Cutback Asphalt Patching Mixtures

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Asphalt patching mixtures should be satisfactory for use at all seasons of the year and should have suitable stability if used immediately after mixing or after storage for long periods of time. The additional requirements are that local materials must be used wherever possible and the mixture should be satisfactory for preparing by the maintenance forces in the districts.

In the study reported, one aggregate was chosen for all phases of the project. This material was a hard dolomitic limestone.

Two methods of curing were used for all cutback. The first method was that of curing the prepared mixes in ovens at a constant temperature of 140 F. The second method of curing was in lengths of stovepipe placed upright on screen wire on the roof of the laboratory and protected from rain. Thus, the mixture was exposed to the air at both ends of the stovepipe.

Series of mixes using both MC cutter stocks and RC cutter stocks were used. The rate of curing of the MC cutbacks indicated that these mixtures could be stored for long periods of time and still be used, but they would cure so slowly in a stockpile that they would not be useable for some time after mixing. Mixes using the RC cutter stocks cured too rapidly.

A Marshall stability of 500 lb was chosen as the desirable minimum stability satisfactory for patching.

A comparison of the distillation curves of RC cutter stocks and MC cutter stocks indicated that the ideal cutter stock would be one having the characteristics of the lighter ends of an RC with the heavy ends of an MC. A blend of 40 percent of RC, 50 percent MC and 10 percent SC cutter stocks produced a distillation curve approximating the desired characteristics.

Patching mixtures prepared with blended cutback gave the desired results. From 30 to 40 percent of the volatile matter was lost during mixing and storing. At this point the Marshall stabilities ranged between 400 and 500 lb. Beyond this point the rate of curing was slow, thus providing a long period of storage where needed.

A tentative specification for cutback asphaltic patching materials was derived from the study. The specification varies from the usual specification in several important points and is very restrictive. Field use will be required for improvement of the specification.

● THIS paper represents some of the results of a research project at the University of Arkansas sponsored jointly by the Arkansas Highway Department and the United States Bureau of Public Roads. The work was under the supervision of the Civil Engineering Department. The laboratory equipment was furnished by the three asphalt producers in Arkansas.

OBJECTIVE

This work was undertaken with the view of producing a cutback asphalt mixture for use in patching highways. The mixture was to meet four conditions:

1. It must be suitable for road mixing or plant mixing by the maintenance forces in the field.

2. Local materials were to be used wherever possible.
3. The mixture should be suitable for use at all times of the year.
4. The mixture must have suitable stability for use soon after mixing yet it must retain enough workability so that it can be used after long periods of storage.

Some of the cutback asphalt presently produced can be used for patching mixtures that will meet some of these conditions—for instance—any of the less viscous cutbacks can be used for road mix under the usual conditions. Also local materials are commonly used for this type of work. The fourth condition imposes the greatest limitation. If early stabilities are to be obtained the cutback should be of the RC type so that the volatile matter will evaporate rapidly, but with the RC cutbacks all of the volatile material evaporates rapidly thus reducing the length of storage that is possible. If MC cutbacks are used the rate of curing is very slow and the material must be aerated or stored for some time before it can be used satisfactorily.

METHODS OF CURING

Two methods of curing the mixtures were used. In the first method small batches of the mixture were prepared and cured at a constant temperature in electric ovens. The temperature chosen for curing was 140 F. These batches were removed from the oven at intervals and weighed. When a predetermined amount of the volatile matter had been driven off, the specimens were molded and tested. The second method of

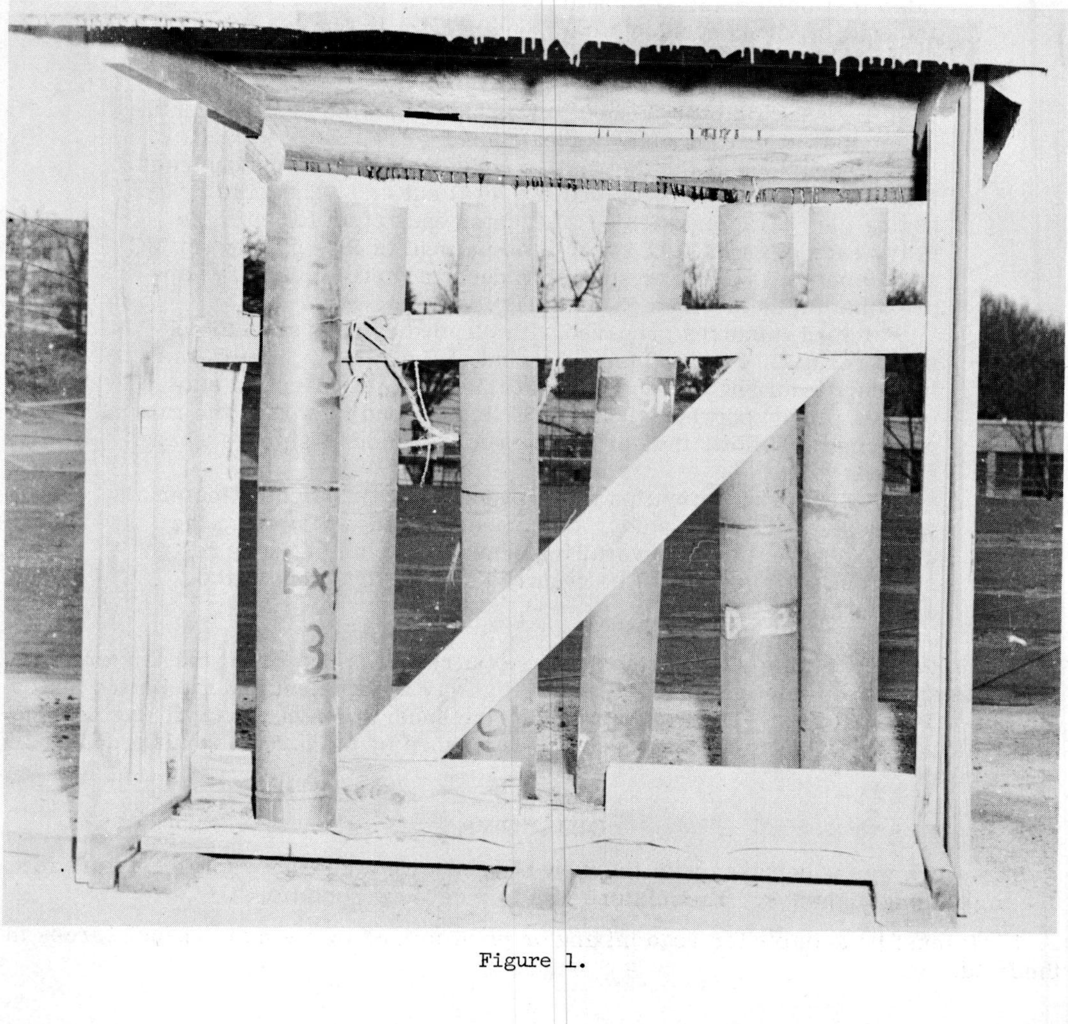

Figure 1.

