RAPID DETERMINATION OF ASPHALT CONTENT USING PENNSYLVANIA PYCNOMETER

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This paper describes the development and testing of the Pennsylvania pycnometer proposed for rapid determination of asphalt content. The method is based on the procedures of ASTM D 2041-67, which have been modified to achieve greater accuracy and precision essential for asphalt content determinations. The Pennsylvania pycnometer has been found to be practical in use and free of operating inconveniences. Asphalt content is determined in approximately 30 min by weight-volume relation and by the aid of nomographs. Paving mixtures containing limestone, sand, gravel, and slag aggregates have been tested for asphalt content. Results are compared to those obtained by use of the reflux equipment. The test data have been analyzed statistically. Greater accuracy is indicated in the results obtained by the Pennsylvania pycnometer. For highly absorptive aggregates, which present problems in complete retrieval of the asphalt, the pycnometer method has better proficiency than the reflux method.

•ASPHALT content is one of the most important factors in the overall quality of asphaltic concrete pavements. As little as 0.5 percent too much asphalt can cause flushing and rutting; an asphalt deficiency of 0.5 percent may cause premature cracking or raveling of the pavement. Thus, a close control of asphalt content is essential for optimum durability and serviceability. The amount of asphalt cement is also important economically because it is the most expensive ingredient in the mix.

Current methods for quantitative extraction of bitumen from bituminous paving mixtures (AASHO T 164-70) consist of four procedures. Although these procedures are relatively simple and have been used for many years, they are extremely time-consuming to perform, and the results obtained are often of questionable value. With the high production capacity of modern asphalt plants, it is essential that test methods be available that can provide an accurate measure of asphalt content within minutes if a meaningful degree of control is to be employed. It is not uncommon for a modern plant to produce 100 to 200 tons of mixture per hour. Therefore, one can readily visualize the possible difficulties that could arise if 3 or 4 hours were required to obtain a test result. The problem could be complicated even further if a check test or tests are necessary. By this time, several hundred tons of mixture would be laid and compacted, thereby making appropriate adjustments in asphalt content impossible for the mixture already placed on the grade.

There is need, therefore, to devise a method that can strike a proper balance among accuracy of test results, cost of equipment, speed with which the test can be performed, and technician training required. To be of optimum value, such a method must be readily adaptable to both laboratory and field use.

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REVIEW OF LITERATURE

Various methods (1, 2) have been investigated for extracting asphalt from asphaltic concrete, some of which were adopted as ASTM or AASHO standard tests subsequently. Besides being time-consuming, these methods have too much variation in the asphalt content results. Steele and Krieger (3) conducted statistical evaluation of equipment and operator effects on the results of asphalt extraction tests and reported significant differences among operators and among laboratories.

In a study (4) undertaken by the Pennsylvania Department of Transportation in 1969 for determining the variations of results among asphalt plant laboratories, significant differences were noted.

Several improvements have been suggested to reduce the time required for extraction. Jones et al. (5) suggested vacuum extraction of asphalt from paving mixtures using methylene chloride as a reagent.

The principle of using nuclear radiation to measure the asphalt content of paving mixtures was established several years ago by Lamb and Zoller (6); since then, it has been investigated by many researchers. Some drawbacks have been reported by Hughes (7) in this method. An improved nuclear gauge for determining asphalt content in the field has also been studied recently (8).

Stain method (9) has been proposed for fine-graded asphaltic concrete mixtures, but it has several limitations such as operator technique and errors related to the amount of fines in the paving mixture. Flask method (10) requires constant attention to ensure complete dissolution of the asphalt by the solvent. The ignition method (11), in which the weight of a sample before and after removal of the asphalt by burning is used, has been reported to show an operator effect associated with the test method.

Steele and Hudson (12) attempted the asphalt content determination by weight-volume relation based on the procedure of ASTM D 2041. The research work under report is also based on the same concept, but a new apparatus and procedure have been developed and tested involving mixtures containing different types of aggregates and varying asphalt contents.

