values obtained by TTI and THD. These stabilities are corrected values obtained by use of the curves of test method THD-40. A different height-correction curve has been obtained by the TTI laboratory from a study made for the highway department and reported to the Highway Research Board.[16] Hveem stabilities corrected by the new method differ from that obtained from the curves of THD-40 primarily at very low and very high stabilities and also for specimens of less than 1.75 inches in height.

Variabilities in density and stability between field and laboratory molded

TABLE 7

Construction Material Evaluation

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac.Sat. Sp. Gr.
THD Design	99	86	56	38	29	10	7			
THD Mold Spec.	100	94	77	57	50	18	4			
TTI Hot Bin	98	82	48	31	23	9	3	9.5	23	2.651
TTI Cold Bin	86	78	57	46	39	16	2	7.9	24	2.634

Construction Mixture

		Spec. Density	Theor. Sp. Gr.	Vac.Sat. Sp.Gr.	Rel. Density	Hveem Stab.	Cohesi- ometer	Asp. content	I-C %
THD Molded	THD Value	2.174	2.253		96.5	50		7.5	
	TTI Value	2.169		2.341	92.7	46	375	7.6	
TTI Molded	THD Value					43			
	TTI Value	2.182		2.341	93.2	48	390		72

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi- ometer	I-C %
Hot Bin	6.9	2.335	2.249	96.3	44	532	54
Cold Bin	7.0	2.378	2.185	92.0	48	397	37

specimens could arise from delay in compacting at the laboratory. This delay would perhaps be more significant for the mixtures containing porous aggregate. The data of Appendix A show that generally the cohesiometer values of the laboratory molded specimens were higher than for the field specimens and that the differences in density and stability were not significant as discussed above. A study[17] on the effects of "curing" asphaltic mixtures on density and strength showed the same pattern as indicated in Appendix A.

The greatest differences occurred for values of theoretical maximum specific gravity. This was so because of differences in accounting for absorption of asphalt by the aggregate. It is believed that the vacuum-saturation specific gravity of the loose asphalt-aggregate mixture is the proper basis from which to compute void contents of compacted mixtures.

The lower portion of Table 7 shows physical properties of specimens made from hot and cold bin aggregates and with asphalt contents determined by the Centrifuge Kerosene Equivalent Test of the State of California.[6] All laboratory mixtures were made with a single source asphalt of 85-100 penetration grade; however, this asphalt was from a source different from that used in the field. The data of Appendix A show that the CKE test is capable of establishing an optimum asphalt content for most aggregate blends. The CKE test is admittedly not adequate for aggregate blends that contain an excessive amount of fines or highly porous and absorptive aggregates.

A most significant finding from the laboratory work was that the sand equivalent value gives an insight to mixture durability as determined by the immersion-compression test. Table 8 shows that all mixtures with sand equivalent values of 45 or greater had a retained strength of at least 75 percent for the immersion-compression test. Also it was indicated that generally the hot bin aggregate had a higher sand equivalent value than the cold bin material. The results of the immersion-compression test are not dependent solely on the cleanliness of aggregates as evaluated by the sand equivalent test. Asphalt kind and content, specimen porosity, and aggregate characteristics also influence the values of retained strength obtained from the immersion-compression test.

Discussion on Tests of Pavement Specimens

In Appendix B are presented test data related to laboratory measurements of changes occurring in the test pavements. These changes are

TABLE 8

Comparison of Sand Equivalent Values and Immersion-Compression Results

Sample	S. E.	I-C Ret. Strength, % Laboratory Mixture	Construction Mixture
5 Cold Bin	60	92	
5 Hot Bin	56	96	76
4 Hot Bin	55	102	88
10 Hot Bin	53	105	72
4 Cold Bin	52	92	
1_D Hot Bin	49	75+	77
11 Cold Bin	43	93	75
12 Hot Bin	42	98	92
6 Hot Bin	42	62	96
8 Hot Bin	37	93	91
10 Cold Bin	35	54	
3 Hot Bin	34	70	56
9 Cold Bin	32	64	
12 Cold Bin	32	120	
9 Hot Bin	30	33	49
2 Hot Bin	29	---	45
1_D Cold Bin	27	84	
3 Cold Bin	26	71	
1_C Cold Bin	24	57	
7 Cold Bin	24	37	
8 Cold Bin	24	95	
1_C Hot Bin	23	74	81
7 Hot Bin	23	54	72
2 Cold Bin	21	50	

primarily in aggregate and asphalt characteristics and were brought about by time in service. It is evident from the data that traffic densified the pavement and that this action continued at varying degrees depending on traffic volume and the structural stiffness of the road. The variations in density values with the expected trend are attributed to differences within the pavement surface; however, it is possible that volume changes in the foundation material could result, indirectly, in decompaction of the surfacing material. A comparison between the densities of laboratory specimens and those of field samples shows that a pavement surface generally reached laboratory densities within eight months if its foundation were rigid and after more than eight months if it were flexible. A notable exception to this increase in compaction is found in Sample 2. This surfacing had an early failure which might be attributed to mixture design and construction procedures.

Different values of void content are naturally expected if the method of determining the reference specific gravity is changed. If, for example, the vacuum saturation specific gravity is used in lieu of the THD theoretical maximum specific gravity the void content would usually be higher. It is apparent from the data that unrealistic void contents (minus values) can result if absorption is not taken into account.

An examination of the viscosity values obtained for the recovered asphalt from the road samples shows that there was a rapid increase during the early life of the pavement and that a nearly constant value was reached in about two years. Also the data indicate that the laboratory hardening of the original asphalt caused by exposure to 225°F for two hours was generally attained in the pavement within a period of less than 5 months. The rate of hardening of asphalt in a hot-mix asphaltic concrete pavement appears to be comparable to that of asphalt in a surface treatment. The rates of hardening expressed in the above statements are based on the consideration that a smooth line was determined by the data points. However, the viscosity of the fresh asphalt is increased considerably during the mixing and placing operations in this type of construction. It is believed to be desirable to know more about the hardening of asphalts that occurs during the construction phase of an asphaltic pavement. More emphasis should be placed on minimum mixing and placing temperatures. It should never be necessary to delay field compaction for temperature reduction in the placed material. Instead, the plant mixing temperature should be lowered.

After approximately 18 months of service, the asphalt of pavement No. 3 had the highest consistency with penetration and viscosity values of 15 units and 46.5 megapoises respectively; the asphalt of test pavement No. 11 at this time had the lowest values of 32 units for penetration and 14 megapoises for absolute viscosity. These differences in the hardening of these two asphalts did not correlate with laboratory aging tests, but there was a definite difference in composition as shown in Table 4.

Changes in aggregate gradation resulting from the action of traffic were expected; however, it is not possible from the data obtained to show a correlation between degradation and service time. The variabilities in the pavement mixtures preclude such a correlation. There are indications that some of the larger particles were reduced in size within the first 8 months of service for mixtures containing crushed limestone.

Pavements No. 1 and No. 11 are considered to have given the best service and these pavements have two common factors. They were both placed over old portland cement concrete and were therefore well densified early in their service life. They both were subjected to considerable traffic. Although the number of vehicles passing over No. 11 was much greater than that for No. 1, the average weight of vehicles on No. 1 was much greater. Differences in the asphalt cement used in these pavements did not appear to be a factor within the time period of the study.

If pavements No. 1 and No. 3 are compared, and these contained asphalt from the same manufacturer, one must point out that there was a definite difference noted in performance. Pavement No. 3 showed distress in less than three years. Two differences were observed for these pavements. Pavement No. 1 was placed on an old portland cement pavement whereas No. 3 was placed on a flexible base. Voids as measured by TTI were quite high for pavement No. 3 and low for No. 1, although both were designed for 5.5 percent asphalt cement. This may mean that one aggregate system was more absorptive while the other was low in this respect. The more open system permitted rapid hardening of the asphalt and this was further accelerated by the thinner films of asphalt on the aggregate particles. Traffic, for all practical purposes, was the same on these roads.

