DURABILITY OF ASPHALT IN HOT MIXED ASPHALTIC CONCRETE PAVEMENT

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SYNOPSIS

Lack of stability of asphaltic pavements is evidence of lack of flexibility of asphaltic concrete which in turn is dependent upon the physical characteristics of its components. If the variables such as grading of aggregates, filler content, asphalt content, mixing conditions, traffic, weather, and variation in the asphalt used, could be controlled to provide flexibility suited to a particular roadbed at the time the pavement was placed, the life of the pavement would be extended indefinitely. Unfortunately pavements laid under modern control methods, which provide sufficient stability for the intended traffic when laid, undergo some change which results in decreased stability with age.

This investigation was intended to determine by controlled field and laboratory tests the effect of varying the following conditions on the rapidity and extent of asphalt hardening: grade of asphalt; asphalt content; filler content; mixing temperature; and mixing time; and to determine the rate and extent of asphalt hardening in the cutback asphalt wearing surface.

The asphalt content was found to have the greatest effect on drop in penetration with service. In 6 years with high asphalt content the peneteration of an 87-penetration asphalt dropped 32 percent and a 49-penetration asphalt dropped 49 percent; while with low asphalt contents the 87-penetration asphalt and a 58-penetration asphalt both dropped 70 percent.

The grade of asphalt used is also shown to effect the rate of penetration drop, while filler content appears to have little effect. During the mixing period the rate of drop depends upon the mixing temperature, but the time of mixing has no effect. The drop in penetration varied from 7 points at 225 F. to 21 points 330 F. mixing temperatures.

The tests indicated that the asphalt in cutback asphalt wearing surface hardens in approximately 6 years to a degree that raveling occurs.

Based on these tests the life of asphaltic concrete pavements would be extended if specifications called for: 80–100-penetration asphalt; a minimum asphalt content of 6.5 percent when sand content is between 25 and 35 percent; and a maximum aggregate temperature of 300 F.

The characteristic tendency of asphaltic concrete pavement to become progressively unstable is by no means a new observation. Usually, the lack of stability is evidence of a lack of flexibility which is manifested by raveling or breaking out of pieces of the wearing surface, and by cracks appearing in the pavement.

Flexibility of asphaltic concrete is dependent on each, as well as on the combination of, the physical characteristics of the components. Some of these variables are: grading of the aggregates; filler content; asphalt content; mixing conditions; traffic and weather conditions; and variation in the asphalt used. It would seem reasonable to assume that these variables could be so controlled that the mixed concrete would have a flexibility suited to the specific type of road bed covered. Also, that if the mix had the correct flexibility for any specific road bed at the time the pavement was placed, the life of the pavement would be extended indefinitely.

After years of trial and error, and finally by more scientific methods, mixes of asphaltic concrete are controlled so that the stability at the time of laying is sufficient for the intended traffic. Unfortunately, observation has indicated that no matter how perfect the mix is at the time it is placed, the pavement does not have indefinite durability. It is evident then that some change occurs in the pavement which results in decreased stability with age.

A considerable number of investigations have been carried out by interested organizations to determine the exact nature of this change. Sufficient data has been obtained to justify the conclusion that the asphalt undergoes a gradual chemical change resulting in undesirable physical characteristics.

The number of methods developed to reclaim the asphalt from a pavement sample for test purposes is nearly as large as the number of investigations. Each claims the advantage that the process of reclaiming by his method alters the chemical structure of the asphalt molecules less than other methods. It is undoubtedly true that the structure of asphalt is altered by any method of reclaiming, especially where solvents are used to extract the asphalt. The fact remains, however, that the results of all investigations indicate a progressive increase in brittleness with age as measured by the standard penetration needle.

Several articles have been published which severely criticize the use of penetration as a valid means of determining the hardness or brittleness of asphalt. It is not questioned that there are other physical changes in asphalt as it ages in pavement that are not shown by the penetration test. Regardless of this probability, neither the criticism of the validity of the penetration test or of the method of recovery alters the results of many investigations which consistently indicate good correlation between pavement failure and penetration of the recovered asphalt.