BACKGROUND AND DEVELOPMENT OF TEST APPARATUS

The concept of determining the maximum specific gravity of bituminous paving mixtures was developed by James M. Rice under the auspices of the National Crushed Stone Association. This contribution is growing in importance as the use of absorptive aggregates becomes increasingly necessary. The vacuum saturation technique employed in this method makes possible the determination of the effective specific gravities of the aggregate and both the effective and total asphalt content of the paving mixture. It has been recognized that, when the average specific gravities of the aggregate remain constant, the major factor affecting the maximum specific gravity of the paving mixture is the volume of asphalt. Under these conditions, the vacuum saturation procedure affords a rapid means for determining asphalt content.

MATHEMATICAL COMPUTATIONS

There are two parts to the required computations (12). The first part is to find the specific gravity of the asphalt-aggregate mixture and then to determine the ratio of asphalt to total mix that corresponds to this specific gravity.

The maximum specific gravity of the mixture is computed by the use of Eq. 2 in ASTM C 2041:

$$\text{Specific gravity } G_m = \frac{A}{A + D - E} \tag{1}$$

where

A = weight of specimen (mix) in air,
D = weight of pycnometer filled with water at test temperature, and
E = weight of pycnometer filled with water and specimen at test temperature.

Figure 1. Work sheet 1.

BITUMEN CONTENT OF PAVING MIXTURES--PENNSYLVANIA PYCNOMETER METHOD

Project No. ______________ Producer ______________
Type Aggregate ______________ Plant ______________
Mix Type ______________ Location ______________

Line		Sample Identification					
1	Wt. Pyc. + Mix						
2	Wt. dry Pyc.						
3	(1-2) = Wt. of Mix (A)						
4	Wt. Pyc. + Water (D)						
5	Line 3 + Line 4						
6	Wt. Pyc. + Mix + Water (E)						
7	(5-6) = Vol. of voidless Mix						
8	(3 ÷ 7) = Max. Sp. Gr. of Mix, G_m						
9	(G_a ÷ 8)-1						
10	(J x 9) = % Bitumen						

G_a	Effective Specific Gravity - Aggregate =
G_b	Specific Gravity - Asphalt =
F	$G_a - G_b$ =
J	(100 x G_b) ÷ F =

Operator ______________ Date ______________
Laboratory ______________

Figure 2. Work sheet 2.

EFFECTIVE SPECIFIC GRAVITY OF AGGREGATE (G_a)

Type Aggregate ______________ Producer ______________
Mix Type ______________ Plant ______________

Line			Sample Identification					
1	Line 8 (G_m) of Sheet No. 1	G_m						
2	Known % bitumen	P						
3	Sp. Gr. of bitumen	G_b						
4	Line 2 ÷ Line 3	P/G_b						
5	100.0 - Percent bitumen	100-P						
6	Line 1 x Line 4	$(G_m \times P)/G_b$						
7	Line 1 x Line 5	G_m (100-P)						
8	100.0 - Line 6	$100-G_mP/G_b$						
9	Line 7 ÷ Line 8 = Eff. Sp. Gr.	G_a						

Operator ______________
Date ______________

Figure 1, steps 1 through 8, can be used to solve this equation.

The relation of this specific gravity G_m to the specific gravities of the asphalt and the combined mineral aggregates, and their respective percentages in the mixture, is expressed by the following equation:

$$G_m = \frac{100}{\frac{P}{G_b} + \frac{100 - P}{G_a}} \qquad (2)$$

where

G_m = specific gravity of the mixture as determined by Eq. 1,
G_b = specific gravity of the asphalt at test temperature,
G_a = effective specific gravity of the combined mineral aggregate at test temperature, and
P = percentage of total mix by weight of asphalt.