The mixtures and designs used in pavements No. 4 and No. 11 were strikingly similar in all cases except one and that was the amount of material passing the No. 200 sieve. The original field specimens contained 12 and 3 percent minus No. 200 materials for pavements No. 4 and No. 11 respectively. Both pavements contained about 4.5 percent asphalt cement, each from a different source, but both sources are known to produce materials of good quality. The real difference in these pavements was in service. No. 4 showed distress in less than three years whereas No. 11 was giving good service after six years. This difference in service is attributed to the difference in effective asphalt as measured by film thickness on the aggregate particles. Pavement No. 11 had much more effective asphalt due to considerably less aggregate surface area.

Pavement No. 5 was placed in two lifts and these lifts were not separated by foil. It was therefore not practical to separate one layer from the other for the usual tests. This pavement has given reasonably good service.

Pavement No. 6 became brittle within less than one year after construction probably due to initial high voids and a mildly absorptive aggregate. For the traffic and materials used this design would probably have given better service with more asphalt and improved compaction during construction.

The shell-sand aggregate used in pavement No. 7 was highly absorptive of asphalt and quite water susceptible. Laboratory tests by TTI indicated that this material and mix design should not normally be used as a surface course on primary roads. The aggregate degraded in service and showed a high wear rate under traffic. Possibly a mix of this type would render improved service if design had called for less material retained on the No. 10 sieve and somewhat more material passing the No. 200 sieve. A further suggestion in connection with this change would be to use a harder asphalt cement and more than that normally indicated by grading and laboratory tests. The shell particles are predominately flat. This results in a much higher surface area per unit weight of this aggregate.

The asphalt cement in pavement No. 8 hardened rapidly during the first four months of its service life possibly due to high voids in the mat as constructed. This pavement was placed on brick, and this generally means poor bond at the brick-pavement interface. Distress was in evidence in about three years. An examination of the aggregate grading shows a considerable quantity of No. 80 and No. 200 and minus No. 200 material. This, of course, calls for more asphalt cement for equal durability if compared to a similar design which was on the coarse side of grading requirements at the fine end of the specification.

Pavement No. 9 located in a hot dry climate was placed as an overlay on an old bituminous pavement. Although the aggregate used was primarily a crushed basalt of rather high specific gravity, TTI laboratory measurements show the material to be absorptive. Reference is made to Appendix B. Construction procedures called for rolling this highly textured mixture with flat wheel and heavy pneumatic rollers but ultimate compaction was not obtained until the pavement was about two years old. During this time interval the road was subjected to heavy traffic (15,000 to 20,000 ADT). This slow rate of reduction in voids was accompanied by a rapid increase in viscosity, some 27 fold in the first fourteen months. Early densification of a mix of this type might be facilitated by keeping the grading on the fine side of specifications and by slightly increasing the asphalt content. Compaction should be effected immediately behind the laydown machine with the mat temperature as high as practical considering possible damage to the binder.

The data in Table 8 and Appendix A show the hot bin material from Pavement No. 10 to be clean and resistant to the action of hot water. This pavement was densified almost to ultimate density during construction as may be noted from Appendix B. Associated with this early densification is a low rate of hardening for the binder. It is interesting to note that this pavement was rolled at a temperature 50°F higher than pavement No. 9. Aggregates in both these pavements were essentially all crushed but that in No. 9 was more textured. It should also be pointed out that the binder used in No. 10 is considered to be one of low temperature susceptibility.

Pavement No. 11 was discussed in connection with No. 4; however, some additional comments should be made. The material was placed and rolled at 300°F in a one-inch lift on an old concrete pavement. Densification was obtained early in the life of the pavement by construction and heavy traffic. After the first two months the binder hardened at a slow rate as may be noted from Appendix B. For the asphalt used normal hardening of the binder during construction falls in the range of three to five fold increase in viscosity; that measured at age two months and shown in Appendix B, as approximately a six fold increase in absolute viscosity.

Pavement No. 12 located in an area of mild climate and high rainfall was placed on an old concrete pavement and densified with steel rollers only. Reference to Tables 2 and 3 and Appendixes A and B reveals nothing particularly unusual about this road. The binder hardened progressively but at a decreasing rate. The greatest change was caused by oxidation during mixing, handling, placing and compacting the mix. The road has given reasonably good service.

Deflectometer Study of Road Samples

This portion of the report is concerned with the initiation of a study on the resistance to repetitive loads of asphaltic concrete paving materials utilized in several Texas highways. In particular, it was the purpose of this study to follow the changes in the fatigue characteristics of these mixtures that occurred during service and also to determine correlations, if any, between laboratory prepared specimens and field cores for the above characteristic.

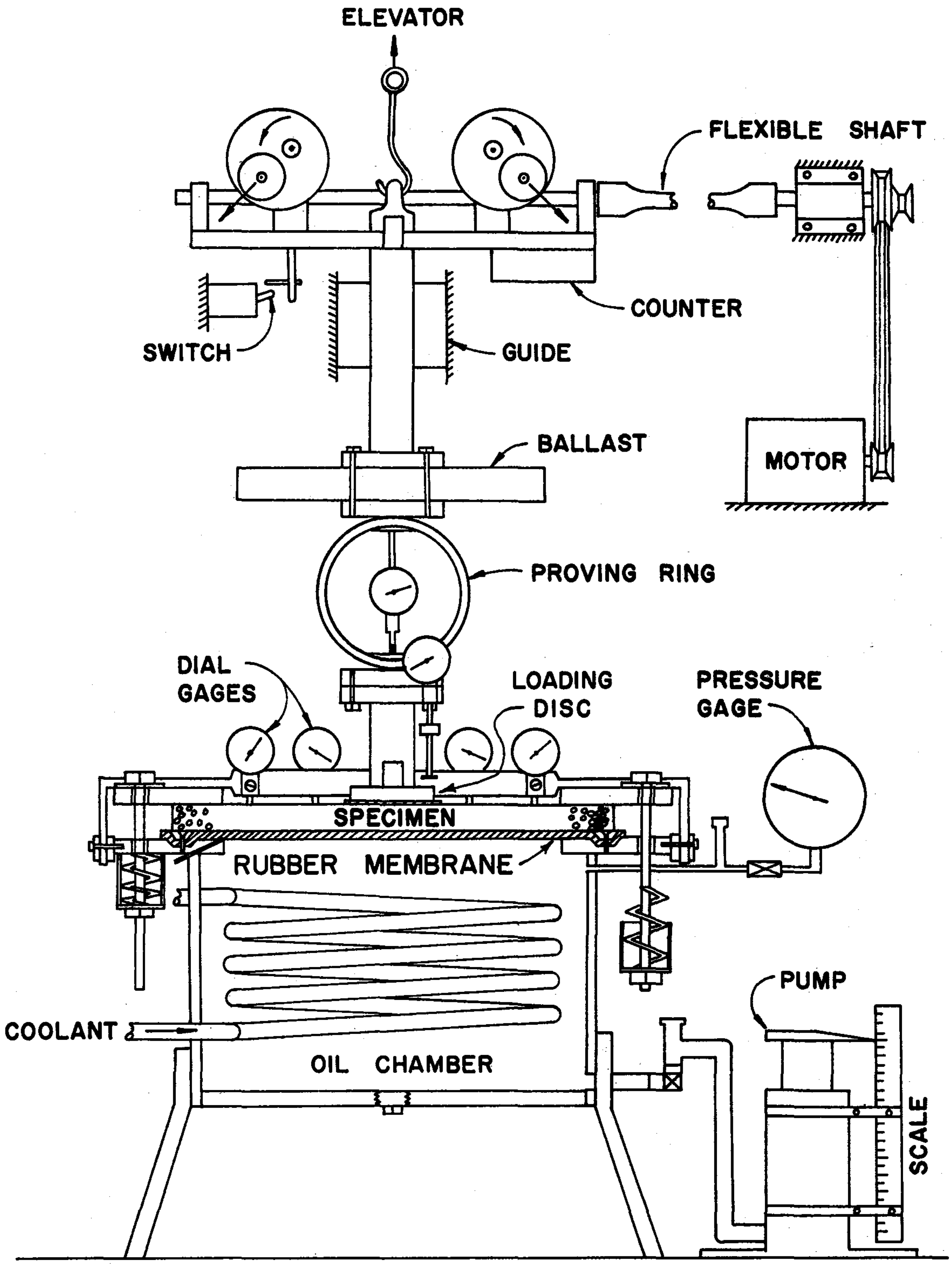
The duration of the study was too short to make possible the achievements of the above objectives; however, the findings obtained are of such importance and interest as to warrant consideration in future research of this type.