The purpose of the investigation or research being done, and the use of the results, determines whether or not the method of reclaiming must be valid in the sense of obtaining a sample of asphalt in exactly the same chemical and physical condition as it was in the pavement.

It is self-evident that the real remedy for asphalt hardening and subsequent pavement failure would be the development of an asphalt so treated, with additives or by processing, that further changes with age do not occur. It is also self-evident that research preliminary to such development must be valid in reclaiming samples of asphalt in exactly the same physical and chemical condition as it is in the aged concrete specimen. On the other hand, any reliable method of recovery, or one which gives consistent and reproducible results, would be satisfactory for comparative types of investigations where in the rate or degree of change in the brittleness of the asphalt under certain conditions is compared to the change under other conditions. By such comparisons, the grade of asphalt, the proportion of asphalt, and the time and temperature of the mix can be determined which will deter, if not prevent, the loss of pavement flexibility.

Until such a time as the desired quality of asphalt is developed, time spent on methods which result in a prolonged asphalt life is certainly of economic value.

PURPOSE

The purpose of this investigation was to determine, in so far as possible by controlled field and laboratory tests, the effects of varying conditions on the rapidity and extent of asphalt hardening. Specifically, the purpose resolved into the following:

1. The effect of grade of asphalt on asphalt hardening;
2. The effect of asphalt content on asphalt hardening;
3. The effect of filler content on asphalt hardening;
4. The effect of mixing temperature on asphalt hardening;
5. The effect of mixing time on asphalt hardening; and
6. The rate and extent of asphalt hardening in the cutback asphalt wearing surface.

The effect of grade of asphalt was limited to a comparison of 50–60 penetration asphalt with 80–100 penetration asphalt.

The effect of asphalt and filler content was limited to a comparison of high and low asphalt and filler contents within the existing specifications.

The effect of mixing temperatures was limited to a comparison of mixing temperatures as they occurred at the time samples were taken.

The effect of mixing time was limited to a comparison between mixing times of 45 seconds, 1 minute, 90 seconds, and 2 minutes.

The extent of hardening of asphalt in the cutback asphalt wearing surface was limited to the same period of time required to determine the effects of the varying conditions.

TEST PROCEDURE

Location—Two test sections on the Columbia River Highway between Scappoose and St. Helens were chosen for the determination of the effect of asphalt content, filler content, grade of asphalt, and the normal hardening of cutback asphalt. The exact location at which each experimental mix was placed was noted both by station number and by permanent land marks such as telephone and power poles.

The effects of mixing temperature and mixing time were determined on mixes placed on Sandy Blvd., Portland, the North River Road, Salem, and Highway 99W, south of Corvallis.

Table 1 shows the exact location of test sections.

Grades of Asphalt Used

50–60 Asphalt—The specifications for the Warren-St. Helens section called for the use of 50–60-penetration asphalt. Therefore, the experimental mixes were made using the asphalt as it was normally supplied to the mixer. A sample of asphalt was taken before each experimental mix and tested in the laboratory for penetration. All the experimental mixes were not made in consecutive order and considerable time elapsed between the first and the last mix. Consequently, asphalt for the experimental mixes came from more than one car and the original penetration was not the same for all mixes. Also, on four of the eight experimental mixes, the workmen had left the cutback asphalt valve open resulting in a 50–60 asphalt diluted with cutback. The asphalt for the 8 experimental mixes consisted of the following:

2—base course—original penetration 49,
2—base course—original penetration 58,
4—leveling course—original penetration 83 (diluted with cutback).