For convenience in repeated use, Eq. 2 can be rearranged algebraically (12) and written as follows:

$$P = \frac{100\ G_b}{G_a - G_b}\left(\frac{G_a}{G_m} - 1\right) \qquad (3)$$

The effective specific gravity G_a of the combined aggregates is not necessarily the specific gravity as determined by standard methods. It is found experimentally by testing specimens of known asphalt content and substituting in Eq. 3 the known values of P, G_b, and G_m. G_m is determined by Eq. 1. Effective specific gravity of the aggregates can be conveniently determined by completing steps 1 through 9, Figure 2.

The first part of Eq. 3 is a constant for any particular asphalt-aggregate combination, and is computed using Figure 1. The percentage of asphalt is computed in steps 9 and 10, Figure 1.

Steele and Hudson (12) used this concept and were able to determine the asphalt content with much success, though their adaption of a vacuum dessicator as a pycnometer resulted in some operating inconveniences.

There was a need to develop an apparatus for practical use in the field as well as in the central laboratory. It was desired to have the following features to eliminate operating inconveniences and to obtain better reproducibility of the test results:

1. The pycnometer should be of such size that its manual handling to release the air bubbles is easy and convenient. A pycnometer of 4,000-ml capacity was considered to be suitable.

2. The pycnometer should be transparent, strong, and reasonably resistant to scratching. This would facilitate the observation of air bubbles while applying vacuum. Therefore, a heavy-wall glass pycnometer was considered. As compared to plastic or other material, glass is more resistant to scratching by the aggregates in the mix. Being inexpensive, it can be replaced when too much scratching is caused by prolonged use.

3. The construction of the pycnometer should be such that a stirring rod is accessible to all the areas within the pycnometer to manipulate air bubbles. The proposed Pennsylvania pycnometer (Fig. 3) has a wide mouth and a tapered shape to meet this requirement.

4. The pycnometer should be of rigid construction. Flexibility is not desirable because the pycnometer can distort under stresses when handled, introducing error in its constant volume.

5. A fine capillary stopper and overflow cap were desired to have increased precision in calibration and testing.

To meet these requirements, the authors developed the Pennsylvania pycnometer (Fig. 3) for practical use in both the field and the laboratory. The apparatus and its accessories are shown in Figure 4. Approximate total cost is $80.00. It is possible to determine the asphalt content in approximately 30 min.

Figure 3. Pennsylvania pycnometer, 4,000-ml capacity.

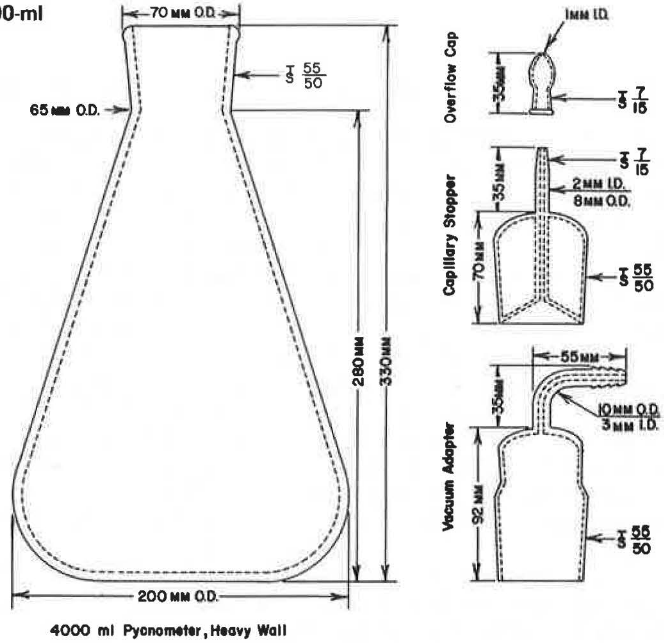

Figure 4. Pennsylvania pycnometer assembly with accessories.