curing the mixtures was to place these mixtures in lengths of stovepipe placed on the roof of the laboratory. The stovepipes were 6 in. in diameter and 26 in. high. In some cases double lengths of stovepipe were fitted together for providing more capacity. These stovepipes were placed on a coarse screen wire placed 2 in. above the roof. A shelter was placed over the top of the stovepipes to prevent rain from entering. This roof was approximately 18 in. above the top of the stovepipe. Figure 1 shows these stovepipes.

TABLE 1

PROPERTIES OF AGGREGATE USED IN BITUMINOUS MIXTURES

Type	Crushed Limestone
Aggregate Gradation:	
Screen	Percent Passing
1/2 in.	100.0
3/8 in.	76.0
No. 4	55.0
No. 10	40.0
No. 40	25.5
No. 100	16.5
No. 200	2.5
Los Angeles Abrasion	26%
Bulk Specific Gravity of Above Gradation	2.58
Absorption of Coarse Aggregate in 24 Hours	2.0%

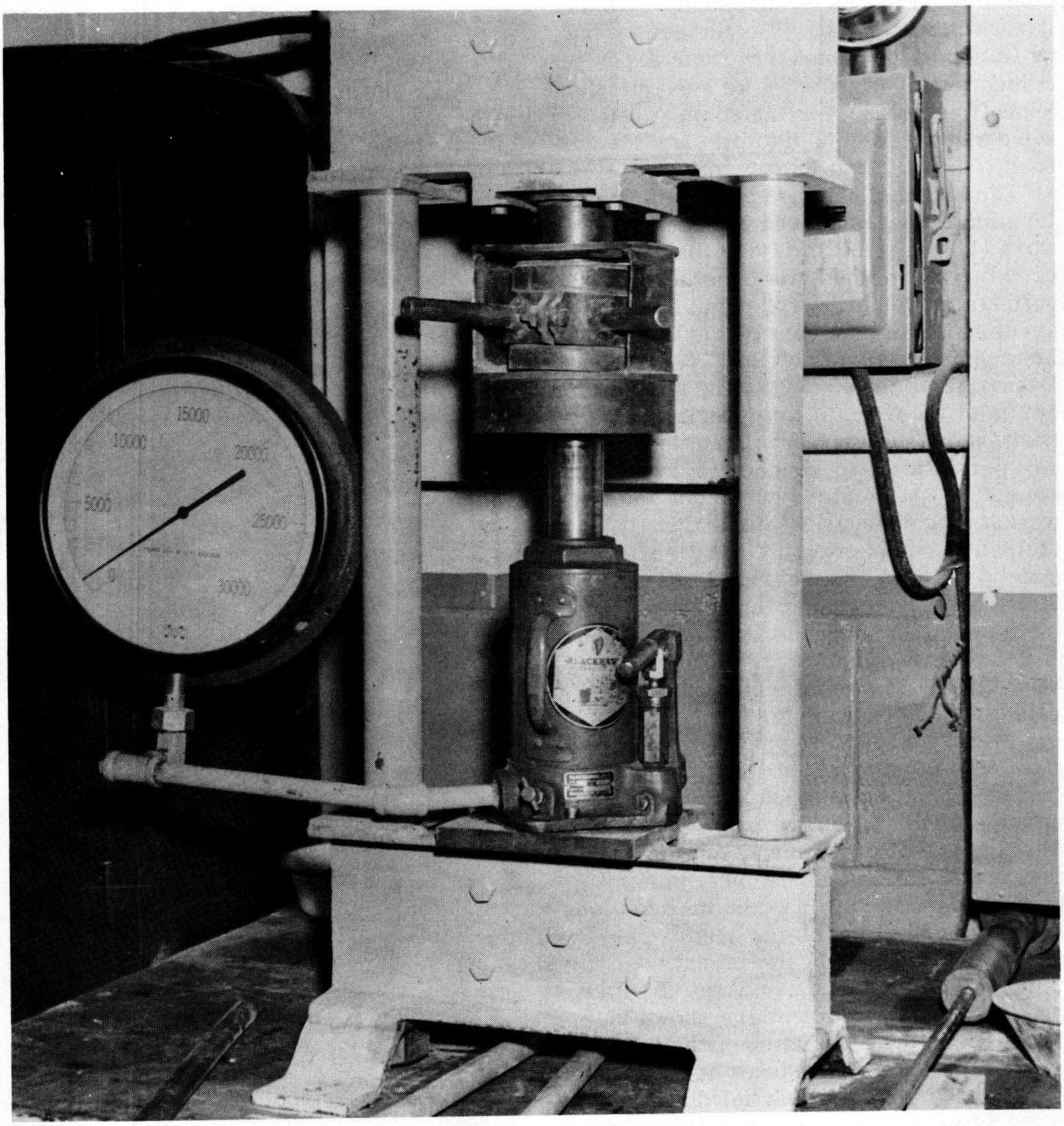

Figure 2.