The Texas Transportation Institute has developed and evaluated an apparatus for subjecting asphaltic concrete specimens to repetitive loads. This device, called a deflectometer, has been described in a report[18] entitled, "An Apparatus for Laboratory Investigations of Asphaltic Concrete Under Repeated Flexural Deformation," which was submitted to the Texas Highway Department in January, 1962. Subsequently, reports on the deflectometer have been presented to technical societies.[19, 20] Figure 7 shows a schematic diagram of the original deflectometer. The above reports also describe the effects of mixture variables on the resistance to repeated loads of laboratory prepared specimens. The deflectometer was employed to evaluate the fatigue life of actual construction mixtures reported herein. Samples of the asphaltic concrete mixture were taken from the paving machine during construction and from the pavement at a later date so that the composition of two sets of test specimens would be identical, except for the effects of service and time.

Test Roads

Table 9 presents a list of the test sections that were considered for study. It will be noticed that the numbering sequence is a continuation of the parent project mentioned above.

Personnel from the different Texas Highway Department district offices placed aluminum foil on the road immediately ahead of the laydown machine. The placement of foil was done to facilitate the separation of the surfacing material from the base of large diameter core samples to be taken in the



SCHEMATIC DIAGRAM OF DEFLECTOMETER

NO SCALE

Figure 7

TABLE 9

Location of Road Samples for Deflectometer Study

Sample No.	Location
13	Falls County, State 7, East of Marlin
14	Gregg County, Spur 63 in Longview
15	Polk County, U. S. 59, North of Livingston
16A	Galveston County, FM 518, South of U. S. 75
16B	Matagorda County, FM 1095, South of El Maton
17	Caldwell County, U. S. 183, North of Lockhart
18	Brazos County, State 6 at College Station
19	Dallas County, State 114 junction with I.S. 35

future. As mentioned previously, paving mixture was taken from the hopper of the paver; this sampling was done under the direction of the field inspector. The loose paving mixture was sent to the laboratory of the Texas Transportation Institute for standard testing and also for evaluation with the deflectometer.

Tests and Results

In Appendix C are presented data and tests results obtained in the evaluation of the paving mixtures. Mixture composition is shown on the basis of aggregate gradation and asphalt content.

Standard measurements were made on molded specimens for Hveem stability and cohesiometer value. These specimens were compacted by the standard Texas gyratory-shear method, by vibratory-kneading compaction, and by construction and traffic for the cores taken from the pavements. The vibratory-kneading compaction method is described in the above reference[18] and was developed for molding the large specimens (18"D) required for testing with the deflectometer.

The deflectometer test results show average values of applied stress or strain. Since the deflectometer applies an essentially constant load, variations in stress or strain result from differences of specimen thickness and/or loaded area. The calculated values of stress and strain are based on elastic theory, on an assumed value for Poisson's ratio equal to 0.2, and generally calculated for a value of support pressure of 1.5 psi.

Discussion of Results

The listings of aggregate gradations shown in Appendix C indicate that in general the mixtures studied had similar particle size distribution. Figure 8 presents graphically the similarity of gradations of the aggregates obtained from the different road samples.

The data on density and strength of 4-inch diameter specimens prepared by both the standard Texas and vibratory-kneading methods show that differences exist for these two sets of specimens primarily in their strength characteristics. In most cases the specimens molded by vibratory kneading compaction were of higher strength than those formed by the Texas method even though the former were of lower density.