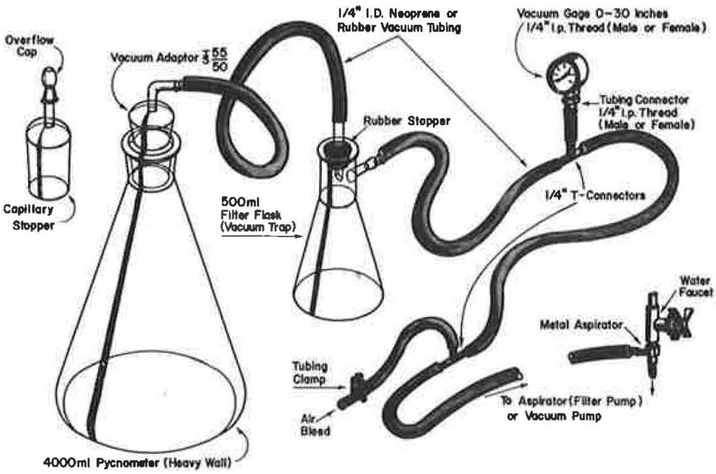

Table 1. Asphalt content test data.

Limestone			Sand and Gravel			Slag		
Actual	Extraction	Pycnometer	Actual	Extraction	Pycnometer	Actual	Extraction	Pycnometer
4.96	5.10	4.75	5.94	5.90	6.14	6.96	6.80	6.56
4.96	4.90	4.87	5.95	5.70	5.88	6.98	7.10	6.93
4.96	4.90	5.15	5.96	5.90	6.01	7.02	7.10	6.68
5.95	5.60	6.01	6.94	7.30	6.84	7.96	8.30	7.54
6.00	6.00	6.01	6.94	6.70	7.16	7.98	8.00	7.72
6.01	6.10	5.96	6.94	6.90	6.08	7.99	7.70	7.85
6.88	6.80	6.87	7.89	7.70	8.06	8.95	9.20	9.07
6.92	6.90	6.87	7.92	7.70	7.80	8.97	9.00	8.89
7.04	7.00	7.04	7.93	7.70	8.12	9.96	10.00	10.54
7.91	7.91	8.02	8.81	8.50	8.95	9.97	10.40	10.36
7.93	7.93	8.02	8.86	8.60	8.83	10.05	9.90	10.54
8.13	8.20	8.19	8.91	8.60	9.08	–	–	–
Average difference from actual	-0.026	+0.009		-0.149	-0.003		+0.104	-0.010

Note: All materials ID-2 wearing course mixtures.

TEST PROCEDURE AND DISCUSSION OF RESULTS

The detailed test procedure is given in the Appendix. The proposed method was attempted on Pennsylvania ID-2 and FJ-1 wearing course mixtures containing known asphalt contents. Series of mixtures were prepared with limestone, sand, gravel, and slag aggregates to check if the method is applicable to all types of aggregate. One highly absorptive sand and gravel aggregate that had posed problems in complete extraction of the asphalt was also included in the study. Quantitative extraction of asphalt from these paving mixtures was also carried out by AASHO T 164-70 (method D) with some modifications. Test data on asphalt content by these two methods are given in Tables 1 and 2 together with the actual asphalt content.

For statistical comparisons, the asphalt contents obtained by the two procedures have been paired with the actual asphalt content. By using this approach, as suggested by Snedecor and Cochran (13), it is possible to discover and evaluate the differences among results rather than the results themselves. With only a single pair, it is impossible to say whether the difference in behavior is to be attributed to the difference in treatment, to the natural variability of the mixes, or partly to both. Therefore, several pairs of test data from mixtures containing different asphalt contents have been used in the statistical analysis. Besides test of significance of differences between the actual and obtained data, this analysis gives 95 percent confidence interval for the mean difference. Table 3 gives an example of detailed statistical analysis of the differences for one type of mixture.

Table 4 gives the summary of statistical analyses performed on the data (Tables 1 and 2) obtained in this study. The differences from actual asphalt contents are not significant in all cases.

From the values of mean of differences $\overline{D}$, it would appear that the results obtained by Pennsylvania pycnometer have greater accuracy than those by the reflux method. The negative value of $\overline{D}$ in most cases obtained by the latter method indicates a bias that is not revealed in the pycnometer method. This is most evident in the extraction results on the mix containing highly absorptive sand and gravel aggregates.