One aggregate was chosen for use throughout the first phase of this work. This aggregate was a hard dolomitic limestone produced locally. Table 1 gives the properties and gradations of this aggregate. The gradation chosen for use in most of this work was one that gave very nearly the maximum dry rodded density for the material of one-half inch maximum size. The gradation producing the maximum density for the coarse aggregate was determined by plotting the densities of various mixtures on a triaxial chart. After the maximum density of the coarse aggregate was determined the next smaller size aggregate was added in small increments until the dry rodded density began to decrease. The gradation varies from this maximum density gradation only in very minor respects. The percentage of the different materials was adjusted to produce a gradation having a smooth curve. The maximum size coarse aggregate was chosen as one-half inch because many of the patches would be feather edged.

All of the asphalt materials used were commercial products furnished by the producers in Arkansas. The cutbacks were prepared in the laboratory from asphalt cements and solvents. The solvents and asphalt cements from the same producer were always combined to produce the cutback.

The Marshall Method of stability determinations was chosen for use in this work (1). A stability of 500 lb as measured by this method was considered as satisfactory stability for patching. The specimens were molded by the Gyratory Method as developed by the Texas Highway Department (see Fig. 2). The kneading action of the Gyratory compaction produced more uniform specimens especially as the mixtures approached the cured out point. As the mixture cured out and the workability decreased, the Marshall Method of compaction did not give as good specimens. In many cases there were voids and often crushed aggregate in specimens compacted by the Marshall Method. All of the specimens were tested for stability at 140 F. The specimens were raised to this temperature by immersion in a water bath. This part of the investigation was carried out to determine the curing characteristics of MC cutter stocks under the laboratory conditions. The MC-1 grade of cutback was not used in this investigation because preliminary trials indicated that it would take too long to cure these mixes in the oven. The properties of the asphalt cement used in this cutback are shown in Table 2. The properties of the solvent are shown in Table 3 and the properties of the laboratory prepared liquid asphalt are shown in Table 4. A series of partial distillation tests were made on prepared cutbacks to determine the volatile loss as a percent

TABLE 2

PROPERTIES OF ASPHALT CEMENT USED IN PREPARING CUTBACKS

Producer "C"

Penetration (77 F, 100 g, 5 sec)	100
Specific Gravity (77/77)	1 0191
Melting Point, F	115
Flash Point, F	635
Fire Point, F	705
Percent Soluble in Carbon Tetrachloride	99.63
Spot Test (naptha solvent)	negative

TABLE 3

PROPERTIES OF KEROSENE USED IN PREPARING CUTBACKS

Producer "C"

Specific Gravity (77/77)		0.8018
Flash Point, F		145
Distillation:		
	Percent Over	Temperature, F
	I. B. P.	358
	10	384
	20	392
	30	398
End Point: 526 F	40	406
Recovery: 99%	50	414
Residue: 1%	60	422
	70	432
	80	447
	90	472
	95	500

TABLE 4

PROPERTIES OF LABORATORY PREPARED MEDIUM CURING LIQUID ASPHALTS

Producer "C"

	Cutback Grade	
	MC-2	MC-3
Viscosity, Furol at 140 F, sec	170	299
Distillation:		
Initial Boiling Point, F	454	464
Distillate (percent of total distillate to 680 F)		
To 437 F	0	0
To 500 F	44 3	34.8
To 600 F	85.0	81.5
Residue from distillation to 680 F		
Volume percent, by difference	74.6	78.6
Penetration of residue (77 F, 100 g, 5 sec)	202	196
Specific gravity of residue (77/77)	1 013	1.014
Specific gravity of distillate (77/77)	0.791	0.788
Temperature, F at 115 sec Viscosity, Furol	155	165
Volatiles evaporated at 120 sec Float test, percent of total cutback	21.0	16.8
Texas curing index:		
By evaporation test	600	425

TABLE 5

RELATION OF STABILITY TO CURING OVEN CURED MIXES

Volatiles Lost				
Percent of Total Volatiles	Percent of Total Cutback	Marshall Stability, lb	Flow 0.01 in	Density, percent
MC-2				
12	3	300	21	100
27	7	500	15	100
59	15	500	9	97.5
79	20	475	9	94
MC-3				
23	5	600	16	99.8
56	12	500	10	96.4
84	18	500	9	94.5

by volume of the cutbacks at the cured out point. The cured out point was taken from Hank's work as 120 sec float test at 122 F (2). Hank learned from field experience that RC-2 cutbacks were satisfactorily cured out when approximately 80 percent of the volatiles had been evaporated. At this point the consistency of the residues from the cutbacks averaged a float test of 120 sec at 122 F. He then assumed this point as the cured out point and designated the time required to reach this 120 sec float test as the curing index in comparing RC and MC cutbacks. Experience indicates that this arbitrary cured out point will not apply to cutbacks prepared with asphalt cements with either a very high or a very low penetration. The cured out point was not used as a marker in the subsequent parts of this study so the variation did not affect the work.

Ten mixes were prepared using the MC-2 cutback and nine using the MC-3 cutback. These mixes were designed to have a residual asphalt cement content of 5.0 percent by weight. This asphalt cement content was determined from a series of optimum asphalt determinations for this gradation. Each sample weighed 2,500 grams. Both the aggregate and the asphalt were heated to a temperature that would give the cutback a viscosity of 115 sec. For the MC-2 this temperature was 155 F and for the MC-3 the temperature was 165 F.

The mixes were removed from the oven and weighed at intervals so that a check could be kept on the percentage of volatile matter lost. When the mix had lost a predetermined percentage of the volatiles it was removed from the oven and molded immediately for stability determination. Six hundred hours in the oven were required for the MC-2 mixes to reach the cured out point. About 400 hours in the oven were required to cure out the MC-3 mixes.