The 4 experimental leveling course mixes were not placed in the same location as the 4 experimental base course mixes. For each cut sample there was one sample of normal mix for every sample of experimental mix. The original asphalt for these normal mix samples was:

TABLE 1
EXACT LOCATION OF TEST MIXES

No.	Course	Location	
		By Station Number	By Land Marks
		Warren—St. Helens	
1	Base	650-25 to 649-75	2 ft. North Tel. Pole 27/10
2	Base	639-25 to 638-75	At Power Post 751903
3	Base	623-80 to 623-20	At Tel Pole 27/34
4	Base	622-10 to 622-50	5 ft. North Tel. Pole 27/35—1282
5	Leveling	622-12 to 621-35	50 ft. North Tel. Pole 27/35—1282
6	Leveling	620-05 to 619-40	15 ft. North Tel. Pole 27/37
7	Leveling	618-00 to 617-40	13 ft. South Tel. Pole 27/39
8	Leveling	615-85 to 615-00	52 ft. South Tel. Pole 27/41—1288
9	Leveling	Over No. 1	
10	Leveling	Over No 2	
11	Leveling	Over No. 3	
12	Leveling	Over No. 4	
13	Base	Under No. 5	
14	Base	Under No 6	
15	Base	Under No. 7	
16	Base	Under No. 8	
		Scappoose—Warren	
1	Base	876-55 to 877- 9	25 ft. North Tel. Pole 22/40
2	Base	877-65 to 878-15	72 ft. South Tel. Pole 22/40
3	Base	878-60 to 879-13	61 ft. South Tel. Pole 22/39
4	Base	879-55 to 880- 4	25 ft. South Tel. Pole 22/38
5	Leveling	876-91 to 877- 9	Over No. 1
6	Leveling	877-88 to 878-15	Over No. 2
7	Leveling	878-25 to 878-50	At Tel. Pole 22/39
8	Leveling	878-80 to 879-13	Over No 3
9	Leveling	879-60 to 880- 5	Over No. 4
10	Base	878-25 to 878-50	Under No. 7
11	C.A.W.S.[a]	876-91 to 877- 9	Over No. 5
12	C.A.W.S.	877-88 to 878-15	Over No. 6
13	C.A.W.S.	878-25 to 878-50	Over No. 7
14	C.A.W.S.	878-80 to 879-13	Over No. 8
15	C.A.W.S.	879-60 to 880- 5	Over No. 9

[a] Cutback asphalt wearing surface.

4—base course—original penetration 59,
3—leveling course—original penetration 59,
1—leveling course—original penetration 83 (diluted with cutback).

80–100 Asphalt—The specifications for the Warren-Scappoose section called for the use of 60–70 penetration asphalt. Permission was obtained to use one car of 80–100 penetration asphalt for the experimental mixes. The original penetration for the 8 experimental mixes and for 2 normal mixes was 87, determined by laboratory tests on the car sample.

Cutback Asphalt—Since the grade of asphalt used to make the cutback was not known, the original penetration was arbitrarily set at the penetration of the asphalt in the first cut sample.

60–70 Asphalt—The asphalt used in the determination of the effect of mixing temperature and mixing time ranged from 59 penetration to 65 penetration by laboratory test.

Experimental Mixes—For the determination of the effect of asphalt content and filler content on the hardening of asphalt, 4 mixes were used, in addition to the normal mix, with both the 50–60 asphalt on the Warren-St. Helens section and the 80–100 asphalt on the Scappoose-Warren section. The 4 mixes consisted of the extremes in the permissible range in the specifications. The combinations were as follows:

1. High asphalt and high filler content;
2. High asphalt and low filler content;
3. Low asphalt and high filler content;
4. Low asphalt and low filler content.

Samples—Cut samples were taken at the location of each experimental mix at varying time intervals. Due to the fact that the Scappoose-Warren section was placed two years after the Warren-St. Helens section, the age of the pavement at the time samples were taken do not correspond. The time intervals for the two sections were as follows:

Warren-St. Helens: 10 days, 6 mo., 1 yr., 1½ yr., 2 yr., 2½ yr., 3½ yr., 8 yr.

Scappoose-Warren: 10 days, 6 mo., 1½ yr., 6 yr., 7 yr. The long gap between 3½ and 8 yr., and between 1½ and 6 yr. was due to the war period. Samples were taken during 1947 from the Scappoose-Warren section only.