On comparison of 95 percent confidence limits for the mean difference, it appears that the pycnometer method is more precise for the mixtures containing limestone aggregates. This can be attributed to the uniformity of limestone aggregates resulting in consistent, effective specific gravity values. The pycnometer method seems to have better precision when dealing with highly absorptive aggregates from which all the binder is difficult to retrieve by reflux method.

In case of slag and gravel aggregates, the effective specific gravity in individual samples is not as consistent as in limestone aggregates, so the results obtained by the Pennsylvania pycnometer method are less precise but still acceptable. As mentioned in the appended test method, for ±0.01 variation in the effective specific gravity, the asphalt content will vary ±0.1 percent.

Table 4 also gives the estimated percentage of results within ±0.4 percent of actual asphalt contents. These results appear to indicate that the proficiency of the pycnometer method is comparable to the reflux method.

It may be mentioned that all the data reported in this study were obtained at random by three operators and include a working range of asphalt content for each type of mix. Thus, the final results reflect variability among operators and among samples. Better results would expectedly be obtained if the testing were done by a single operator on mixtures containing the same asphalt content.

CONCLUSIONS

The design features of the Pennsylvania pycnometer have proved to be practical and convenient for the operators.

Results obtained by the Pennsylvania pycnometer, using the recommended procedure, appear to have greater accuracy than those obtained by the conventional reflux method. Precision seems to be equal to or better than the reflux method for the mixtures containing limestone aggregates or highly absorptive gravel aggregates. Accord-

Table 2. Test data.

Limestone[a]			Slag[b]			Absorptive Sand and Gravel[b]			
Actual	Extraction	Pycnometer	Actual	Extraction	Pycnometer	Actual	Extraction	Actual	Pycnometer
5.93	6.00	5.94	7.99	8.10	7.58	5.20	4.90	5.50	5.90
5.97	6.10	5.83	7.99	7.90	7.64	5.20	4.80	5.50	5.70
5.98	6.10	5.66	8.01	7.90	7.98	5.20	5.00	5.50	5.40
6.71	6.70	6.69	9.00	9.20	9.19	5.20	4.90	5.50	5.40
7.01	7.30	7.09	9.04	9.10	8.67	5.20	5.00	5.50	5.90
7.01	6.90	6.97	9.06	9.20	9.30	5.20	4.80	5.50	5.80
7.95	8.00	8.17	9.92	9.90	10.39	5.20	4.80	5.50	5.30
7.95	8.00	8.06	10.00	10.00	10.34	5.20	4.70	5.50	5.40
7.95	8.00	8.00	10.06	9.90	10.17	5.20	4.90	5.50	5.60
8.87	8.60	8.80	11.00	10.80	11.31	5.20	4.90	—	—
8.91	8.80	9.03	11.05	10.40	11.08	—	—	—	—
8.98	8.80	9.20	11.11	11.00	10.68	—	—	—	—
Average difference from actual	+0.007	+0.018		-0.069	+0.008		-0.330		+0.433

[a]FJ-1 wearing course mix. [b]ID-2 wearing course mix.

Table 3. Typical statistical analysis of differences (FJ-1 wearing course mix).

Pair Number	Actual Asphalt Content (percent)	Asphalt Concrete, Pycnometer Method (percent)	Difference, $D = X_2 - X_1$	Deviation, $d = D - \overline{D}$	Squared Deviation
1	5.93	5.94	+0.01	-0.0083	0.0001
2	5.97	5.83	-0.14	-0.1583	0.0250
3	5.98	5.66	-0.32	-0.3383	0.1144
4	6.71	6.69	-0.02	-0.0383	0 0015
5	7.01	7.09	+0.08	0.0617	0.0038
6	7.01	6.97	-0.04	-0.0583	0.0034
7	7.95	8.17	+0.22	+0.2017	0.0407
8	7.95	8.06	+0.11	+0.0917	0.0084
9	7.95	8.00	+0.05	+0.0317	0.0010
10	8.87	8.80	-0.07	-0.0883	0.0078
11	8.91	9.03	+0.12	+0.1017	0.0103
12	8.98	9.20	+0.22	+0.2017	0.0407