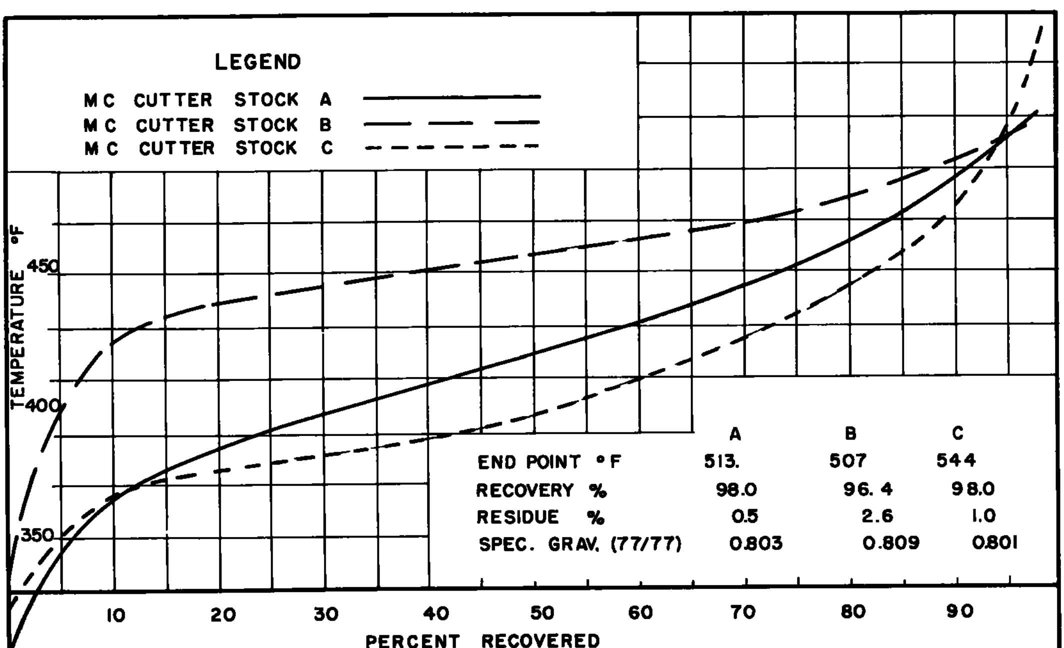

Figure 3. Distillation curves, MC cutter stock.

Table 5 shows the averages of the test specimens at different times of curing.

For each of these cutbacks the 500-lb stability was obtained when less than 30 percent of the volatile matter had been evaporated. In the case of the MC-2 this percentage was 27 percent and the MC-3 was 23 percent. For higher percentage of volatile matter evaporated, the stabilities did not increase. Part of this could be attributed to the lack of good compaction. At temperatures of 140 F it was not possible to get as good compaction as would have been obtained with higher temperatures.

TABLE 6

ROOF STORAGE MIXES

PROPERTIES OF ASPHALT CEMENT USED IN PREPARING CUTBACKS

Brand of Asphalt Cement	A	B	C
Penetration (77 F, 100 g, 5 sec)	126	129	124
Specific Gravity (77/77)	1 0213	1 0132	1 0713
Softening Point, F (R and B)	109	111	109
Flash Point, F	661	653	644
Fire Point, F	727	721	700
Spot Test (naphtha solvent)	Neg	Neg	Neg
Ductility, cm (77 F, 5 cm/min)	150+	150+	150+
Percent Soluble in Carbon Tetrachloride	99.9	99 8	99 7

STOVEPIPE METHOD OF CURING

The mixes were placed in a stovepipe and stored on the roof of the laboratory for curing in an attempt to simulate some of the conditions found in the center of a stockpile. Observation of stockpiles indicated that the surface formed a hard crust while the center of the stockpile remained very workable. Fifty-pound batches were prepared in a laboratory type pugmill and placed on the roof of the laboratory. Seven samples were mixed on August 4 and 5. These samples were immediately placed in the stovepipes on the roof of the laboratory. The gradation was the same as used in the oven-cured mixes previously reported, but three brands of cutback asphalt were used in these mixes. These brands were listed as A, B, and C. Figure 3 shows the distillation curves of the solvent used in these mixes. Table 6 shows the properties of the cutback asphalts and Table 7 indicates the test results of the prepared cutbacks. The residual asphalt content of these mixes was 5.0 percent by weight.

Samples were taken from the batch as soon as it came out of the pugmill for the purpose of determining the percent of volatile matter that was lost during mixing.

At intervals varying from two to three weeks, samples were taken from the bottom of the stovepipes for the purpose of determining stabilities and loss of volatiles. Table 8 shows the results of the stability determinations and the volatiles lost. The volatile contents of the samples were determined by AASHO Method T110-42. The specimens were all compacted at 100 F and stabilities were determined by the Marshall Method at 140 F. Compaction was by the Gyratory Method.

The length of storage of these mixes indicated that it was possible to obtain satisfactory storing periods with mixes prepared from MC cutbacks. It was also apparent

TABLE 7

ROOF STORAGE MIXES

CUTBACKS USED IN BITUMINOUS MIXES

Blend Number	1A	2A	3A	2B	2C
Furol Viscosity					
122 F, sec	94	139			125
140 F, sec	58	79	148	132	71
Distillation					
Distillate (percent of total distillate to 680 F)					
To 437 F	2.0	7.4	0	0	0
To 500 F	49.4	55.0	44.8	27.0	48.8
To 600 F	85.5	88.7	84.4	79.9	84.3
Residue from distillation to 680 F volume percent by difference	68.9	71.4	76.0	74.5	69.8
Penetration of Residue (77 F, 100 g, 5 sec)	213	196	173	220	219
Volatiles in cutback at 120 sec float test at 122 F of total cutback	26.6	25.4	19.8	23 4	26.6
Calculated Texas Curing Index using 120 sec float test at 122 F as cured out point	360	320	280	980	480

TABLE 8
ROOF STORAGE MIXES
STABILITY VERSUS VOLATILE CONTENT

Flow	Marshall Stability	Percent of Total Volatiles Lost	Volatiles Lost Percent Total Cutback
Mix 1A — Mixed August 4, 1952 Last sample taken May 8, 1953 Total storage time 277 days			
During mixing		23	7
15	540	54	17
13	440	54	17
14	565	55	17
17	545	57	18
11	700	83	26
Mix 2B — Mixed August 4, 1952. Last sample taken May 8, 1953 Total storage time 277 days			
During mixing		20	5
17	470	32	8
19	530	36	9
16	490	41	10
21	555	45	11
12	700	57	15
Mix 2C — Mixed August 4, 1952 Last sample taken April 8, 1953 Total storage time 247 days			
During mixing		30	9
21	345	38	11
20	565	52	16
17	460	54	16
16	530	56	17
Mix 2A-1 — Mixed August 4, 1952 Last sample taken April 10, 1953 Total storage time 249 days			
During mixing		23	7
12	610	42	12
14	590	43	12
13	525	49	14
12	730	54	15
Mix 2A-2 — Mixed August 5, 1952 Last sample taken April 10, 1953 Total storage time 248 days.			
During mixing		19	5
11	520	41	12
15	500	44	13
13	760	55	16
11	670	57	16
Mix 3A-1 — Mixed August 4, 1952 Last sample taken April 13, 1953 Total storage time 252 days			
During mixing		23	6
12	660	34	8
10	625	41	10
11	730	47	11
10	665	48	12
Mix 3A-2 — Mixed August 4, 1952 Last sample taken April 13, 1953 Total storage time 251 days			
During mixing		27	6
11	630	43	10
15	750	49	12
13	635	54	13
14	1,000	69	17

