Asphalt Content Determination By the Ignition Method

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A method for the rapid determination of asphalt content has been developed in which the weight of a sample before and after removal of the asphalt by burning is utilized. Virtually complete combustion of the asphalt is achieved by subjecting the asphaltic paving mixture sample to a very high temperature and an excess of oxygen in a special, but inexpensive, furnace using oxygen and butane as fuel.

The time required to complete a test varies with the sample size, the asphalt content of the mixture, and the temperature of the mixture before beginning the test. The time required for one operator to complete a test on a 1000-gm sample is approximately 25 minutes. The ignition test equipment can be used equally well in the field or the laboratory and is simple to operate.

Results indicate that the ignition method can be used to determine from single samples the asphalt content of hot-mix paving mixtures within ±½ percent and within ±¼ percent when the results from several samples are averaged. One aspect of the ignition method in its present conception is that preliminary calibration tests must be performed to assess correction factors for different operators and aggregate types.

•A NEW method for the rapid determination of the asphalt content of an asphaltic paving mixture has been developed that utilizes the weight of a sample of the mixture before and after removal of the asphalt by burning. This ignition method achieves virtually complete combustion of the asphalt by subjecting the paving mixture sample to a very high temperature and an excess of oxygen in a special, but inexpensive, furnace using butane as a fuel.

The ignition method, which has been undergoing continual development and evaluation over the past 2½ years, requires very little equipment and is suitable for both field and laboratory use. In addition, it does not require the constant attention of an operator while the test is in progress.

EQUIPMENT

The equipment and materials required for the ignition method consist of (a) a special furnace; (b) a supply of welding grade oxygen; (c) a supply of butane, propane, or similar gas; (d) a high-capacity balance sensitive to ± 0.1 gm; (e) a device to ignite the butane-oxygen mixture; and (f) a pair of thick asbestos gloves. Figure 1 shows most of the equipment in position for conducting a test.

The furnace consists of three units: the lower unit or weighing pan, the middle unit or combustion chamber, and the upper unit or fines collector.

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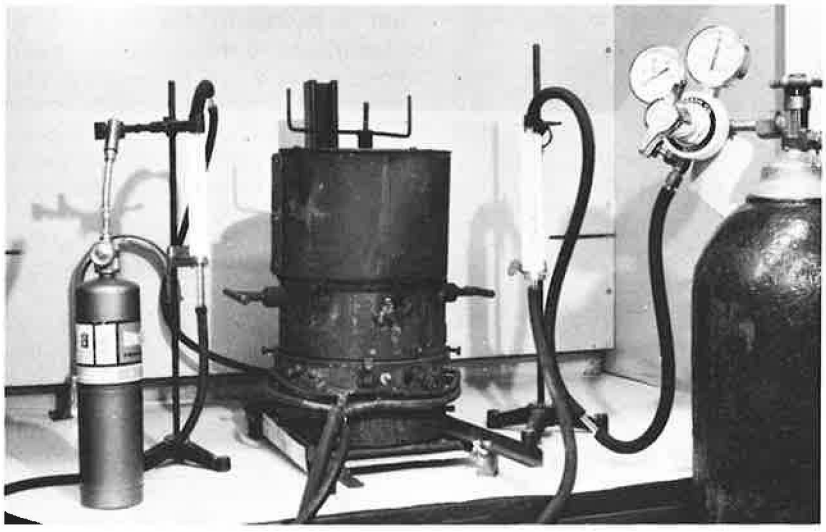

Figure 1. Ignition method equipment in position for a test.

The lower unit (Fig. 2) is a steel pan that supports the sample basket and catches any material passing through the sample basket. The sample basket consists of a Monel rod frame, a No. 40 mesh Inconel wire cloth sidewall, a No. 4 mesh Inconel wire cloth bottom, and a No. 40 mesh Inconel wire cloth sub-bottom. The sub-bottom is slightly dished to insure that material passing through the No. 4 mesh bottom will pass through the hottest zone in the combustion chamber on its way to the weighing pan.

Figure 2. Weighing pan and sample basket assembly: (a) disassembled sample basket and weighing pan with carrying frame, and (b) weighing pan and sample basket in weighing position.