The samples were cut manually and consisted of pieces about a foot square taken from the edge of the pavement. The pieces were then broken in two and the outside piece discarded. The test specimen then consisted of a piece about 6 by 12 in. taken about 6 in. from the edge of the pavement. The consecutive samples at each location were taken far enough apart to avoid any possible effect of the asphalt in the patch made at the previous sample location.

Samples to determine the effect of time and temperature of mixing were taken from the truck immediately after mixing.

Samples of asphalt to determine the original penetration were taken from the weigh bucket immediately before emptying into the mixer.

Extraction—On arrival at the laboratory each cut sample was separated into its three layers of base, leveling, and wearing courses by means of a chisel and hammer. Each layer was then broken up into small pieces with a hammer. For each extraction, 3000 g. were placed in two Dulin Rotorex bowls which were then placed in an oven held at 105 C. After the material became heated to this temperature, the bowls were removed, the covers placed on, and three washings using about 300 cc. of benzene (boiling range 70 to 81 C.) in each were made on each bowl, the washings of one bowl used for washing the second. Two hundred cc. of clean benzene were then run through the second bowl. The final washing in each bowl came out fairly light colored. Of the 1100 cc. used about 500 cc. were lost due to evaporation and absorption of the aggregate. The aggregate in one bowl was thoroughly cleaned with toluol and the per cent asphalt and granulometric analysis obtained. To extract the last traces of filler, the extracted asphalt and benzene were poured into six 100 cc. International centrifuge tubes and centrifuged for two hours at 1800 rpm. Of this 600 cc. of solvent and asphalt about 200 cc. were lost by evaporation. The remaining 400 cc. were placed in a short-necked 600-cc. round bottomed flask, similar to that specified by ASTM D 20–30, and distilled using an open flame and water cooled condenser. At the start of the distilling, care was taken in applying heat to prevent foaming over due to traces of water unavoidably extracted from the cut sample. When 160 C. was reached, sufficient flame was applied to increase the temperature to 300 C. in ten minutes or less. At this temperature the asphalt was immediately poured into a penetration can, placed on an inverted lid which was on a warm piece of Transite board and stirred continuously until the temperature dropped to 160 C. When the sample reached room temperature, the can was filled with water, covered and saved for penetration.

Samples taken from the mixer or truck were placed in the oven until they were warmed throughout, then weighed into the rotarex bowls and treated thereafter exactly as the cut samples

condensed benzene. The vertical extension above the T is flared out to permit the attachment of a water cooled reflux condenser. The ¼-in. pipe forming the horizontal leg of the T is turned down at the edge of the cylinder and bent toward the center at the bottom following the contour of the cone. The two ¼-in. pipes pass through a two holed cork into a round bottomed 800-cc. distilling flask. Three cone shaped screens consisting of a 200 mesh, 100 mesh, and a 40 mesh, are placed in the bottom of the cylinder. The sample of broken-up asphaltic concrete is then placed on the screens (the cylinder full of

TABLE 2
ST. HELENS—WARREN SECTION

No.	A.C.	Filler	Penetration									A.C.[a]	Pass 200[a]
			Orig.	10D	6 Mo.	1 Yr.	1½ Yr.	2 Yr.	2½ Yr.	3½ Yr.	8 Yr.		
Base Course													
												%	%
1	High	High	49	42	37	35	30	29	24	29	29	6.7	5.5
2	High	Low	49	41	37	30	24	28	23	23	19	6.9	3.8
3	Low	Low	58	43	39	30	33	34	32	28	15	5.9	3.0
4	Low	High	58	43	36	36	23	23	24	19	15	5.4	5.7
13	Normal		59	41	26	22	25	24	20	13	14	5.2	5.1
14	Normal		59	43	34	28	26	24	23	17	14	5.6	4.7
15	Normal		59	42	36	30	27	27	25	18	18	5.9	4.5
16	Normal		59	44	35	32	28	27	28	21	21	5.9	4.3
Leveling Course													
5	High	High	83[b]	60	45	34	36	32	28	28	27	7.6	6.9
6	High	Low	83[b]	62	44	32	34	32	30	31	25	7.5	4.9
7	Low	Low	83[b]	59	41	28	27	26	26	19	17	5.4	5.1
8	Low	High	83[b]	63	45	30	28	24	26	21	19	6.1	5.6
9	Normal		59	47	40	31	25	24	24	19	16	6.1	4.7
10	Normal		59	46	39	28	27	24	22	20	16	6.3	4.5
11	Normal		59	36	33	25	23	22	23	19	17	6.6	5.2
12	Normal		83[b]	60	43	30	30	27	26	23	17	7.2	7.0