that the flash-off of volatile matter during mixing would not be sufficient to produce satisfactory stabilities. It appeared from these mixes that satisfactory stabilities with the medium curing cutbacks would not be attained until about 40 percent of the volatile matter has been lost.

BLENDED CUTTER STOCKS

It is evident from the curing characteristics of the first storage mixes that approximately 40 percent of the volatiles would need to be driven off before minimum stabilities could be obtained. The rate of curing beyond this point was satisfactory, indicating that if there were about 60 percent medium curing cutter stock in the cutback a satisfactory curing period would result. The ideal curve would be one in which about 35 percent to 40 percent of the volatile matter were lost fast and then the curing rate slowed down to that of an ordinary MC cutter stock. The first part of the curve should resemble that of an RC cutter stock. From this it was decided to blend RC and MC cutter stocks to form a solvent for preparing cutbacks. A curve for an ideal solvent based on the characteristics stated above was drawn. Blends of RC, MC and in some cases SC cutter stocks were then made and their distillation curves compared with the desired distillation curve.

Several blends of cutter stocks were tried and their distillation curves plotted. Table 9 shows some of the blends of cutter stock from producer A and producer B. It was determined from the distillation curves that some of these blends would not be satisfactory and were considered no further. Actually the blends shown here were only a few of the large number that were tried. From the results of those tried, one blend was chosen from producer A and one blend from producer B with which to produce cutbacks for further study. Figure 4 shows the curves of these two blended cutter stocks. Also shown is the curve D-223, a solvent prepared by one of the producers. This solvent was prepared to match the curve of the proposed ideal solvent. Table 10 shows the physical properties of the asphalt cement and Table 11 shows the properties of cutbacks prepared with these blended cutter stocks.

Several pan mixes were prepared using blends 4A and 2B for testing the stability and the rate of curing of the actual asphaltic concrete mixes. The batches were mixed at 140 F and were cured in ovens at 140 F. The approximate loss of volatile matter was determined by weighing the pans from time to time. Four different volatile contents were chosen at which specimens would be tested. Test specimens were chosen when approximately 30 percent of the volatile matter had been evaporated. Other specimens were taken when 50 percent, 75 percent and 90 percent of the volatile mat-

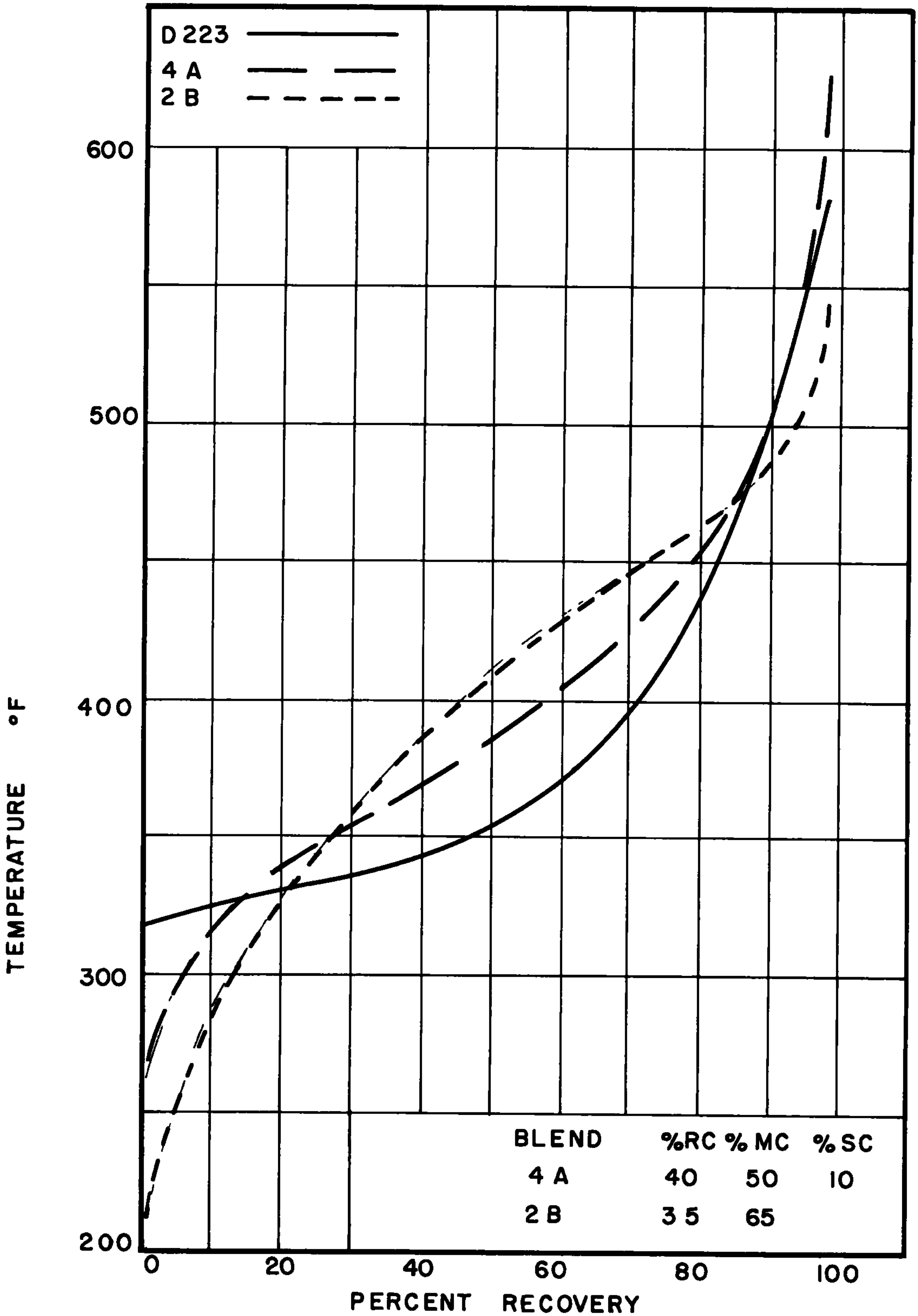

Figure 4. Distillation curves, blended cutter stocks.