Note: $\overline{D} = +0.0183$ and $n = 12$. $S_D [\Sigma d^2/(n - 1)]^{0.5} = [0.2751/(12 - 1)]^{0.5} = 0.152$. $S_{\overline{D}} = S_D/n^{0.5} = 0.152/12^{0.5} = 0.0439$. $t = \overline{D}/S_{\overline{D}} = 0.0183/0.0439 = 0.4168$. $t_{P\,0.05} = 2.201$; 11 degrees of freedom, so differences are not significant. 95 percent confidence limits = $\overline{D} \pm t\,(S_{\overline{D}}) = +\,0.0180 \pm 0.097 = +0.12$ and -0.08 (rounded).

Table 4. Summary of statistical analysis of differences.

Type of Mix	Analytical Method	Range of Known Asphalt Content	$\overline{D}$	t	$t_{P0.05}$	Significant Difference	95 Percent Confidence Limits		Percent Within ± 0.4 Percent of Actual
ID-2 W (limestone)	Pycnometer	4.96 to 8.13	+0.009	0.030	2.201[a]	No	+0.07	-0.06	100
	Extraction	4.96 to 8.13	-0.026	0.745	2.201	No	+0.05	-0.10	100
FJ-1 (limestone)	Pycnometer	5.93 to 8.98	+0.018	0.417	2.201	No	+0.12	-0.08	89
	Extraction	5.93 to 8.98	+0.007	0.159	2.201	No	+0.10	-0.09	82
ID-2 W (sand and gravel)	Pycnometer	5.94 to 8.91	-0.003	0.035	2.201	No	+0.19	-0.19	82
	Extraction	5.94 to 8.91	-0.112	1.836	2.201	No	+0.29	-0.51	91
ID-2 W (slag)	Pycnometer	6.96 to 10.05	-0.010	0.092	2.228[b]	No	+0.23	-0.25	73
	Extraction	6.96 to 10.05	+0.064	0.985	2.228	No	+0.21	-0.08	87
FJ-1 (slag)	Pycnometer	7.99 to 11.11	+0.008	0.086	2.201	No	+0.21	-0.20	73
	Extraction	7.99 to 11.11	-0.069	0.312	2.201	No	+0.02	-0.11	91
ID-2 W (absorptive sand and gravel)	Pycnometer	5.50	+0.100	1.282	2.306[c]	No	+0.28	-0.08	88
	Extraction	5.20	-0.330	11.000	2.262[d]	Yes	-0.26	-0.40	57

[a]11 degrees of freedom. [b]10 degrees of freedom. [c]8 degrees of freedom. [d]9 degrees of freedom.

ing to the theoretical percentage within the range of ±0.4 from actual, the proficiency of this method is comparable to the reflux method.

In comparison to the reflux method the time required for testing by this method is appreciably reduced.

The initial cost of the Pennsylvania pycnometer is reasonable. No expenditure on solvents is involved in this method.

Use of the Pennsylvania pycnometer should be considered as a more rapid and economical means of determining asphalt content of paving mixtures.

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APPENDIX

METHOD OF TEST FOR BITUMEN CONTENT OF BITUMINOUS CONCRETE MIXTURES (PENNSYLVANIA PYCNOMETER METHOD)

Scope

This method of test is intended for determining the bitumen content of bituminous concrete mixtures.