The middle unit (Fig. 3a) consists of two pieces of steel tubing. The lower piece supports two separate manifolds, one supplying butane to 4 nozzles and one supplying oxygen to 4 nozzles. Also in this lower piece is an opening to permit ignition of the butane and oxygen mixture. The upper piece of the combustion chamber serves as a spacer to keep the fines collector clear of the sample basket. This upper piece has an opening that permits viewing of the sample while a test is in progress to determine when combustion of the asphalt is complete. Attached to this upper piece is a trolley unit that fits inside the vertical box member, thus enabling the combustion chamber to be raised and lowered without difficulty.

Associated with the combustion chamber are flow gages (Fig. 3b) used to regulate the amounts of oxygen and butane for each test. Sensitive flow gages were necessary because the extremely small movement of the hand-operated gas valves could

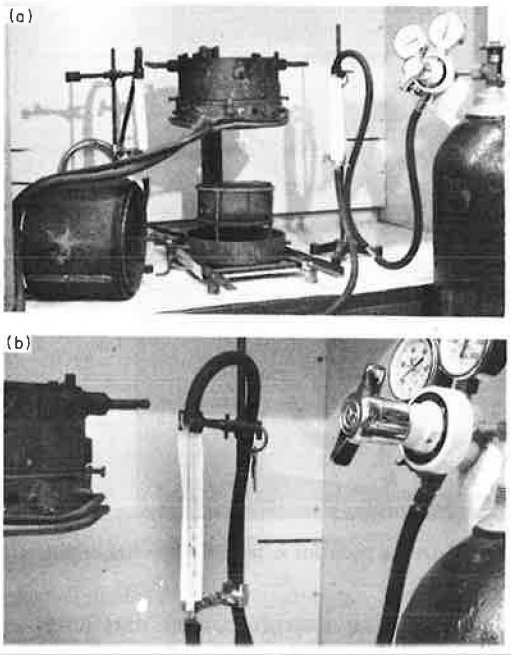

Figure 3. (a) Disassembled burner, and (b) oxygen flow gage.

not be duplicated for each test without the assistance of these gages. Each flow gage consists of a length of glass tubing in which a lightweight bead is suspended. The bead in the oxygen flow gage is attached to a piece of elastic thread and the bead in the butane flow gage is attached to a hairspring.

The upper unit consists of several pieces whose collective function is to cool the exhaust gases, trap carbon particles carried in the exhaust gases, and return aggregate fines to the combustion chamber. Figure 4 shows the fines collector in two stages of assembly, and the fully assembled fines collector appears in the lower left-hand portaion of Figure 3a. Included in the fines collector is a combination chopper-stirrer that is used to keep the burning mixture loose in the sample basket. It is estimated that the furnace could be custom made for less than $250.

PROCEDURE

The weighing pan and sample basket assembly are weighed empty before introducing a sample of the paving mixture. After the weight of the pan-basket-sample combination is recorded, the assembly is placed in position under the combustion chamber. The chamber is lowered until it is firmly seated on the weighing pan, and then the fines collector is secured in position directly above the combustion chamber.

After the furnace is assembled, oxygen is allowed to enter the combustion chamber, and the furnace ignitor is lit and its flame is directed through the lower opening in the chamber. Only then is the butane allowed to enter the combustion chamber. (Strict adherence to this sequence will avoid explosions due to an accumulation of unburned butane in the combustion chamber.) The butane and oxygen valves are then adjusted

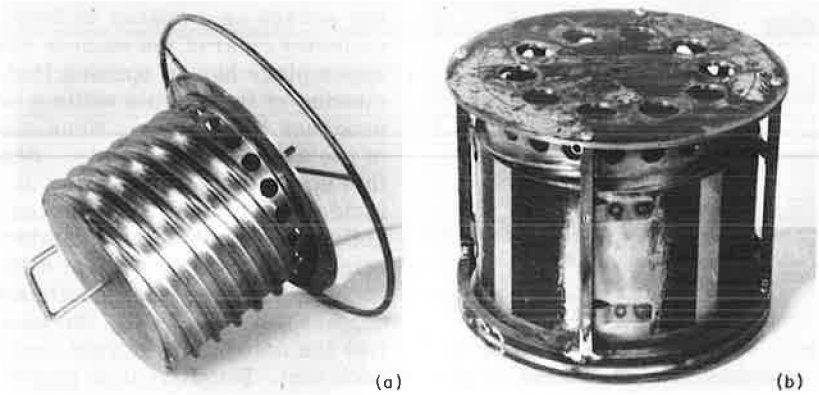

Figure 4. Fines collector: (a) innermost assembly and early version of stirrer, and (b) inner cover and frame for outer cover in place.

until the flow gages indicate that the desired amounts of fuel are entering the combustion chamber.