TABLE 9

PROPERTIES OF BLENDS OF CUTTER STOCKS

Blend	2A	4A	5A	1B	2B
Percent Over			Temperature F (corrected for barometric pressure)		
I. B. P.	262	257	264	275	212
10	327	322	329	374	293
20	349	336	349	401	330
30	365	356	363	419	361
40	378	370	379	433	387
50	390	385	399	444	408
60	408	403	419	455	430
70	430	424	444	464	446
80	451	453	473	477	462
90	480	507	518	495	482
End Point	518	621	606	547	538
Recovery, percent	99.0	98.5	98.0	97.0	98.5
Residue, percent	0.6	1.1	1.6	2.9	1.2
Distillation Loss, percent	0.4	0.4	0.4	0.1	0.3
Specific Gravity (77/77) F	0.789	0.790	0.794	0.790	0.780

Blend	Percent RC	Percent MC	Percent SC
2A	30	70	0
4A	40	50	10
5A	30	60	10
1B	10	90	0
2B	35	65	0

ter had been driven off. Because of the size of the mixes and sensitivity of the scales used, it was not possible to determine accurately the percentage of volatile matter driven off from these mixes. Two distillation tests were made on each sample taken for stability tests to give a more accurate indication of the percent of volatile matter lost. Three specimens were prepared for testing by the Marshall Method and three specimens were prepared for testing by the Hveem Method, from each pan mixed. All of these stability specimens were compacted by the Gyratory Method and tested at 140 F, after being brought to temperature in a water bath. Table 12 indicates results of the tests. Figure 5 indicates the rate of loss of volatiles from these two mixes. The percent relative stability by the Hveem Method was determined from curves of

TABLE 10

PROPERTIES OF ASPHALT CEMENT USED IN PREPARING CUTBACKS

Brand of Asphalt Cement	A	B
Penetration (77 F, 100 g, 5 sec)	120	129
Specific Gravity	1.0176	1.0132
Softening Point F (R and B)	110	111
Flash Point, F	662	653
Fire Point, F	729	721
Spot Test (naphtha solvent)	Neg	Neg
Ductility, cm (77 F, 5 cm/min)	150	150+
Percent Soluble in Carbon Tetrachloride	99.8	99.8

TABLE 11

CUTBACKS USED IN BITUMINOUS MIXES

Blend	4A	2B
Furol Viscosity		
122 F, sec	187	268
140 F, sec	108	140
Distillation		
Distillate (percent of total distillate to 680 F)		
To 437 F	15	12
To 500 F	31	25
To 600 F	43	41
Residue from distillation to 680 F volume, percent by difference	75	75
Tests on Residue		
Penetration (77 F, 100 g, 5 sec)	265	260
Volatiles in cutback at 120 sec float test at 122 F, percent of total cutback	23	22
Calculated Texas Curing Index using 120 sec float test at 122 F as cured out point	390	370

TABLE 12

STABILITY RESULTS USING BLENDED CUTTER STOCKS

Mix	Marshall Stability lb	Flow	Percent by Volume, total volatiles off	Percent by Volume, total cutback off	Percent Theoretical Density
	465	17	37	9	100
	560	8	43	11	100
	600	12	42	11	100
	630	9	48	12	99.6
	645	10	46	12	98.7
	710	9	52	13	99.1
	920	8	93	23	96.2
4A	Percent Hveem Stability				
	35		40	10	99 6
	36		43	11	100
	41		57	14	98.7
	43		80	20	96.2
	51		94	24	95.0
	52		98	24	95.0
	535	13	39	10	100
	655	10	48	12	99.1
	690	7	51	13	100
	800	8	73	18	96 2
	830	8	78	20	97.0
	875	9	93	23	95.8
2B	Percent Hveem Stability				
	29		36	9	100
	35		41	10	100
	42		52	13	100
	44		76	19	97.0