[a] Asphalt content and per cent material passing No. 200 are averages of all samples.
[b] Asphalt accidently adulterated with cutback.

Since resumption of activity in this investigation in 1946, the laboratory has developed a different method of extraction based on the reflux condenser principle. The apparatus consists of a steel cylinder 3 in. in diameter and 18 in. long. Each end of the cylinder is threaded. On the lower end a steel cone, with a ¼-in. pipe extending 3 in. below the cone, is attached to the cylinder by means of a threaded collar. The cover is attached on the upper end, also by means of a threaded collar. A ¼-in. pipe extending ¼ in. below the cover passes through the center of the cover and forms a T about 1 in. above the cover. The horizontal leg of the T is at a slight angle to prevent the backward flow of asphaltic concrete containing 5 per cent asphalt will provide sufficient asphalt for penetration). After screwing the cover tight, about 500 cc. of benzene are poured through the condenser and when sufficient has drained through, heat is applied to the flask. The process of extraction requires about an hour and a half. The advantage over the rotarex is two fold: (1) the toxic vapors of benzene are avoided and (2) the process insures that the aggregate is completely cleaned of all asphalt. The results of this procedure checked within the ASTM permissible variation for penetration with the rotarex procedure and is recommended for future extractions with benzene.

TEST RESULTS

The results of tests are given in Tables 2 to 6. Table 2 shows the results of tests on samples from the St. Helens-Warren section. Table 3 shows the results of tests on samples from the Scappoose-Warren section. Table 4 shows the results of tests on samples taken to determine the effect of mixing time and temperature.

An examination of the results of tests in Tables 2 and 3 indicates no correlation between the filler content and the drop in penetration. The asphalt content and the grade of asphalt do appear to have an influence on the rate of hardening. In Table 5 the averages of the high asphalt content for each grade and the low asphalt content for each grade is shown. Figure 1 shows the values in Table 5 graphically.

TABLE 3
SCAPPOOSE—WARREN SECTION

No.	A.C.	Filler	Penetration						A.C.[a]	Pass[a] 200
			Orig.	10D	6Mo.	1½Yr.	6Yr.	7Yr.		
Base Course										
									%	%
1	High	High	87	68	69	62	57		6.5	5.8
2	High	Low	87	70	59	55	65		6.8	6.5
3	Low	High	87	51	52	45	24	21	5.7	6.4
4	Low	Low	87	61	52	35	28	20	5.5	5.6
10	Normal		87	66	50		31		5.8	5.2
Leveling Course										
5	Normal		87	60	49	39	19		5.7	3.2
6	Hi h	High	87	69	55	53	55		6.8	6.0
7	High	Low	87	73	50		60		7.3	5.2
8	Low	High	87	51	78	63	27	21	5.2	5.8
9	Low	Low	87	59	52	38	27	20	5.2	4.8
Cutback Asphalt Wearing Surface										
11	Normal			62	48	34	14			
12	Normal			64	44	29	19			
13	Normal			62	35		19			
14	Normal			52	50	35	24			
15	Normal			51	50	36	24			

[a] Asphalt content and per cent material passing No. 200 are averages of all samples.

An examination of Table 4 shows no correlation between the mixing time and drop in penetration. For the 87-penetration asphalt the mixing temperature up to 300 F. appears to have no bearing on the drop in penetration. However, when the average drop in penetration of those samples whose mixing temperature is above 300 F. is compared to the average drop of those mixed below 300 F., some correlation between mixing temperature and drop in penetration is indicated. Table 6 shows these averages.