When the sample ignites, it is periodically agitated by the combination stirrer-chopper until the flames die out. At this point the oxygen and butane flows are terminated, the fines collector is removed, the combustion chamber is raised, and the pan-basket assembly is removed to the balance with the aid of the carrying frame. A weighing is made immediately, the burned mixture is quickly removed, and the empty pan-basket assembly is weighed again.

The two weighings made prior to the burning of the sample establish the weight of the mixture and the two weighings taken after the burning establish the weight of the mixture residue. The difference between these two weights is the weight loss due to burning, and it is equal to the weight of asphalt removed by the burning and a small loss in weight of the aggregate due to the high temperature (approximately 1500 F) in the combustion chamber. The correction for the aggregate weight loss must be determined by burning a mixture with a known asphalt content.

The time needed to complete a test varies with the asphalt content of the mixture, the temperature of the mixture prior to starting the test, and the size of sample. Mixtures with high asphalt contents and large sample sizes take longer to burn; preheated mixtures take less time. The asphalt content of mixtures at room temperature and with normal asphalt contents can be determined in 20 to 35 minutes with 10 to 25 minutes of this being the actual burning time for a 1000-gm sample.

Tests conducted during the development and evaluation of the ignition method used approximately 20 cu ft of oxygen and less than 1 cu ft of butane per test. It is estimated that for 1000-gm samples and a normal range of asphalt contents, the combined oxygen and butane cost would be approximately 20 cents per test.

TEST METHOD EVALUATION

Evaluation of the ignition method included consideration of (a) time per test, (b) aggregate weight loss, (c) aggregate type, (d) aggregate breakage, and (e) test reproducibility.

Time Per Test

During the development of the ignition method it became apparent that sample size affected the burning time, and burning times varied for a given sample size. A program to evaluate the variation in burning times was carried out by having one operator perform a number of tests on one mixture. Table 1 gives the total time needed to complete each test. The time required for completely burning a 1000-gm sample was 30 minutes or less, and several operators consistently completed 8 or more tests in a 4-hr period. Table 1 indicates that the length of time required to complete a test increases with the sample size, but the test time per gram of sample decreases with increasing sample size.

TABLE 1

RELATIONSHIP OF SAMPLE SIZE AND TIME PER TEST

Sample No.	Total Time for Test[a] (minutes)			
	Mix 7[b]	Mix 8[b]	Mix 9[b]	Mix 10[b]
1	21.5	23.2	23.5	29.0
2	15.6	22.3	22.5	31.0
3	13.0	20.5	21.3	30.5
4	13.0	21.5	20.2	32.2
5	13.5	20.2	19.5	27.8
6	15.8	19.5	19.0	29.3
7	13.5	19.0	21.8	29.5
8	13.5	20.7	23.8	28.8
9	15.3	19.8	22.5	28.8
10	13.7	19.5	22.2	29.0
Average time	14.8	20.6	21.6	29.6
Sample size	500 gm	750 gm	1000 gm	1500 gm

[a]Time measured from start of test to start of next test.
[b]Mixture is identified and described in Tables 5 and 6.

Aggregate Weight Loss

Early work indicated that heating aggregates alone in the burner did not subject the aggregate to the same conditions that prevail when burning asphalt is present. Therefore, two

series of burnings were conducted on asphalt-aggregate samples prepared with graded crushed stone aggregate. One series consisted of samples prepared in the basket by pouring on a predetermined weight of asphalt. The second series consisted of samples that were mixed one at a time in a mechanical mixer.

The difference between weight loss on burning and known weight of the asphalt was assumed to be aggregate weight loss since the exact amounts of asphalt and aggregate in the sample were known. The weight discrepancy in the second series was also assumed to be aggregate weight loss; however, in this case it was necessary to calculate the amounts of asphalt and aggregate in the sample by correcting the batch weights by the amounts of asphalt and aggregate retained in the mixing bowl after discharging the mix into the sample basket.