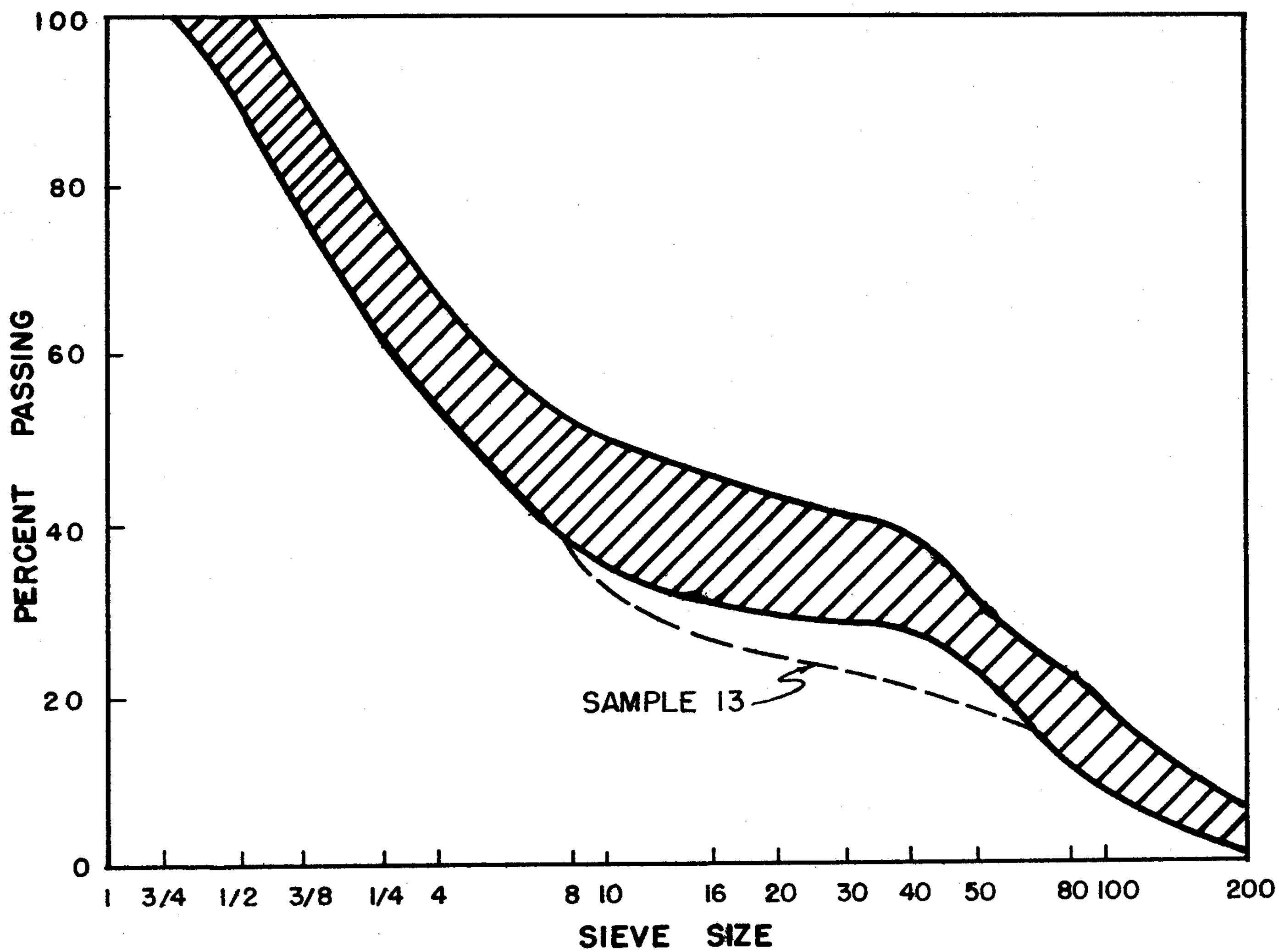


Figure 8 GRADATION BAND FOR ROAD SAMPLES

It is noted that the 18-inch diameter specimens prepared in the laboratory had lower densities than comparable field cores, this is contrary to previous comparisons. A possible explanation for the lower densities of laboratory specimens appears to be that the viscosity of the asphalt at laboratory molding conditions was appreciably higher than at field compaction. The data on the recovered asphalts show that generally the viscosity of the asphalt from the laboratory specimens was approximately twice that from the field cores.

Findings of great interest that were obtained in this study are the relationships shown in Figure 9. In this figure are presented plots of both applied stress and strain for the corresponding number of load repetitions to cause failure in the deflectometer. It should be noted that no attempt has been made to establish unique relationships between stress or strain vs. number of load applications; this is so because of the limited amount of data collected. However, should one connect the points for such mixtures as sample No. 14 or No. 17, it can be seen that these lines are essentially parallel and, perhaps, the relationship shown by these lines also existed for all of the mixtures. This is not too surprising in view of the following considerations:

1. The gradations of the pavement mixtures were quite similar to each other.

2. The increase in stiffness of laboratory specimens brought about by higher asphalt consistency was counteracted by loss of stiffness due to lower degree of compaction than for road cores.

It appears that the strain-repetitions correlation is more reliable than the stress-repetitions comparison. This behavior can be explained on the basis of the elastic theory used to calculate the stress and strain conditions, in that due to stress relaxation, the maximum stress is redistributed. It should be recalled that asphaltic concrete is a viscoelastic material. Also, in the computations for stress or strain the deflections of test specimens do not affect the stress values obtained as much as they do the strain values. That is, the stiffness of a specimen as indicated by the deflections under test has a great influence on the computed strain.

The apparent lack of conformity of the Dallas cores (No. 19) may be explained on the basis that failure was obtained primarily by shear rather than by flexure since these cores were of the greatest thickness, (2 1/8"), and contained the softest asphalt.

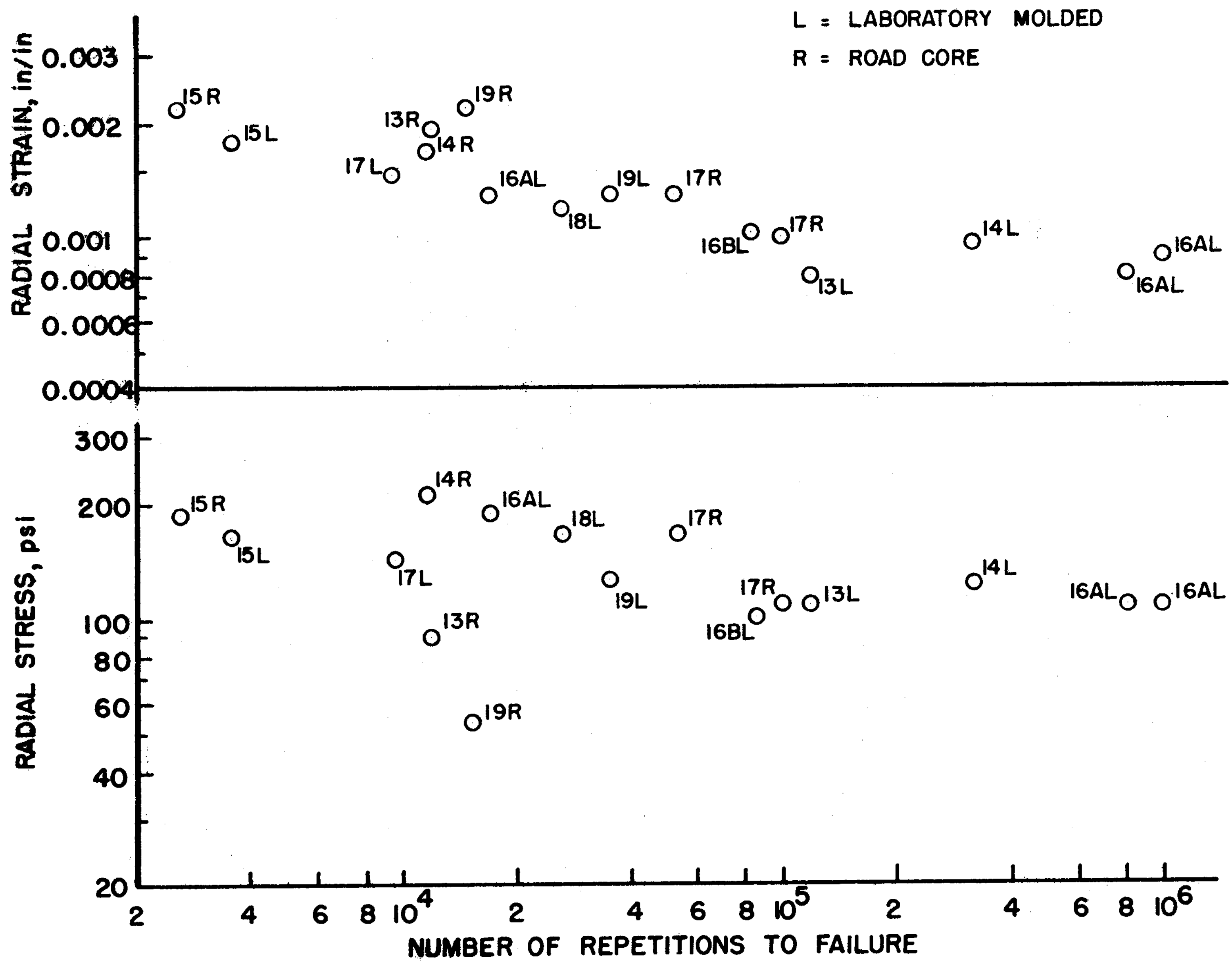


Figure 9 STRESS AND STRAIN VS. NUMBER OF REPETITIONS TO FAILURE

Road Sample No. 17 showed the best comparisons between laboratory prepared specimens and field cores; however, it appears that the pavement mixture might have been over heated.

Conclusions and Recommendations

1. The State's specifications for aggregate gradation on Types C and D generally result in yielding dense graded aggregate blends. However, it is possible to meet specification requirements with an overly gap-graded blend. It is recommended that gradation be expressed in "total percent passing."

2. The sand equivalent test is recommended for use in controlling the cleanliness of aggregates for hot-mix asphaltic concrete. A minimum sand equivalent value of 45 is suggested since the data showed that immersion-compression test requirements were met for such mixtures.

3. The centrifuge kerosene equivalent test was capable of establishing the design-amount of asphalt for the aggregates evaluated.

4. The vacuum-saturation specific gravity of the loose asphaltic-aggregate mixture is recommended as the basis of computation for void content. The use of this specific gravity value is logical since it allows for absorption of asphalt by the aggregate and the data have shown that this value was not exceeded by pavement densities.