TABLE 4
TIME AND TEMPERATURE OF MIX

No.	Type of Mix	Mix Time	Mix Temp.	Original Penetration	Reclaimed Penetration
Warren—Scappoose Section					
		Sec.	*deg. F.*		
1A	Base	47	300	87	72
1B	Base	49	260	87	69
1C	Base	48	280	87	66
2A	Base	60	300	87	70
2B	Base	60	300	87	76
2C	Base	45	290	87	64
3A	Base	45	275	87	66
3B	Base	47	275	87	57
3C	Base	49	280	87	68
4A	Base	45	295	87	72
4B	Base	45	290	87	72
4C	Base	45	290	87	75
5	Leveling			87	72
6	Leveling	63	275	87	71
7	Leveling	63	285	87	77
8	Leveling	45	275	87	65
9	Leveling	45	295	87	69
North River Road—Salem					
1	Leveling	50	339	62	45
2	Leveling	45	341	62	36
3	Leveling	75	312	60	44
4	Leveling	30	302	60	44
Sandy Blvd.—Portland					
1	Leveling		275	60	51
2	Leveling		255	60	53
3	Leveling		300	60	47
4	Leveling		320	60	50
5	Leveling	60	255	66	56
6	Leveling	120	325	66	49
7	Leveling	60	340	66	52
8	Leveling	120	325	66	49
9	Leveling	90	295	59	45
10	Leveling	90	320	59	40
11	Leveling	45	250	59	43
12	Leveling	45	330	59	38
Corvallis—South—Highway 99W					
1	Leveling		210	65	51
2	Leveling		220	65	52
3	Leveling		225	65	53

CONCLUSIONS

Results of tests indicate that:

1. When other factors are constant, the grade of asphalt used has a definite effect on the penetration of asphalt after a period of service.

2. The asphalt content is the greatest single factor that determines the amount of drop in penetration of the asphalt with service. The combination of a 87-penetration

TABLE 5
WARREN—ST. HELENS SECTION

Nos.	A.C.	Penetration										
		Orig.	10D	6 Mo.	1 Yr.	1½ Yr.	2 Yr.	2½ Yr.	3½ Yr.	6 Yr.	7 Yr.	8 Yr.
Warren—St Helens Section												
1, 2	6.8	49	41.5	37	32.5	27	28.5	23	26			24
3, 4, 13, 14, 15, 16, 9, 10, 11	5.9	58	43	35	29	27	25	24.5	19			16
Scappoose—Warren Section												
1, 2, 6, 7	6.8	87	70	58		57				59.5		
8, 4, 5, 8, 9, 10	5.5	87	58	55.5		44				26	20.5	
11, 12, 13, 14, 15	Cutback Asphalt		58	45		33.5				20		

TABLE 6
DROP IN PENETRATION ABOVE AND BELOW MIXING TEMPERATURE OF 300 F.
Original Asphalt 60–70 Penetration
Average Drop Above 300 F. 17
Average Drop Below 300 F. 12