In neither case was there an obvious relationship between asphalt content and aggregate weight loss. The variability of these results is due, in part, to laboratory technique because several different laboratory technicians conducted the tests. There is, however, a distinct difference in the magnitude of aggregate weight loss when the unmixed samples are compared with the mixed samples. The average aggregate weight loss for 21 unmixed samples was 4.4 gm, while the average aggregate weight loss for 17 mixed samples was 7.1 gm. This difference supports earlier observations that burning asphalt produces a more severe heating condition. The unmixed samples did not have a uniform coating of asphalt around every aggregate particle, and consequently the aggregate particles were not heated to temperature extremes responsible for aggregate breakdown.

Results of several hundred tests conducted on plant-mixed samples confirm that there is an aggregate weight loss. Average apparent losses are tabulated in the last column of Table 7. They were obtained by taking the difference between the average asphalt content indicated by the ignition method and the job mix asphalt content. The exact value of the aggregate contribution cannot be determined from the values listed in Table 7 because several aggregate types are represented. In all likelihood, the asphalt content as determined by the centrifuge test is not the true asphalt content of the mixture (1, 2), and hence it was not used to calculate the apparent aggregate contribution. Use of the asphalt content as calculated from actual batch weights would have been preferred for determining the apparent aggregate contribution, but batch weights were not available for any of the mixes.

Aggregate Type

Burnings were made to determine if various aggregate types would lose more weight than others when subjected to the high temperatures present in the combustion chamber. Much of the data collected did not indicate significant differences in aggregate weight loss.

Results for one series of tests in which a single operator conducted all the tests are given in Table 2. Two mixes were made in the laboratory and each contained the same amount of asphalt, fine aggregate, and coarse aggregate; however, limestone was used as the coarse aggregate in one mix and granite gneiss was used in the other mix. The results of this series of tests indicated that there was a greater weight loss for mixes made with limestone than for mixes made with granite gneiss.

TABLE 2

INFLUENCE OF AGGREGATE TYPE ON INDICATED ASPHALT CONTENT

Coarse Aggregate Type	Size of Mix[a] (gm)	Total Weight Loss per 1000 Grams of Mix (gm)	Indicated Asphalt Content (percent)	Estimated Asphalt Content of Mix[b] (percent)
Granite gneiss	3493	54.2	5.4	5.4
Limestone	3505	59.0	5.9	5.4

[a]Mix split into three samples prior to burning.
[b]Batched asphalt content corrected by subtracting asphalt retained on mixing equipment.

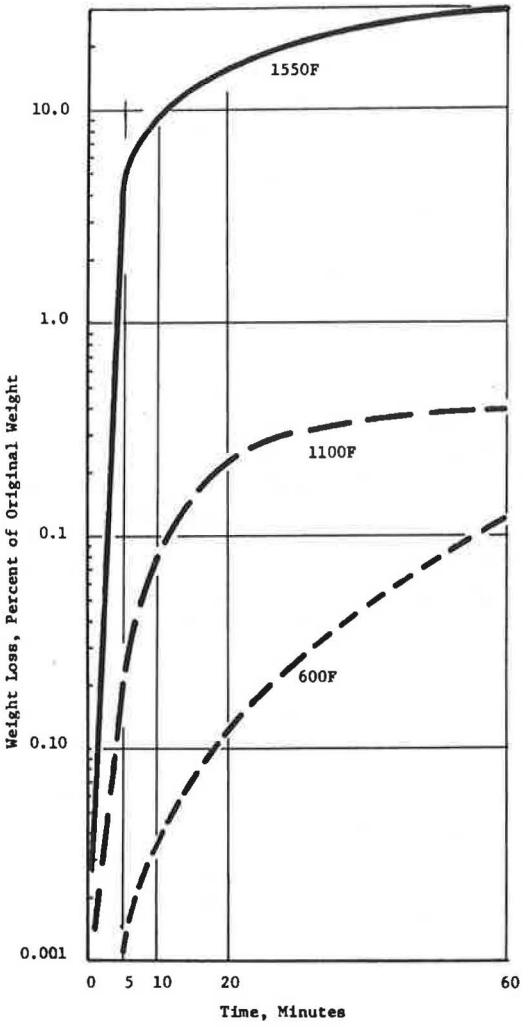

Figure 5. Weight loss—time relationships for limestone at 600, 1100, and 1550 F.

X-ray diffraction tests on granite gneiss were made before and after a normal ignition test. Test results indicated that with this aggregate no mineralogical changes took place during burning.