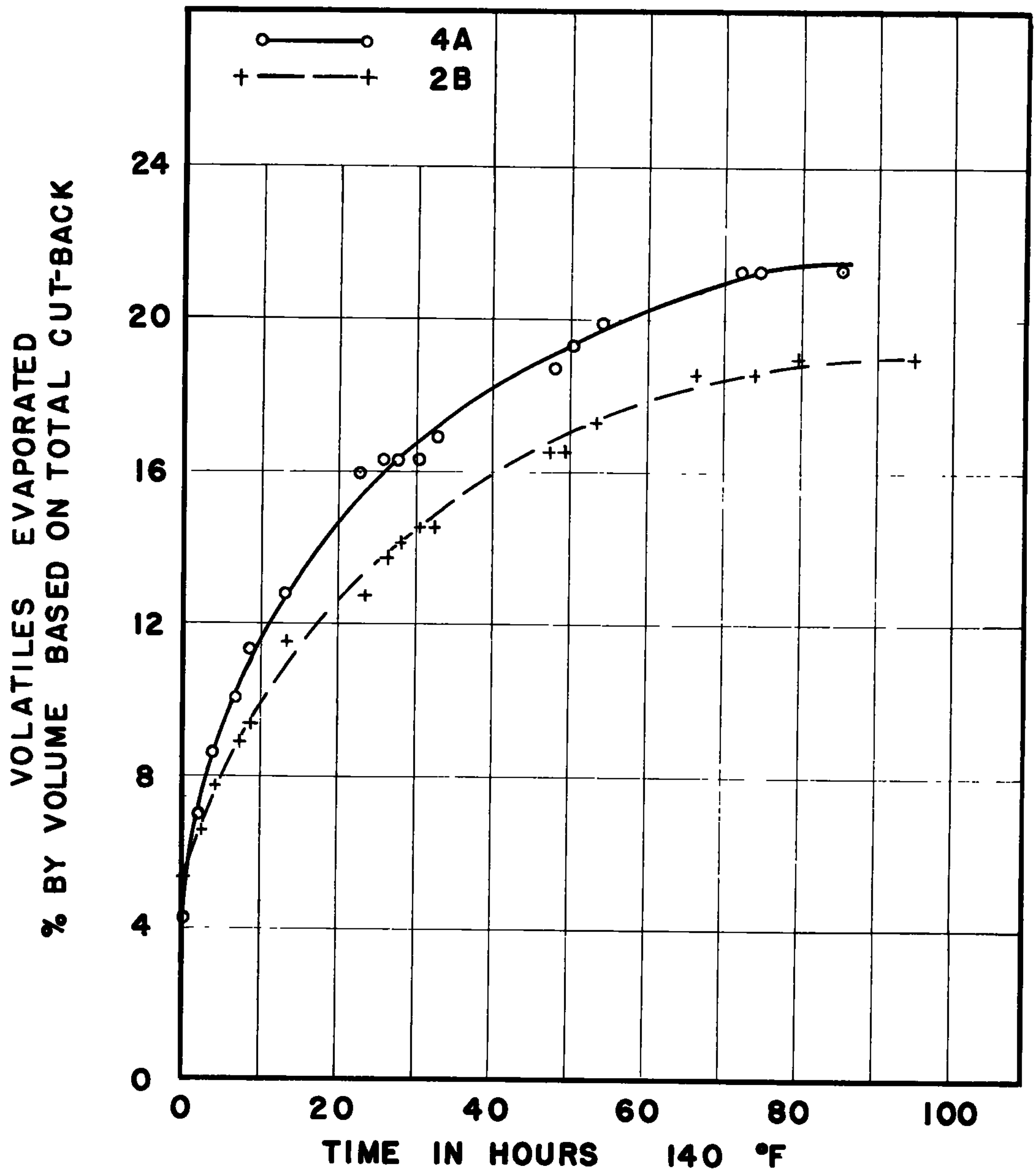

Figure 5. Evaporation curves, pan mixes, blended cutter stocks.

final displacement plotted against Hveem stabilometer gauge reading at 400 psi applied vertical load. These curves were taken from Martin's work at Oklahoma State University (3).

The results obtained from the oven-cured pan mixes were used as a guide in preparing the stovepipe mixes. For this series of stovepipe mixes it was desired to obtain as long a curing period as possible. Therefore two joints of stovepipe were placed together forming a length of about 4 ft. These were mixed in two 50-lb batches in an electrically heated laboratory pugmill. Mixing was accomplished at 140 F. Small samples were taken from each of these mixes at frequent intervals during the early curing period and at much longer intervals of time as curing proceeded. Distillation tests were run on these samples to determine the amount of volatiles lost. Only three

TABLE 13

ROOF-STORED MIXES USING BLENDED CUTTER STOCK

Age Days	Point of Sampling	Percent Volatiles Evaporated	Percent Total Cutback	Stability	Flow	Density
			Mix 4A-1			
0	Pugmill	27.3	6.8			
3	Bottom of pipe	38 0	9.3			
5	Bottom of pipe	32	8.0	630	11	
33	Bottom of pipe	93	23.0			
93	Center of pipe	43.5	10.7			
173	Center of pipe	56.3	13 9			
361	Center of pipe	66.3	16.4			
634	Center of pipe	87.5	21 7	980	10	97.2
634[a]	Center of pipe	87.5	21.7	610	9	94.2
			Mix 4A-2			
0	Pugmill	28.8	7.2			
3	Bottom of pipe	39.0	9.6			
4	Bottom of pipe	32.0	8.1	745	10	
34	Bottom of pipe	64 5	16.2			
174	Center of pipe	60.0	15 0			
635	Center of pipe	90.0	22.5	900	11	93.4
635[a]	Center of pipe	90.0	22.5	670	10	91.2
			Mix D-223			
0	Pugmill	32.8	6.9			
3	Bottom of pipe	37.3	7.9			
11	Bottom of pipe	58.2	12.3			
72	Center of pipe	36.6	7.7			
136	Center of pipe	59.7	12.5			
324	Center of pipe	74.6	15.6			
597	Center of pipe	85.1	17.8	770	10	96.6
597[a]	Center of pipe	85.1	17.8	620	10	94.9

[a] These specimens were molded at 65 F and tested at 140 F.

different samples were prepared for stovepipe curing. Table 13 shows the results of these tests. Two of the mixes were identical with the exception that mix 4A-2 had a residual asphalt content of only 4.0 percent. Mix 4A-1 had a residual asphalt content of 5.0 percent. The mix having the same constituents as mix 4A of the oven-cured mixes, lost 27 percent of its volatiles during the mixing process. At the end of five days, 32 percent of the total volatiles or 8 percent of the total cutback had been evaporated. At this time stability determinations were made. The stability was found to be 630 lb Marshall. Samples taken from the center of the stovepipe at the age of 93 days showed a loss of 43.5 percent of the total volatiles or 10.7 percent of the total cutback. At the age of 173 days these figures were 56 percent and 13.9 percent. At 361 days the figures were 66 percent and 16.4 percent and 634 days 87.5 percent of the total volatiles had been evaporated. At this age samples were compacted for the stability determination. Specimens compacted at 100 F and tested at 140 F gave a stability of 980 lb and a flow of 10. The density was 97.2 percent. One group of samples were compacted at 65 F to observe their workability at lower temperatures. Mix 4A-1 gave a stability of 610 Marshall and a flow of nine under these conditions. The density was 94.2 percent.

It was observed that a crust formed on the top and bottom of these mixes more rapidly than it did on the mixes where a commercial MC cutter stock was used. The depth of this crust did not appear to vary from that of previously observed mixes. When the stovepipe was removed from the roof and placed in the laboratory the temperature in the laboratory was approximately 70 F. When first removed from the stovepipe the mixes were consolidated and very resistant to breaking down. In some cases a hammer had to be used to break them down prior to molding. After the samples were heated to 100 F they became friable and could be easily broken down with the hands.