5. Laboratory design of asphaltic concrete should include some type of durability test. The immersion-compression test was not investigated for this purpose and at this time not enough information is available to verify the present requirement of 75 percent retained strength.

6. Variabilities in the manufacture of and construction with asphaltic concrete precluded establishing a correlation between laboratory aging of asphalt with performance of pavements. The upper limit of asphalt hardening in a pavement was found to be reached at about 2 years of service.

7. Final voids in an asphaltic concrete mixture have a critical effect

on the rate of hardening taking place in the binder. Rate of hardening of the binder is also directly related to temperature and exposure during mixing, transporting and placing of a mix. Every effort should therefore be made to minimize the mixing temperature, the mix cycle, the handling time, and the delay between the laydown operation and compaction.

8. Field density measurement should be required. It is recommended that field density should be not less than 96 percent of laboratory density based on laboratory samples made from material of the same batch on which field density checks are made. Randomized samples should be taken.

9. In reference to the deflectometer study, the amount of data obtained is too limited to warrant positive conclusions. However, there are indications that because of similar aggregates and gradations a unique relationship existed between applied strain and number of repetitions to result in failure.

   From the deflectometer study data it is apparent that any attempt to duplicate road mixtures must be done completely in the laboratory since the reheating of actual paving mixtures in preparation for compaction hardens the asphalt to a degree not usually found in the pavement during its early life.

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APPENDIX A

Appendix A

Construction Material Evaluation

Sample No. 1c Type C (Binder)

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	97	70	50	36	26	18	5			
THD Mold Spec.	100	87	68	44	26	13	4	4		
TTI Hot Bin	100	88	46	40	23	11	3	6.5	23	2.538
TTI Cold Bin	100	85	52	39	16	8	3	5.3	24	2.647

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.215	2.304		96.1	47		5.8	
	TTI Value	2.246		2.420	92.8	50	323	5.8	
TTI Molded	THD Value					34			
	TTI Value	2.300		2.420	95.0	41	318		81

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	5.45	2.326	2.269	97.5	53.5	373	74
Cold Bin	5.66	2.344	2.252	96.1	42.6	492	57

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 1d Type D

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	100	97	57	41	25	16	5			
THD Mold Spec.	100	98	71	39	24	13	4			
TTI Hot Bin	100	100	75	50	33	18	2	3.1	49	2.622
TTI Cold Bin	100	100	69	48	30	16	3	4.9	27	2.641

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.301	2.380		96.7	44		5.5	
	TTI Value	2.314		2.423	95.4	43.5	135	5.5	
TTI Molded	THD Value					37			
	TTI Value	2.363		2.423	97.5	40	272		77

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	4.99	2.469	2.269	91.8	47	186	75*
Cold Bin	5.62	2.401	2.304	96.1	44	354	84

*Soaking time in excess of 24 hrs.

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 2 Type D

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	100	92	72	43	30	19	7			
THD Mold Spec.	100	98	78	48	37	23	11			
TTI Hot Bin	100	100	71	44	34	18	9	14.8	29	2.640
TTI Cold Bin	100	99	79	41	36	25	10	11.1	21	2.603

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.227	2.354		94.8	38		5.6	
	TTI Value	2.220		2.415	92	46	444	5.4	
TTI Molded	THD Value					41			
	TTI Value	2.239		2.415	92.7	47	174		45

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	6.1	2.370	2.266	95.6	48	391	
Cold Bin	5.5	2.377	2.269	95.4	32	182	50

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 3 Type D

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	100	97	65	40	26	14	3			
THD Mold Spec.	100	97	73	43	31	18	7			
TTI Hot Bin	100	100	76	38	30	18	3	7.6	34	2.632
TTI Cold Bin	100	97	74	43	35	27	3	6.8	26	2.663

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.289	2.351*		97.4	56		5.1	
	TTI Value	2.284		2.406	95	51	282	5.3	
TTI Molded	THD Value					53			
	TTI Value	2.289		2.406	95.2	58	215		56

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	5.2	2.392	2.294	96	53	195	70
Cold Bin	5.4	2.379	2.263	95.1	49	94	71

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 4 Type D-D

AGGREGATE

Combination	3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
	Percent Passing Sieve									
THD Design	100	100	69	45	37	27	7			
THD Mold Spec.	100	100	84	46	37	27	12			
TTI Hot Bin	100	100	86	40	30	18	6	9.2	55	2.702
TTI Cold Bin	100	100	80	47	40	29	11	7.9	52	2.802

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.364	2.437		97	43		4.8	
	TTI Value	2.345		2.487	94.5	43.6	144	4.5	
TTI Molded	THD Value					44			
	TTI Value	2.355		2.487	94.6	51	385		88

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	5.39	2.402	2.370	94.4	42	183	102
Cold Bin	5.44	2.403	2.385	95.1	36	157	92

Appendix A

Construction Material Evaluation

Sample No. 5 Type C (Binder)

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	99	82	52	41	30	12	3			
THD Mold Spec.	100	93	61	40	31	16	5			
TTI Hot Bin	100	80	51	36	29	15	3	4.0	56	2.634
TTI Cold Bin	100	80	47	34	25	9	2	3.2	60	2.682

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.352	2.488		94.4	40		4.3	
	TTI Value	2.367		2.530	93.6	41.6	55	4.2	
TTI Molded	THD Value					48			
	TTI Value	2.431		2.530	96.1	50	175		76

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesiometer	I-C %
Hot Bin	4.9	2.505	2.431	96.9	39	212	96
Cold Bin	4.8	2.512	2.437	96.8	43	334	92

Appendix A

Construction Material Evaluation

Sample No. 6 Type C Mod.

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	98	77	56	40	33	22	4			
THD Mold Spec.	100	87	69	38	32	23	5			
TTI Hot Bin	100	98	61	44	34	24	4	5.0	42	2.661
TTI Cold Bin	100	78	60	37	24	15	2	6.6	37	2.681

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi- ometer	Asp. content	I-C %
THD Molded	THD Value	2.348	2.438		96.5	47		5.1	
	TTI Value	2.385		2.452	97.4	44	75	5.0	
TTI Molded	THD Value					42			
	TTI Value	2.390		2.452	97.5	43	272		96

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi- ometer	I-C %
Hot Bin	4.6	2.480	2.369	95.6	45	165	62
Cold Bin	5.2	2.465	2.446	99.1	20	234	65

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 7 Type C Mod.

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -200	S.E.	Vac.Sat. Sp. Gr.
THD Design	99	86	56	38	29	10	7			
THD Mold Spec.	100	94	77	57	50	18	4			
TTI Hot Bin	98	82	48	31	23	9	3	9.5	23	2.651
TTI Cold Bin	86	78	57	46	39	16	2	7.9	24	2.634

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp.Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.174	2.253		96.5	50		7.5	
	TTI Value	2.169		2.341	92.7	46	375	7.6	
TTI Molded	THD Value					43			
	TTI Value	2.182		2.341	93.2	48	390		72

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C. K. E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	6.9	2.335	2.249	96.3	44	532	54
Cold Bin	7.0	2.378	2.185	92.0	48	397	37

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 8 Type C

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	98	74	50	35	23	19	6			
THD Mold Spec.	100	74	55	42	28	31	8			
TTI Hot Bin	100	81	55	41	31	34	8	7.6	37	2.664
TTI Cold Bin	100	76	54	48	41	30	6	5.7	24	2.653

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.376	2.430		97.8	53		4.8	
	TTI Value	2.397		2.455	97.6	33	425	4.7	
TTI Molded	THD Value					42			
	TTI Value	2.412		2.455	98.3	36	395		91

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	5.3	2.473	2.378	97.6	50	296	93
Cold Bin	4.9	2.436	2.314	95	46	175	95