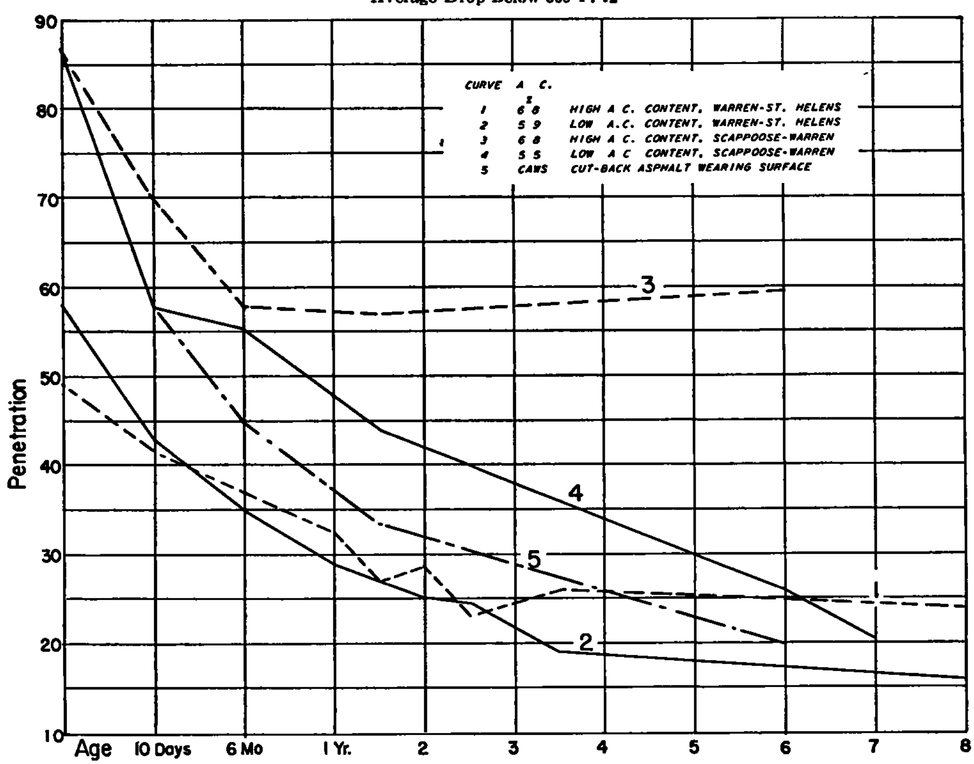

Figure 1. Variation in Penetration with Age

asphalt and a high asphalt content results in the least drop in penetration with service. The combination of 87 penetration asphalt and a low asphalt content results in reclaimed penetrations lower than those obtained from the combination of 49-penetration asphalt and a high asphalt content. The comparative drops in penetration with age in service are shown in Figure 1.

3. There is no definite relationship between

the filler content and the drop in asphalt penetration after a period of service.

4. The temperature of the mix determines the extent of asphalt penetration drop during mixing. The drop in penetration varied from 7 points at 255 F. to 21 points at 330 F.

5. The mixing time has little or no effect on the amount of drop in penetration during mixing.

6. The asphalt in cutback asphalt wearing surface hardens in approximately 6 years to the degree that incipient raveling occurs.

In order to extend the life of asphaltic concrete, the test results indicate that it would be advantageous to specify the use of 80-100-penetration asphalt, a minimum asphalt content of 6.5 per cent when sand content is between 25 and 35 per cent, and a maximum temperature of 300 F. for aggregates as they enter the mixer.

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DEPARTMENT OF MAINTENANCE

W. H. Root, *Chairman*

PROGRESS REPORT OF COMMITTEE ON MAINTENANCE COSTS

COST TRENDS 1935–1947

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SYNOPSIS

The cost of maintaining and operating our national system of state highways is at an all-time high. The trends indicated in the Committee's 1946 report showed the need for a much more detailed study of the year-by-year increase in these costs. Accordingly, this study covering the cost trends during the past 12 years was initiated.

It was determined that the best basis on which to measure these increased costs would be the actual cost of the labor, material, equipment and overhead items necessary to perform each maintenance operation on a representative 10,000 miles of highway, composed of the same proportionate amount of each surface type as contained in the entire national system of state highways. The amount of each of these items necessary for each maintenance operation was first determined The costs of these items, based on yearly reports submitted by the States and weighted in accordance with the proportionate use by each State, were then used to determine the total labor, material, equipment and overhead costs for each year. The yearly cost of each of these components and the total yearly cost were finally used to establish the cost trends, using the 1935 cost as a base.

The study discloses that the 1947 cost of maintaining and operating this representative 10,000 miles of highway throughout the United States is 71 percent higher than the 1935 cost and 58 percent higher than the 1940 cost. The labor, material, equipment and overhead components of that cost are 98, 46, 53 and 62 percent, respectively above the 1935 level and 77, 45, 43 and 47 percent, respec-