Apparatus

1. A balance sensitive to 0.1 g at the maximum weight to be determined.
2. A 4,000-ml heavy-wall glass pycnometer (Pennsylvania pycnometer) fitted with a vacuum adapter, capillary stopper, and overflow cap (Fig. 3). The pycnometer shall be sufficiently strong to withstand a partial vacuum (air pressure less than 30 mm of mercury).
3. Vacuum pump or water aspirator for evacuating air from the pycnometer.
4. Dial-type vacuum gauge (0 to 30 in. of mercury vacuum) or mercury-filled absolute pressure manometer calibrated to at least 1-mm divisions.
5. Vacuum trap consisting of a 500-ml glass filter flask fitted with a rubber stopper.
6. Tubing and connectors assembly as shown in Figure 4.
7. Constant-temperature water bath maintained at a temperature of 77 ±0.9 F (25 ±0.5 C).
8. Thermometer range 66 to 80 F as prescribed in ASTM specifications E-1.

Calibration of Pycnometer

Calibrate the pycnometer by accurately determining the weight of water at 77 ±0.9 F (25 ± 0.5 C) required to fill it with the capillary stopper and overflow cap in place. Allow some water to overflow through capillary tube while inserting the capillary stopper. Make certain that the capillary tube is filled to the top and that no air bubbles are present after the pycnometer is kept immersed in the constant-temperature water bath for 1 hour. Dry the outside of the pycnometer with an absorbent paper or cloth towel prior to weighing.

Test Data

The following data must be obtained in order to calculate the bitumen content:

1. Specific gravity of bitumen G_b at 77 F (AASHO T 228-68), and
2. Effective specific gravity of combined aggregate G_a (this is determined by testing samples having a known bitumen content).

Test Samples

1. The sample shall be obtained in accordance with AASHO T 168-55 on sampling bituminous paving mixtures.
2. The size of the sample of bituminous concrete mixture shall be from 1,000 to 2,000 g. In no case should the selection of a sample of a predetermined weight be attempted.

Procedure

1. Separate the particles of the sample, using care not to fracture the mineral particles, so that the particles of the fine-aggregate portion are not larger than 1/4 in. If the mixture is not sufficiently soft to be separated manually, place it in a large, flat pan, and warm it in an oven until it can be so handled.
2. Cool the sample to room temperature, place it in the pycnometer, and weigh it. Add sufficient water at approximately 77 F (25 C) to cover the sample.
3. Remove entrapped air by subjecting the contents to a partial vacuum (less than

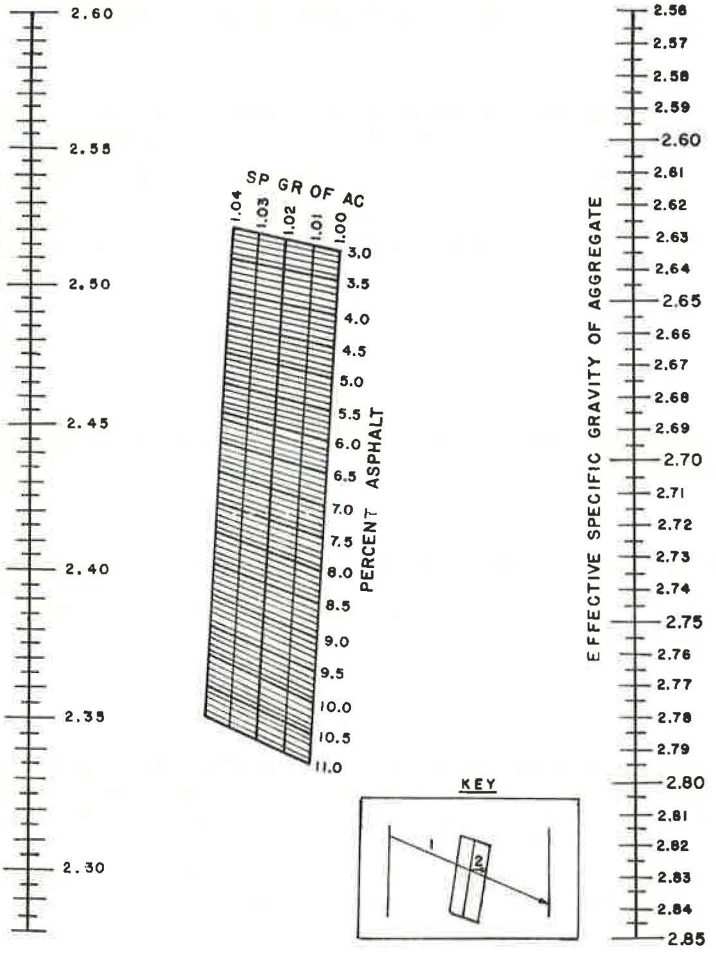
29 in. mercury vacuum or less than 30-mm mercury absolute pressure) for 10 ± 2 min. Agitate the container and contents either continuously by mechanical device or manually by vigorous shaking at intervals of about 2 min.
Note: The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in the concentration of 0.01 percent, or 1 ml of 10 percent solution in 1,000 ml of water.