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 9 Type D

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	100	100	61	38	22	9	3			
THD Mold Spec.	100	99	63	41	28	12	4			
TTI Hot Bin	100	100	74	42	31	13	4	3.5	30	2.750
TTI Cold Bin	100	100	76	42	24	12	4	4.3	32	2.812

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.398	2.501		95.8	49		4.7	
	TTI Value	2.388		2.571	92.8	41	174	5.17	
TTI Molded	THD Value					46			
	TTI Value	2.375		2.571	92.5	49	365		49

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	4.6	2.482	2.420	97.5	39	157	33
Cold Bin	4.8	2.591	2.480	95.8	46	273	64

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 10 Type D

AGGREGATE

Combination	3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
	Percent Passing Sieve									
THD Design	100	98	61	41	27	15	3			
THD Mold Spec.	100	91	73	47	31	18	5			
TTI Hot Bin	100	100	60	39	26	14	4	6.1	53	2.611
TTI Cold Bin	100	100	74	40	33	25	5	6.3	35	2.632

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.315	2.386		97	48		5.5	
	TTI Value	2.315		2.420	95.6	45	229	5.3	
TTI Molded	THD Value					41			
	TTI Value	2.332		2.420	96.4	40	135		72

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	5.6	2.448	2.380	97.2	38	204	105
Cold Bin	4.8	2.471	2.349	95.1	44	142	54

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 11 Type C

AGGREGATE

Combination	Percent Passing Sieve 3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
THD Design	100	75	57	43	32	11	2			
THD Mold Spec.	100	91	65	45	31	15	13			
TTI Hot Bin										
TTI Cold Bin	99	84	57	42	26	11	3	6.0	43	2.694

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.419	2.474		98	51		4.4	
	TTI Value								
TTI Molded	THD Value					56			
	TTI Value	2.360		2.492		56	318		75

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin							
Cold Bin	4.8	2.514	2.438	97	28	202	93

Appendix A, (Cont.)

Construction Material Evaluation

Sample No. 12 Type C

AGGREGATE

Combination	3/4"	1/2"	1/4"	#10	#40	#80	#200	Washed -#200	S.E.	Vac. Sat. Sp. Gr.
	Percent Passing Sieve									
THD Design	100	80	51	37	24	16	8			
THD Mold Spec.	100	92	64	41	39	27	5			
TTI Hot Bin	100	84	60	37	34	22	2	2.3	42	2.643
TTI Cold Bin	100	85	54	41	39	15	2	3.2	32	2.627

Construction Mixture

		Spec. Density	Theor. Sp.Gr.	Vac.Sat. Sp. Gr.	Rel. Density	Hveem Stab.	Cohesi-ometer	Asp. content	I-C %
THD Molded	THD Value	2.288	2.426		94.3	39		4.8	
	TTI Value	2.288		2.444	93.6	42	48	4.8	
TTI Molded	THD Value					36			
	TTI Value	2.289		2.444	93.6	36	90		92

TTI Laboratory Mixture

(one grade and source of asphalt)

Agg.	Asp. Content by C.K.E.	Vac. Sat. Sp. Gr.	Spec. Density	Rel. Density	Hveem Stab.	Cohesi-ometer	I-C %
Hot Bin	4.7	2.506	2.268	90.5	44	75	98
Cold Bin	4.2	2.485	2.280	91.8	47	79	120

APPENDIX B

Appendix B

Road Specimen Evaluation

Sample 1c Type C (Binder)

Compacted Densities

Age, mos.		Lab. Spec.	9	20	34	45
Density	THD	2.215				
	TTI	2.246	2.251	2.239	2.263	2.233
Voids	THD		2.4	3.0	1.6	2.2
	TTI		7.0	7.5	6.4	7.7

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	16	23	29
Sp. Gr.	2.420	2.365	2.353	2.354

Asphalt Consistencies

Age, mos.	Original	9	20	34	45
Content	5.8		6.9	6.9	7.1
Pen.		35.8	23	25	21
Viscosity	.56	9.4	18.5	19.2*	19.8*
A.I.	6.43	1.79	2.02	1.38	1.40

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	96.6	70	49.8	36.5	26.2	19.2	4.8
THD Specimen	100	86.9	62.4	44.5	25.8	12.6	3.5
Road Age, mos.							
20	100	95	76.7	50.0	27.9	13.3	4.6
34	100	94.6	74.9	48.4	24.6	11.5	2.7
45	100	97	79.8	54.3	30.0	16.5	5.8

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 1d Type D

Compacted Densities

Age, mos.		Lab. Spec.	8	19	33	44
Density	THD	2.301				
	TTI	2.314	2.337	2.339	2.337	2.377
Voids	THD		1.8	1.7	1.8	.2
	TTI		3.7	3.6	3.7	2.1

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	14	20	27	32
Sp. Gr.	2.423	2.421	2.462	2.443	2.411

Asphalt Consistencies

Age, mos.	Original	8	19	33	44
Content	5.5	5.2	5.2	5.3	5.1
Pen.		37.2	27	27.0	28
Viscosity	.56	10.5	12.5	19.2*	12.1*
A.I.	6.43	1.56	1.60	1.38	1.52

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	97	57.0	41.0	25.0	15.5	5.0
THD Specimen	100	98	71.0	39.0	24.0	13.0	4.0
Road Age, mos.							
8		100	67.0	36.0	22.0	8.0	1.0
19		100	64.0	35.0	22.9	13.6	4.5
33		100	63.0	34.8	22.2	11.4	2.8
44		100	66.5	36.9	24.3	15.0	4.8

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 2 Type D

Compacted Densities

Age, mos.		Lab. Spec.	5	19	33
Density	THD	2.227			
	TTI	2.220	2.037	2.093	2.100
Voids	THD		13.6	11.1	10.7
	TTI		12.8	10.3	9.8

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	15	16	22	29
Sp. Gr.	2.332	2.425	2.395	2.407	2.414

Asphalt Consistencies

Age, mos.	Original	5	19	33
Content	5.5	5.3	5.3	
Pen.		31.5	20	20
Viscosity	1.10	18.5	28.5	34.5*
A.I.	6.09	1.40	1.09	1.25

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	92	72	43	30	19	7
THD Specimen	100	98	78	48	37	23	11
Road Age, mos.							
5		100	79	48	37	19	5
19		100	78	48	37	21	10
33		100	80	48	38	21	10

Appendix B

Road Specimen Evaluation

Sample 3 Type D

Mixture — Compacted Densities

Age, mos.		Lab. Spec.	8	20	34
Density	THD	2.289			
	TTI	2.284	2.258	2.263	2.273
Voids	THD		0	-0.9	-1.0
	TTI		7.1	6.8	6.5

Vacuum-Saturation Sp. Gr. of Stored Construction Mixture

Age, mos.	0	14	15	21
Sp. Gr.	2.407	2.449	2.480	2.403

Asphalt — Consistencies

Age, mos.	Original	8	20	34
Content	5.5	5.2	5.6	5.2
Pen.		22.	15.	15.
Viscosity	.86	27.5	46.5	49.*
A. I.	6.74	1.37	1.09	1.06

*Film thickness greater than 10 microns

Aggregate — Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	97	65	40	26	14	3
THD Specimen	100	97	73	43	31	18	7
Road Age, mos.							
8		100	75	42	31	14	5
20		100	78.3	46	33	19	7
34		100	71.2	41.8	29.5	17.1	5.3

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 4 Type D-D

Compacted Densities

Age, mos.		Lab. Spec.	7	31
Density	THD	2.364		
	TTI	2.345	2.422	2.398
Voids	THD		0.6	1.6
	TTI		2.6	3.6