Additional laboratory testing was conducted to determine the weight loss that occurred at elevated temperatures for both limestone and granite gneiss. Oven-dry samples of these aggregates were placed in an electric furnace and heated for 1 hour. Test temperatures were 600, 1100, and 1550 F. Periodically, the samples were removed from the furnace and weighed on an analytical balance.

The weight loss for granite gneiss was negligible for all test temperatures used in this study. Results from the weight loss on heating test for limestone are shown in Figure 5. Although the weight loss at 600 F is negligible, the weight loss for limestone becomes significant for higher test temperatures and after longer periods of heating. The limestone lost approximately 30 percent of its oven-dry weight after being heated to 1550 F for 1 hour.

After heating, the limestone was frangible and exhibited a distinct color change. Although frangibility and color changes in limestone were not evident after normal 25-minute ignition tests, results of the loss on heating tests performed at 1550 F indicate that precaution must be exercised in using the ignition method if it involves prolonged heating of aggregates that decompose significantly at elevated temperatures.

The weight losses occurring at elevated temperatures in the electric furnace were also corrobrated by results of burnings conducted on mixes 22 and 23 (Table 7). These two mixes were made with a limestone aggregate and appeared to have a greater "apparent aggregate contribution" than mixes 1 through 10, which were made with granite gneiss.

Mixes 11 through 25 (Table 7) were purposely selected to give, among other things, a variety of aggregate sources. The results obtained were not adequate for a complete statistical analysis, but the existence of several possible interactions between effects, such as mix type, aggregate type, and operator, is likely.

Aggregate Breakage

The possibility of aggregate breakage due to temperature-induced stresses was investigated by determining the aggregate gradation of several 1000-gm samples before and after burning.

The laboratory phase of this part of the investigation involved three separate aggregate conditions. In the first condition, the aggregate was batched as if a mixture were to be made and then a sieve analysis was conducted. In the second condition, a sieve analysis was conducted on aggregate that was batched, mixed with asphalt in the mechanical mixer, and then washed with a solvent to remove the asphalt from the mixture.

TABLE 3

SIEVE ANALYSIS RESULTS: STANDARD LABORATORY MIX[a]

Sieve Size	Percent Passing					
	After Batching	After Mixing and Solvent Extraction (2 samples)		After Burning (3 samples)		
½ in.	100	100	100	100	100	100
No. 4	54.4	52.8	53.5	63.2	61.6	61.1
No. 8	39.6	36.0	38.2	46.2	45.7	44.5
No. 30	18.6	17.6	17.3	22.0	22.3	22.3
No. 200	3.5	3.5	3.1	3.6	3.5	4.6

[a]All aggregate from the Liberty, South Carolina, quarry of Campbell Limestone Company.

In the third condition, a sieve analysis was conducted on a mixture after removal of the asphalt by burning. In each case, samples containing 6 percent asphalt by weight of the aggregate were prepared from granite gneiss aggregate of the same type, amount, and gradation. The results of these tests are given in Table 3. It is evident from these results that the larger sizes were degraded more than the smaller sizes.

Several plant-mixed samples of approximately 1000 gm were also burned, and sieve analyses were conducted on the aggregate residues. Results of this series of tests, given in Table 4, also indicate that the larger aggregate sizes were subject to some degradation.

Test Reproducibility

Over a period of approximately one year, 22 samples of plant mixtures were obtained for the primary purpose of checking the reproducibility of results obtained by the ignition method.

Data for 262 burnings conducted on the samples of plant mixtures are given in Table 5. Table 6 identifies each mixture and Table 7 summarizes various properties of each mixture.

Information summarized in Tables 5 and 7 indicates that a series of burnings on the same mixture gives total weight losses that do not fluctuate widely. The standard deviation for each group of burnings is small, except for mixtures 17 and 22, and the coefficient of variation is less than 5 percent for 19 of the 25 mixtures listed. An analysis

TABLE 4

SIEVE ANALYSIS RESULTS: PLANT MIXTURES

Sieve Size	Percent Passing				
	Surface Mix[a]		Binder Mix[a]		
	Burned Sample	Job-Mix Formula	Burned Sample	Job-Mix Formula	S. C. State Highway Dept. Analysis
1 in.			100	100	100
¾ in.			—	93	98.5
½ in.	100	100	82.6	75	75.5
⅜ in.	—	90	—	—	—
No. 4	71.9	68	40.5	36	35
No. 8	60.7	56	33.1	—	—
No. 10	—	—	—	26	28.5
No. 30	37.8	33	22.5	—	—
No. 100	—	14	—	—	—
No. 200	8.4	7	3.8	—	—

[a]Mixed at the Liberty, South Carolina, plant of Sloan Construction Company.