MIXES EXPOSED TO THE ELEMENTS

At the conclusion of the tests of the blended cutter stock an attempt was made to check this blended cutter stock with aggregates from various areas. Five different aggregates were used. Table 14 shows the physical properties of the aggregates.

The crushed limestone No. 1 is the same aggregate that was used in all of the previous work. All of the aggregates had the same gradation as used in the previous work. Samples of each aggregate weighing 7,000 grams were proportioned and placed in large mixing pans. Cutback 4A was added to each sample in the amount to yield 5.0 percent residual asphalt. The aggregate and the cutback were at a temperature of 140 F when mixed. The aggregate and cutback were thoroughly mixed for a period of seven minutes with a large laboratory spoon. After the aggregate and cutback 4A were thoroughly mixed, the mixture was placed in a wooden container measuring 15- by 11-in. and 5-in. deep. The containers were approximately half full. The bottom of each container was covered with ¼-in. wire screen mesh. The purpose of the screen was to allow air and precipitation to pass through the container. The wooden containers were stored on the roof of the laboratory, on 4- by 4-in. timbers in such a manner that there was free circulation of air under the mixes. These mixes were placed on the roof of the laboratory on September 26, 1955, and removed from the roof on March 15, 1956. No protection whatsoever was placed over the samples so that they were completely exposed to the elements. At the end of this period of exposure there was no evidence of stripping in any of the mixtures. A 1,200 gram sample of each mix was obtained and heated to 140 F in electric ovens. Each heated sample was then compacted by the Gyratory Method. The stability and flow of each compacted specimen was obtained by the Marshall Method. Volatile contents were determined by the Method AASHO T110-42. Table 15 gives the results of these tests. Each stability shown is the average of three specimens.

The visual examination of the crushed syenite indicated that this material had very poor crushing characteristics. A majority of the crushed material was elongated slivers or flat plate shaped particles. At high volatile content this mix had no stability at all. The optimum asphalt contents for these same materials and gradation varied from 5.0 percent for the crushed limestone No. 2 to 6.5 percent for the crushed river gravel.

PROPOSED SPECIFICATION

The results of these studies indicated that there was a need for better control of the manufacture of material if it were to give best results under general conditions. The proposed cutback asphalt specification (Fig. 6) is rather restrictive and it is possible

TABLE 14

Type of Aggregate	Bulk SG for Gradation	Percent Wear L.A. Abrasion	Percent Absorption 24 hours	Soundness (% loss)
Crushed River Gravel	2.545	36	2.3	4.9
Crushed Sandstone	2.537	31	2.3	4.6
Crushed Syenite	2.615	24	0.4	5.6
Crushed Limestone No. 1	2.575	26	2.0	1.0
Crushed Limestone No. 2	2.668	50	0.7	3.5
Type of Aggregate		**Unit Weight (pcf)**		**Percent Voids**
Crushed River Gravel		114.8		27.7
Crushed Sandstone		115.9		26.8
Crushed Syenite		117.8		27.8
Crushed Limestone No. 1		118.6		26.2
Crushed Limestone No. 2		126.8		23.9

TABLE 15

RESULTS OF TESTS ON MIXES EXPOSED TO ELEMENTS

171 Days Exposure—Specimens Molded and Tested at 140 F

Type of Aggregate	Marshall Stability (lb)	Flow (0.01 in.)	Percent Theoretical Density	Percent Volatiles Evaporated
Limestone No. 2	1,165	13	96.8	96.4
Limestone No. 1	1,054	11	94.7	95.3
Crushed Syenite	705	11	93.5	91.7
Crushed River Gravel	496	10	91.8	89.3
Crushed Sandstone	746	11	93.9	84.6

that some relaxing of parts of this specification will be necessary. This specification varies in two places from the usual cutback asphalt specifications. In the first place this specification requires the fractions from the distillation tests be given as the percentage of the total cutback. It is desirable that this be done so that the people using the material will have some idea of how much volatile matter is in the cutback, and that the volatile matter be controlled a little more closely. It is customary in many cases in the field to shoot a given quantity of cutback regardless of the asphalt content of this cutback. It is felt desirable to control the solvent as far as practical. Experience in the laboratory indicates that the solvents presently in use vary widely. It was found in a few cases that an MC solvent from one producer would very nearly match the RC solvent from another producer. This is indicated from the variations in the curing index of the materials shown in Table 7.

PROPOSED SPECIFICATION FOR

CUTBACK ASPHALT

FOR PREPARATION OF PREMIX MATERIAL WITH CRUSHED AGGREGATE

This cutback shall be prepared from a steam and vacuum straight-reduced asphalt, and a petroleum solvent:

The cutback shall meet the following requirements.

Flash, Tag Open Cup, Min.	95°F
Viscosity, S. Furol at 140°F, Sec.	90-130
Distillation (ASTM D402, excepting fraction as percentage of cutback).	
Initial boiling point, Min.	375°F
To 374°F, %	0
437°F, %	7-10
500°F, %	15-17
600°F, %	21-24
680°F, %	24-27
Test on residue from distillation	
Penetration at 77° F, 100g., 5 sec.	200/300
Ductility at 77° F,	60+
Spot Test	Neg.
Solubility in Carbon Tetrachloride	99.5+
The solvent shall meet the following requirements:	
By AASHO Distillation T 115	
Initial Boiling Point ° F,	300+
Temperature at 40% Recovery ° F,	340-365
Temperature at 80% Recovery ° F,	425-460
End Point ° F	600-650

Figure 6.

REFERENCES

1. Marshall Consulting and Testing Laboratory, Jackson, Mississippi, "The Marshall Method for the Design and Control of Bituminous Paving," Third Revision, (February 1949).
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3. Martin, J. Rogers, "Some Fundamental Principles in Relation to Asphaltic Concrete Pavements as Applied to the Hveem-Gyratory Method of Design," Publication No. 69, Engineering Experiment Station, Oklahoma State University.