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	14	15	21	28
Sp. Gr.	2.487	2.461	2.492	2.475	2.490

Asphalt Consistencies

Age, mos.	Original	7	31
Content	4.7	4.4	4.65
Pen.		34.8	28.
Viscosity	1.19	13.8	17.*
A.I.	5.04	1.34	1.29

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design		100	69	45	37	27	7
THD Specimen		100	84	46	37	27	12
Road Age, mos.							
7		100	83	50	37	25	11
31		100	85	46	36	25	11

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 5 Type C (Binder)*

Compacted Densities

Age, mos.		Lab. Spec.	7	17	31	43
Density	THD	2.352				
	TTI	2.367	2.332	2.388	2.393	2.417
Voids	THD		6.4	4.0	4.0	3.1
	TTI		7.7	5.5	5.4	4.5

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	14	15	21
Sp. Gr.	2.530	2.463	2.505	2.493

Asphalt Consistencies

Age, mos.	Original	7	17	31	43
Content	4.3	4.7		4.75	4.7
Pen.		32.3	24	25.	
Viscosity	1.10	17.5	19.0	23.5*	20.5*
A.I.	8.00	1.71	1.76	1.57	1.52

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	99	82	52	41	30	12	3
THD Specimen	100	93	61	40	31	16	5
Road Age, mos.							
7	100	91	59	39	29	15	5
31	100	86	56	37	27	16	7
43	100	86.1	60.6	37.6	29.1	16.3	5

*Road sample a composite of both binder and surface courses.

Appendix B

Road Specimen Evaluation

Sample 6 Type C Mod.

Mixture — Compacted Densities

Age, mos.		Lab. Spec.	7	19	33	43
Density	THD	2.385				
	TTI	2.380	2.312	2.395	2.398	2.417
Voids	THD		5.2	1.8	1.6	1.0
	TTI		5.7	2.3	2.2	1.5

Vacuum-Saturation Sp. Gr. of Stored Construction Mixture

Age, mos.	0	14	15	21	33
Sp. Gr.	2.452	2.439	2.475	2.448	2.472

Asphalt — Consistencies

Age, mos.	Original	7	19	33	43
Content	5.1	5.04	5.3	4.45	4.7
Pen.		40.8	29.	36.	30.
Viscosity	.74	9.7	19.5	12.6*	13.3*
A. I.	4.80	1.23	1.14	1.21	1.30

Aggregate — Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	97.6	76.9	55.7	40.2	32.8	22.1	4.1
THD Specimen	100.0	87.0	69.	38	32	23	5
Road Age, mos.							
7	100.0	85.	65	35	30.	21	5
19	100.0	81.6	63.8	38.7	30.	20	4
33	100.0	80.	60.4	36.6	28.5	19.4	4
43	100.0	80.8	63.1	36.8	29.1	20.2	4.4

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 7 Type C Mod.

Compacted Densities

Age, mos.		Lab. Spec.	8	18	30	44
Density	THD	2.174				
	TTI	2.169	2.120	2.158	2.185	2.178
Voids	THD		5.8	4.2	2.8	3.3
	TTI		9.3	7.8	6.6	7.0

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	12	13	19
Sp. Gr.	2.340	2.322	2.345	2.362

Asphalt Consistencies

Age, mos.	Original				
Content	7.5	7.5	8.1	7.9	7.7
Pen.		32.2	26.	26.	
Viscosity	1.08	14.8*	18.8	22.5*	25.1*
A.I.	5.28	1.91	1.37	1.29	1.45

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	99	86	56	38	29	10	7
THD Specimen	100	94	77	57	50	18	4
Road Age, mos.							
8	100	97	83	62	47	27	5
18	100	98	85	64	50	18	5
30	100	99.5	81	59	44	5	4
44	100	97	83.2	61.6	48.1	21.2	6.2

Appendix B, (Cont.)

Road Specimen Evaluation

Sample 8 Type C

Compacted Densities

Age, mos.		Lab. Spec.	4	16	30
Density	THD	2.376			
	TTI	2.397	2.344	2.366	2.372
Voids	THD		3.5	2.6	2.3
	TTI		4.3	3.5	3.4

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	10	11	16	28
Sp. Gr.	2.455	2.455	2.462	2.456	2.494

Asphalt Consistencies

Age, mos.	Original	4	16	30
Content	4.8	5.7	5.6	5.1
Pen.		27.5	20.	25.
Viscosity	1.16	19.5*	25.5	25.5*
A.I.	5.21	1.33	1.20	1.13

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	98	74	50	35	23	19	6
THD Specimen	100	74	55	42	28	21	8
Road Age, mos.							
4	100	85	65	42	27	21	8
16	100	91.1	62.7	43.6	29.9	20	3.8
30	100	83.1	59.3	42.7	28.2	21	7.9

Appendix B

Road Specimen Evaluation

Sample 9 Type D

Compacted Densities

Age, mos.		Lab. Spec.	14	26
Density	THD			
	TTI	2.388	2.424	2.489
Voids	THD		2.8	0.3
	TTI		6.6	3.0

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	8	10	16
Sp. Gr.	2.571	2.534	2.497	2.492

Asphalt Consistencies

Age, mos.	Original	14	26
Content	5.0	5.2	5.2
Pen.		20.	24.
Viscosity	.96	26.7	23.0*
A.I.	6.25	1.16	1.33

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	99.8	60.8	38	22.2	9.2	3.3
THD Specimen	100	99.4	63.4	40.6	28.	11.8	3.6
Road Age, mos.							
14	100	100.0	76	43	29	14	4.
26	100	100.0	77	42	26	13	4.5

Appendix B

Road Specimen Evaluation

Sample 10 Type D

Compacted Densities

Age, mos.		Lab. Spec.	2	14
Density	THD	2.315		
	TTI	2.315	2.354	2.352
Voids	THD		1.5	1.5
	TTI		2.7	2.7

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	8	9	14
Sp. Gr.	2.420	2.420	2.439	2.443

Asphalt Consistencies

Age, mos.	Original	2	10	14
Content	5.5	5.38		5.6
Pen.		37.7	37.7	28.
Viscosity	.88	10.9*		15.5
A.I.	4.66	1.42		1.16

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	98	61	41	27	15	3
THD Specimen	100	91	73	47	31	18	5
Road Age, mos.							
7	100	100	76	45	31	15	5
14	100	100	73	45	31	17	5

Appendix B

Road Specimen Evaluation

Sample 11 Type C

Compacted Densities

Age, mos.		Lab. Spec.	2	16	27	38	45	50	50
Density	THD	2.432							
	TTI	2.380	2.417	2.451	2.448	2.4472		2.432	
Voids	THD		2.4	0.8	0.7	0.8		1.6	
	TTI		3.0	1.5	1.7	1.6		2.5	

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	8	10	15	27
Sp. Gr.	2.492	2.473	2.488	2.490	2.496

Asphalt Consistencies

Age, mos.	Original	2	16	27	38	45	50
Content	4.4	4.29	4.95	4.4	4.2	4.6	4.5
Pen.		38.8	32.2	30.		24.	
Viscosity	1.95	13.5*	13.7	17.2*	15.7*	19.3	
A.I.	5.08	1.67	1.53	1.40*	1.59*	1.33	

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100.0	75	57	43	32	11	2
THD Specimen	100.0	91	65	45	31	15	3
Road Age, mos.							
2	100.0	87	53	32	17	3	1
16	100.0	68.3	52.0	37.5	23.0	12.5	4.0
27	100.0	93.1	57.4	38.7	25.2	11.3	4.1
38	100.0	93.9	58.7	38.1	25.1	11.9	4.9
50	100.0	92.8	56.2	38.0	24.9	12.0	5.5