TABLE 5

DATA FOR BURNINGS MADE ON PLANT MIXTURES

Sample No.	Total Weight Loss Due to Burning (gm)												
	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9	Mix 10	Mix 11	Mix 12	Mix 13
1	63.0	59.1	58.6	66.0	55.4	36.7	30.9[a]	49.8	63.4	99.0[a]	66.0	60.0	52.0
2	64.3	57.6	58.9	63.6	52.6	36.7	30.9	48.0	63.7	97.3	67.0	59.8	54.0
3	68.9	56.5	59.5	65.7	53.1	35.8	31.1	50.3	63.0[a]	96.0	65.6	60.0	51.5
4	65.3	57.5	61.0	61.4	53.3	30.7	31.8	50.6	64.2	91.7[a]	66.0	63.0	49.0
5	65.3	55.8	62.0	63.0	55.8	38.2	31.8	46.0[a]	65.1	93.6	65.0	60.2	55.0
6	67.5	61.6	64.0	61.1	55.0	41.3	32.6[a]	47.7	63.7	96.0	67.5	60.5	55.0
7	62.3	63.3	62.5	67.9	56.0	37.1	32.9	47.9	62.9[a]	91.3[a]	66.2	58.0	56.0
8	63.5	61.2	63.8	68.0	52.0	38.0	32.3	46.2[a]	66.0	95.5	67.0	56.0	50.8
9	62.8	59.3	62.1	69.3	56.0	37.9	30.8	46.8	63.2	96.1	65.0	56.5	54.0
10	63.0	59.8	62.3	63.7	54.0	38.1	32.9	49.3	66.3	96.1	63.6[b]	54.4	55.5
11	64.9	58.5	62.9	69.9	50.6						66.0	53.0	51.1
12	62.1	59.0	63.2	68.8	61.7								
13	67.0	59.8	58.3	68.3	57.6								
14		56.1	59.5		52.8								
15					53.9								
Sample size	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	500 gm	750 gm	1000 gm	1500 gm	1000 gm	1000 gm	1000 gm
Operator	A	B	C	A	A	B	D	D	D	D	E	E	E

Sample No.	Total Weight Loss Due to Burning (gm)											
	Mix 14	Mix 15	Mix 16	Mix 17	Mix 18	Mix 19	Mix 20	Mix 21	Mix 22	Mix 23	Mix 24	Mix 25
1	64.7	70.7	73.3	42.5	42.4	54.1	67.6	54.4	48.9	88.9[b]	71.4	66.7
2	68.0[b]	71.8	68.1	40.4	51.2	51.3[b]	66.4	52.5	58.6	88.6[b]	70.0	70.2
3	68.6	66.7[b]	77.8	36.8	44.4	57.3	70.8	53.0	63.6[b]	96.8	66.7	67.6
4	65.0[b]	70.1	78.0[b]	41.3	47.8	62.8	66.3	53.6	53.6	94.8	66.4	66.5
5	63.9[b]	68.5	74.1[b]	49.7[b]	44.3	53.1	65.0	54.7	61.5[b]	89.7[b]	72.1	66.9
6	67.0	67.9	73.4[b]	42.7	48.8	60.5	68.7[b]	53.0	47.9	90.5	69.7	65.8
7		72.1	74.7	48.7[b]	47.3	60.2	65.6	53.0[b]	32.7	92.0	69.8	67.5
8		70.6	73.6	56.5	44.7[b]	54.3	64.6	53.7	63.4[b]	93.1	67.6	66.5
9		68.5[b]	76.2	55.2	46.8	59.2	65.7	54.0			65.6	
10		68.4	72.4	47.7	49.8	54.6[b]	67.2	54.1			68.9	
Sample size	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm	1000 gm
Operator	E	F	F	F	F	F	F	F	F	F	F	F

[a]Sample was first sample to be burned on a given day.

[b]Appearance of sample after burning indicated complete combustion was not obtained.