4. Fill the flask with water. If air bubbles are caused by filling, these should be removed by means of a stirring rod. Bring the contents to a temperature of 77 F ± 0.9 F (25 ± 0.5 C) in a constant-temperature bath. Determine the weight of the pycnometer (completely filled) and contents 10 ± 1 min after completing previous step. Ensure that the capillary tube is filled to the top and that the capillary cap is in place. Dry the outside of the pycnometer prior to weighing.
Note: For rapid determinations, warm bituminous mix can be introduced in the pycnometer and then sufficiently cold ice water added to regulate and obtain a resulting temperature of 77 F ± 0.9 F.

Calculations

1. The maximum specific gravity of the voidless mix G_m is determined using Eq. 1. The equation can be solved by operations in steps 1 through 8, Figure 1.

Figure 5. Asphalt content using Pennsylvania pycnometer method.



2. G_a shall be determined as explained later, and G_b shall be determined using AASHO T 228-68. Knowing G_a, G_b and G_m, the percentage of bitumen content P can be determined by operations shown in steps 9 and 10, Figure 1, or by solving Eq. 3.

3. Knowing the values G_a, G_b, and G_m, the bitumen content can also be determined by the use of Figure 5, which has been prepared to solve Eq. 3. G_m and G_a are connected by a straight line. At the point where this line crosses the 1.02 specific gravity of AC line, proceed horizontally to the line applicable to the specific gravity of the asphalt being used and read the percentage of asphalt by weight in the total mix.

Effective Specific Gravity of Aggregate

1. G_a is determined by testing a sample of the mix that has been prepared in the laboratory with a known P. Accurate results can be obtained if the gradation and asphalt content of the sample match, as closely as possible, the gradation and asphalt content of the mix being produced at the plant. The sample should be of about the same size as the samples that are tested for bitumen content.

2. Transfer the prepared mix to the pycnometer and determine G_m as outlined previously using Figure 1. Once P and specific G_b are known, G_a can be determined by Eq. 3, which has been rearranged algebraically as Eq. 4:

$$G_a = \frac{G_m(100 - P)}{100 - \frac{G_m \times P}{G_b}} \quad (4)$$

This equation can be conveniently solved by operations in steps 1 through 9, Figure 2.

3. At least 10 bituminous mix samples of known asphalt content should be tested to establish G_a for an asphalt plant. Calculate the average of the 10 determinations and then determine the maximum plus and minus variations from this average. If the values vary more than ±0.010, discard these values, recalculate the average, and redetermine the variation. A minimum of 6 values should be used to establish the average finally.

4. The specific gravity of the aggregate may change during production. G_a should be redetermined if the type of source of any of the aggregates being used in the mix is changed, or if the gradation of the mix changes enough to require a change in the job mix formula.

Note: While transferring the mix from the mixing bowl to the pycnometer, some fine materials will still be stuck to the bowl and spatula. This should be accounted for to determine P in the mix.

Accuracy of Method

The bitumen content of the bituminous mixture will vary by ±0.10 percent for the following variations in measurements: weight of specimen, ±1.0 g; weight of displaced water, ±0.5 g; maximum specific gravity of mix, ±0.003 units; specific gravity of bitumen, ±0.010 units; and effective specific gravity of aggregate, ±0.010 units.