Appendix B

Road Specimen Evaluation

Sample 12 Type C

Compacted Densities

Age, mos.		Lab. Spec.	7	10	23	41
Density	THD					
	TTI	2.288	2.353	2.313	2.320	2.325
Voids	THD					
	TTI		3.8	5.5	5.2	5.0

Vacuum-Saturation Sp. Gr. of Stored Construction Mixtures

Age, mos.	0	6	8	13	25
Sp. Gr.	2.444	2.452	2.454	2.458	2.436

Asphalt Consistencies

Age, mos.	Original	7	10	23	41
Content	4.8	4.9	4.9	4.9	4.8
Pen.		39.	30.	29.	22.
Viscosity		10.2*	15.4	19.0*	22.9
A.I.		2.28	1.64	1.76	1.57

* Film thickness greater than 10 microns

Aggregate Gradation, percent passing

Sieve	3/4"	1/2"	1/4"	#10	#40	#80	#200
THD Design	100	80	51	37	24	16	8
THD Specimen	100	92	64	41	38	27	5
Road Age, mos.							
7	100	90	57	39	36	13	1
23	100	92.4	60	38.5	36	25	4.5
41	100	88.4	56.8	36.5	34.4	24.8	4.6

APPENDIX C

Appendix C

DATA FROM DEFLECTOMETER STUDY

Sample No. 13 County Falls Road State 7 (E. of Marlin)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18" D		100	73	32	21	14	5	4.0
Field Core - 18" D		100	72	32	21	12	5	4.1

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesiometer gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.398	2.452	97.8	46	242		
Vib.-Knead-4"D	2.325	2.452	95.0	45	281		
Vib.-Knead-18"D	2.282	2.452	93.2			25.5	16.4
Field Core - Age 1 mos.							
18"D	2.324	2.452	95.0			39.0	6.10
4"D from 18"D	2.308	2.452	94.2	17	182		

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (2 Spec.)	118	105	7.70
Field Core (3 Spec.)	12	87	19.0

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 14 County Gregg Road Spur 63 (Longview)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18" D		100	78	46	34	15	6	5.3
Field Core - 18" D		100	75	44	35	15	7	5.3

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesio-meter gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.410			46	334		
Vib.-Knead-4"D	2.400			49	478		
Vib.-Knead-18"D	2.306					28	17.6
Field Core - Age 8 mos.							
18"D	2.402					43	7.68
4"D from 18"D							

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (3 Spec.)	317	120	9.30
Field Core (3 Spec.)	11.8	203	16.3

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 15 County Polk Road U.S. 59 (N. of Livingston)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18" D		100	80	37	32	14	4	5.0
Field Core - 18" D		100	70	36	32	15	5	5.3

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesiometer gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.345			26	294		
Vib.-Knead-4"D	2.340			30	443		
Vib.-Knead-18"D	2.237					39.5	9.10
Field Core - Age 1 mos.							
18"D	2.328					47.6	6.40
4"D from 18"D							

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (2 Spec.)	3.6	160	17.6
Field Core (1 Spec.)	2.6	184	21.6

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 16A County Galveston Road FM 518 (S. of U.S. 75)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18" D		100	76	35	22	17	2	4.9
Field Core - 18" D								

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesiometer gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.372	2.449	96.6	44	208		
Vib.-Knead-4"D	2.305	2.449	94.0	38	181		
Vib.-Knead-18"D	2.271	2.449	92.8			26	13.5
Field Core - Age ____ mos.							
18"D							
4"D from 18"D							

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (6 Spec.)	(17) (800) (1,000)	(185) (105) (105)	(12.5) (7.8) (8.7)
Field Core (____ Spec.)			

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 16B County Matagorda Road FM 1095 (S. of El Maton)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18" D	100	92	69	47	32	23	7	5.2
Field Core - 18" D								

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesiometer gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.315	2.414	96.0	45	173		
Vib.-Knead-4"D	2.243	2.414	93.1	54	148	28	12.5
Vib.-Knead-18"D	2.213	2.414	91.7				
Field Core - Age ___ mos.							
18"D							
4"D from 18"D							

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (3 Spec.)	85.0	98.0	9.0
Field Core (___ Spec.)			

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 17 **County** Caldwell **Road** U.S. 183 (N. of Lockhart)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve							Asphalt Content Percent
	3/4	1/2	1/4	#10	#40	#80	#200	
Lab Mold - 18" D		100	72	47	37	15	3	5.2
Field Core - 18" D		100	75	50	38	15	3	5.3

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesiometer gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.238			52	160		
Vib.-Knead-4"D	2.116			41	133		
Vib.-Knead-18"D	2.077					28	15.4
Field Core - Age 11 mos.							
18"D	2.162					27.5	19.3
4"D from 18"D	2.158						

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $\times 10^{-3}$	Radial Stress, S_R psi	Radial Strain $\times 10^{4}$
Lab Mold (3 Spec.)	9.6	140	14.1
Field Core (3 Spec.)	(52) (100)	(161) (106)	(12.6) (9.7)

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 18 County Brazos Road State 6 (College Station)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18"D		100	76	36	30	20	6	4.7
Field Core - 18"D								

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesio-meter gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°V Megapoises
Lab Mold							
Standard THD-4"D	2.414	2.450	98.4	28	258		
Vib.-Knead-4"D	2.413	2.450	98.4	37	306		
Vib.-Knead-18"D	2.310	2.450	94.4			26	15.3
Field Core - Age 3 mos.							
18"D	2.387	2.450	97.6				
4"D from 18"D							

DEFLECTOMETER TEST RESULTS

	Reps. To Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (2 Spec.)	26.5	165	11.9
Field Core (Spec.)	Too weak to test		

Appendix C, (Cont.)

DATA FROM DEFLECTOMETER STUDY

Sample No. 19 County Dallas Road State 114 (Dallas)

MIXTURE COMPOSITION

	Aggregate Gradation Percent Passing on Sieve 3/4	1/2	1/4	#10	#40	#80	#200	Asphalt Content Percent
Lab Mold - 18"D	100	90	58	32	27	10	1	4.8
Field Core - 18"D	100	87	62	34	28	12	1	5.1

PHYSICAL PROPERTIES

	Spec. Density gm/cc	Vac.-Sat. Sp. Gr. gm/cc	Rel. Density %	Hveem Stab. %	Cohesio-meter gm/w/3"H	Recovered Asphalt Pen. 77°F	Recovered Asphalt Visc., 77°F Megapoises
Lab Mold							
Standard THD-4"D	2.391			43	206		
Vib.-Knead-4"D	2.389			45	251		
Vib.-Knead-18"D	2.327			37	245	17	33.0
Field Core - Age 2 mos.							
18"D	2.400					52	3.7
4"D from 18"D	2.386			26	242		

DEFLECTOMETER TEST RESULTS

	Reps. to Fail $x10^{-3}$	Radial Stress, S_R psi	Radial Strain $x10^4$
Lab Mold (3 Spec.)	35	122	13.9
Field Core (2 Spec.)	15	52	21.1

PUBLICATIONS

Project 2-8-57-3
Road Tests on Hot-Mix Asphaltic Concrete

1. Research Report 3-1, "A Laboratory Study of the Operator Variable on Molding Procedure and Mix Design Variations in Hot-Mix Asphaltic Concrete" by Bob M. Gallaway and R. A. Jimenez.

2. Research Report 3-2, "A Laboratory Study of Oven Curing Loose and Compacted Asphaltic Concrete Mixtures" by R. A. Jimenez and Bob M. Gallaway.

3. Research Report 3-3, "Road and Laboratory Tests on Hot-Mix Asphaltic Concrete" by R. A. Jimenez and Bob M. Gallaway.