TABLE 6

IDENTIFICATION OF PLANT MIXTURES IN TABLE 5

Mix No.	Mixture Type[a]	Mixture Source	Aggregate Designation	Aggregate Type
1, 2, 3	Surface 1	Liberty, S.C., Sloan Const. Co.	Liberty	Granite gneiss
4	Surface 1	Liberty, S.C., Sloan Const. Co.	Liberty	Granite gneiss
5	Binder 2	Liberty, S.C., Sloan Const. Co.	Liberty	Granite gneiss
6	Black base	Liberty, S.C., Sloan Const. Co.	Liberty	Granite gneiss
7, 8, 9, 10	Surface 1	Liberty, S.C., Sloan Const. Co.	Liberty	Granite gneiss
11	Surface 1	Columbia, S.C., Sloan Const. Co.	Palmetto	Granite
12	Binder 2	Greenville, S.C., Ashmore Bros., Inc.	Lakeside	Granite gneiss
13	Binder 2	Pacolet, S.C., Sloan Const. Co.	Pacolet	Granite gneiss
14, 15	Surface 1	Columbia, S.C., Sloan Const. Co.	Palmetto	Granite
16	Surface 1	Greenwood, S.C., Sloan Const. Co.	Palmetto	Granite
17	Black base	Columbia, S.C., Sloan Const. Co.	Palmetto	Granite
18	Black base	Pacolet, S.C., Sloan Const. Co.	Pacolet	Granite gneiss
19	Binder 2	Columbia, S.C., Sloan Const. Co.	Palmetto	Granite
20	Surface 1	Pacolet, S.C., Sloan Const. Co.	Pacolet	Granite gneiss
21	Sand asphalt	Kershaw, S.C., Asphalt Products Corp.	Kershaw	Quartz and feldspar
22	Black base	Charlotte, N.C., Rea Const. Co.	Kings Mtn.	Limestone
23	Surface 1	Charlotte, N.C., Rea Const. Co.	Kings Mtn.	Limestone
24	Surface 1	Greenville, S.C., Ashmore Bros., Inc.	Lakeside	Granite gneiss
25	Surface 1	Sumter, S.C., Asphalt Products Corp.	Hagood	Quartz and feldspar

[a]Each mixture manufactured to conform with applicable Highway Department specifications.

TABLE 7

ANALYSIS OF BURNINGS MADE ON PLANT MIXTURES

Mix No.	Average Total Weight Loss (gm)	Range	n[a]	s[b]	C[c] (percent)	Indicated Asphalt Content (percent by wt. of mix) (A)	Asphalt Content by Centrifuge Test (percent)	Job Mix Asphalt Content (percent) (B)	Apparent Aggregate Contribution (percent) (A) - (B)
1	64.6	62.1-68.9	13	2.12	3.3	6.46	NA[d]	6.0	+0.5
2	58.9	55.8-63.2	14	2.16	3.6	5.89	NA	6.0	-0.1
3	61.3	58.3-64.0	14	2.01	3.3	6.13	NA	6.0	+0.1
4	65.9	61.1-69.9	13	3.05	4.6	6.59	6.1	6.1	+0.5
5	54.7	50.6-61.7	15	2.68	4.9	5.47	4.6	4.6	+0.9
6	37.0	30.7-41.3	10	2.67	7.2	3.70	NA	3.9	-0.2
7	31.8	30.8-32.9	10	0.8	2.5	6.36	6.1	6.0	+0.4
8	48.3	46.0-50.6	10	1.7	3.5	6.44	6.1	6.0	+0.4
9	64.2	62.9-66.3	10	1.2	1.9	6.42	6.1	6.0	+0.4
10	95.3	91.3-99.0	10	2.4	2.5	6.35	6.1	6.0	+0.4
11	65.9	63.6-67.5	11	1.1	1.7	6.59	6.0	6.1	+0.5
12	58.3	53.0-63.0	11	3.0	5.1	5.83	4.8	4.8	+1.0
13	53.1	49.0-56.0	11	2.3	4.3	5.31	4.5	4.7	+0.6
14	66.2	63.9-68.6	6	1.9	2.9	6.62	6.0	6.1	+0.5
15	69.5	66.7-72.1	10	1.8	2.7	6.95	6.0	6.1	+0.9
16	74.2	68.1-78.0	10	2.9	3.9	7.42	NA	NA	—
17	46.2	36.8-56.5	10	6.5	14.1	4.62	4.0	NA	—
18	46.8	42.4-51.2	10	2.8	6.0	4.68	4.0	NA	—
19	56.7	51.3-62.8	10	3.8	6.7	5.67	4.8	5.0	+0.7
20	66.8	65.0-70.8	10	1.9	2.8	6.68	5.9	6.2	+0.5
21	53.6	52.5-54.7	10	0.7	1.3	5.36	NA	4.5	+0.9
22	53.8	32.7-63.6	8	10.5	19.5	5.38	NA	4.0	+1.4
23	91.8	88.6-96.8	8	2.9	3.2	9.18	NA	6.0	+3.2
24	68.8	65.6-72.1	10	2.2	3.2	6.88	6.2	6.0	+0.9
25	67.2	65.8-70.2	8	1.3	1.9	6.72	5.9	5.5	+1.2

[a]Number of burnings.
[b]Standard deviation (total weight loss).
[c]Coefficient of variation.
[d]Value not available.

TABLE 8

ASPHALT CONTENT BY IGNITION METHOD AND CENTRIFUGE TEST

Mix Identification
Mix No.: 26 Mixture type: Surface 1 Mixture source: Liberty, S.C., Sloan Construction Co. Aggregate designation: Liberty Aggregate type: Granite gneiss Job-mix asphalt content: 6.0 percent Centrifuge test asphalt content: 6.02 percent (test run at batch plant) Sample size: 1000 gm

Test Results

Item	Indicated Asphalt Content (percent by wt. of mix)	
	Ignition Method	Centrifuge Test[a]
Sample 1	6.45	6.23
Sample 2	6.74	6.09
Sample 3	6.50	5.86
Sample 4	6.74	5.95
Sample 5	6.41	5.93
Sample 6	6.67	6.00
Sample 7	6.49	6.14
Sample 8	6.50	6.05
Sample 9	6.30	5.53
No. of samples	9	9
Avg. indicated A/C	6.53%	5.98%
Range of indicated A/C	0.44	0.70
Standard deviation	0.14	0.20
Coefficient of variation	2.2%	3.3%

[a]Tests performed by South Carolina State Highway Department personnel.

of the ranges of total weight loss values for the mixtures indicated that, for most of the mixtures listed, the range for indicated asphalt contents of a particular mixture would be 1 percent or less. It was noted from data obtained for mixtures 7, 8, 9, and 10 (Table 5) that data from the first burning of a series were apparently compatible with data from subsequent burnings even though the equipment was relatively cool at the beginning of the test. Weight-loss data tabulated for mixtures 11 through 13 in Table 5 are inconsistent because burning was not complete for a number of samples. Yet a close inspection of the data indicates that an incomplete burn did not result in a weight loss significantly different from weight losses for complete burns.

The presence of an operator effect is the only effect that could be established with some degree of confidence. This was done by performing a statistical analysis of the data listed for mixtures 1, 2, and 3, and mixtures 14 and 15. F-tests at an α-level of 0.05 result in the acceptance of the hypothesis that the population variances are equal and t-tests at an α-level of 0.05 result in the rejection of the hypothesis that the population means are equal. Hence, it can be said that the variances obtained are probably caused by the material and the test method, while the differences in the mean indicated asphalt contents probably can be attributed to the operators.

Limited testing was done to determine if the reproducibility of results obtained by the ignition method is any better than the reproducibility of results obtained by using the centrifuge test. Table 8 gives the asphalt contents obtained by testing eighteen 1000-gm samples taken from a plant-made surface mix. The statistics given in Table 8 suggest that when the aggregate contribution is known, the ignition method is as good as the centrifuge test for determining the asphalt content of a surface mix.

CONCLUSIONS

Tests on laboratory-made and plant-made mixtures have established that the ignition method can be used to determine from single samples the actual asphalt content of hot-mix asphaltic paving mixtures within ± ½ percent, and possibly within ± ¼ percent when the results from several samples are averaged and a calibration factor for the particular operator-mix combination is applied. The method may also be used for other types of mixtures provided that heating does not cause significant weight loss in the aggregates.

The time required for one operator to complete a test on a 1000-gm sample is approximately 30 minutes. The test method is simple and no more than one demonstration is needed to acquaint operators with proper use of the equipment. The equipment is not sophisticated and is estimated to cost approximately $250. The only significant operating cost is the cost of fuel, which was 20 cents per burn for 1000-gm samples. In spite of the fact that the ignition method has been evaluated on hot-mix asphaltic paving mixtures, it is not limited to this type of mixture.

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