EVALUATION OF VACUUM PYCNOMETER

FINAL REPORT

BY

DONALD E. CAREY
BITUMINOUS RESEARCH ENGINEER

Research Report No. 111

Research Project No. 72-6B(B)
Louisiana HPR 1 (14)

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT
Research and Development Section
In Cooperation with
U. S. Department of Transportation
Federal Highway Administration

June, 1977

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report is concerned with the evaluation of the Yale vacuum Pycnometer to determine the feasibility of its use for the rapid determination of maximum specific gravity and asphalt content of bituminous paving mixtures. Asphalt contents of plant-mixed samples from four Louisiana mix types were calculated from the pycnometer determined maximum specific gravities. A comparison of these calculated asphalt contents with both the known and the reflux extraction asphalt contents of these samples would indicate: (1) The accuracy and precision of the Yale pycnometer in determining asphalt content was equivalent to that of the reflux extraction for 3 of 4 mix type tested; and (2) the poor results obtained with the fourth mix type were caused by inconsistent effective specific gravities of a highly absorptive expanded clay aggregate.

IMPLEMENTATION

The Department should consider making use of the Yale pycnometer as a means of compaction control for Louisiana Type 4 mixes. Currently, the fluctuations in specific gravity of Type 4 field cores and/or plant briquettes (due to variations in the percent lightweight aggregate in the sample) makes referencing field compaction to a percentage of plant briquette gravity impossible. However once specific gravities of field cores have been determined in their normal manner, it may be appropriate to determine the maximum specific gravity (zero air voids) of each individual core by the pycnometer. Compaction control and acceptance could then be referenced against a zero air voids density.

INTRODUCTION

In 1971, the Yale Chemical Corporation of Raleigh, North Carolina began marketing a large-scale vacuum pycnometer designed for use in determining the maximum specific gravity of bituminous paving mixtures. Since the maximum specific gravity of a mix is sensitive to the volume of asphalt present in the mix, the procedure is also adaptable to the rapid determination of the asphalt content of bituminous mixtures.

The concept of determining maximum specific gravities by a weight/volume relationship based on the procedure of ASTM Test D-2041 (Maximum Specific Gravity of Bituminous Paving Mixtures) was expanded upon by G. W. Steel and S. B. Hudson (1).* Their research involved the use of a large sized vacuum pycnometer capable of handling a 6,000-gram sample. The accuracy of the results obtained by such large sample sizes on asphalt content determinations and also the speed of such determinations prompted additional study; further refinements were felt necessary to the equipment before it could be usable in the field for plant testing. The result of such equipment refinements was the Yale vacuum pycnometer.

*Underlined numbers in parentheses refer to list of references.

PURPOSE OF STUDY

This research was undertaken to evaluate the Yale vacuum pycnometer and to determine the feasibility of its use for the rapid determination of maximum specific gravity and asphalt content of bituminous paving mixtures.

SCOPE

The study consisted of comparing the asphalt content determined from the maximum specific gravities of the Yale pycnometer with both the actual asphalt content of a mix and the asphalt content as determined by reflux extraction (ASTM D-2172, Method B). These asphalt content comparisons were made on four Louisiana mix types, each type representing a different aggregate material and a different asphalt content.

Equipment and Test Procedure

The Yale vacuum pycnometer is shown in Figure 1. It is constructed of a lightweight, durable, transparent plastic, designed to allow for visual observation of the effects of the vacuum and to withstand the treatment it might be subjected to in field or plant use. The pycnometer is comprised of a bottom section and a removable top section, which allows for the addition of a large sample into the pycnometer. Both sections are positively sealed together for the application of vacuum by a built-in O ring and by spring loaded latches. Handles are provided so that the pycnometer can be shaken while still under full vacuum; this shaking facilitates the necessary air bubble release required for accurate and precise gravity determinations. The pycnometer comes with all the required fittings for the vacuum connection, including a pressure release valve, a pressure gauge, and a small filter screen to inhibit sucking of fine aggregate particles into the vacuum system.

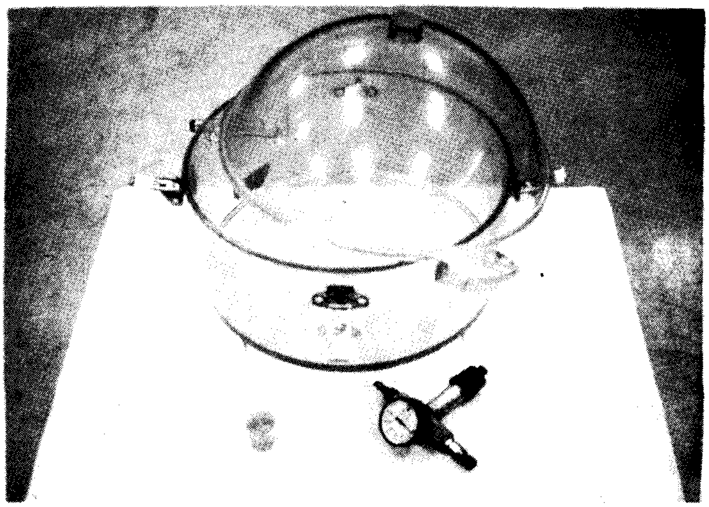

Figure 1: The Yale Vacuum Pycnometer

The use of the Yale pycnometer for maximum specific gravity determinations (and subsequent asphalt content calculations) is dependent upon a preliminary calibration of the pycnometer. This calibration relates the weight of the pycnometer filled with water to the temperature of the water, and is used in the gravity determinations to calculate the weight of the water displaced by a tested bituminous mixture. The procedure used to calibrate the pycnometer is given in Appendix A. The calibration curve developed in this study is given in Figure 2. It is pointed out that wetting agent, Aerosol OT, was added to the water for this calibration and also for the subsequent maximum specific gravity determinations.

The Yale pycnometer procedure used to test a bituminous mixture for its maximum specific gravity basically consists of sucking all of the free air out of an approximate 6,000-gram sample under water and then measuring the volume of the voidless mass by its water displacement. The maximum specific gravity thus determined is used to calculate the asphalt content of the mixture, provided the effective specific gravity of the mix aggregate is known. It is this relationship between the maximum specific gravity of a mix, the effective specific gravity of the combined aggregates and the volume (or percent) of asphalt in the mix that was researched so well by Steele and Hudson. The Yale procedure given in Appendix A* makes use of the fact that a knowledge of any two of the above factors will allow a computation of the third.

The computations for this study were made using the calculation sheets developed by Yale. Sheet 1 is used with a known effective specific gravity of the aggregate and a determined maximum specific gravity of a mix to calculate the asphalt content of a mix. Sheet 2 is used with a known asphalt content and a determined maximum specific gravity of a mix to calculate the effective specific gravity of the combined

*For this study, the "hot method" was used.

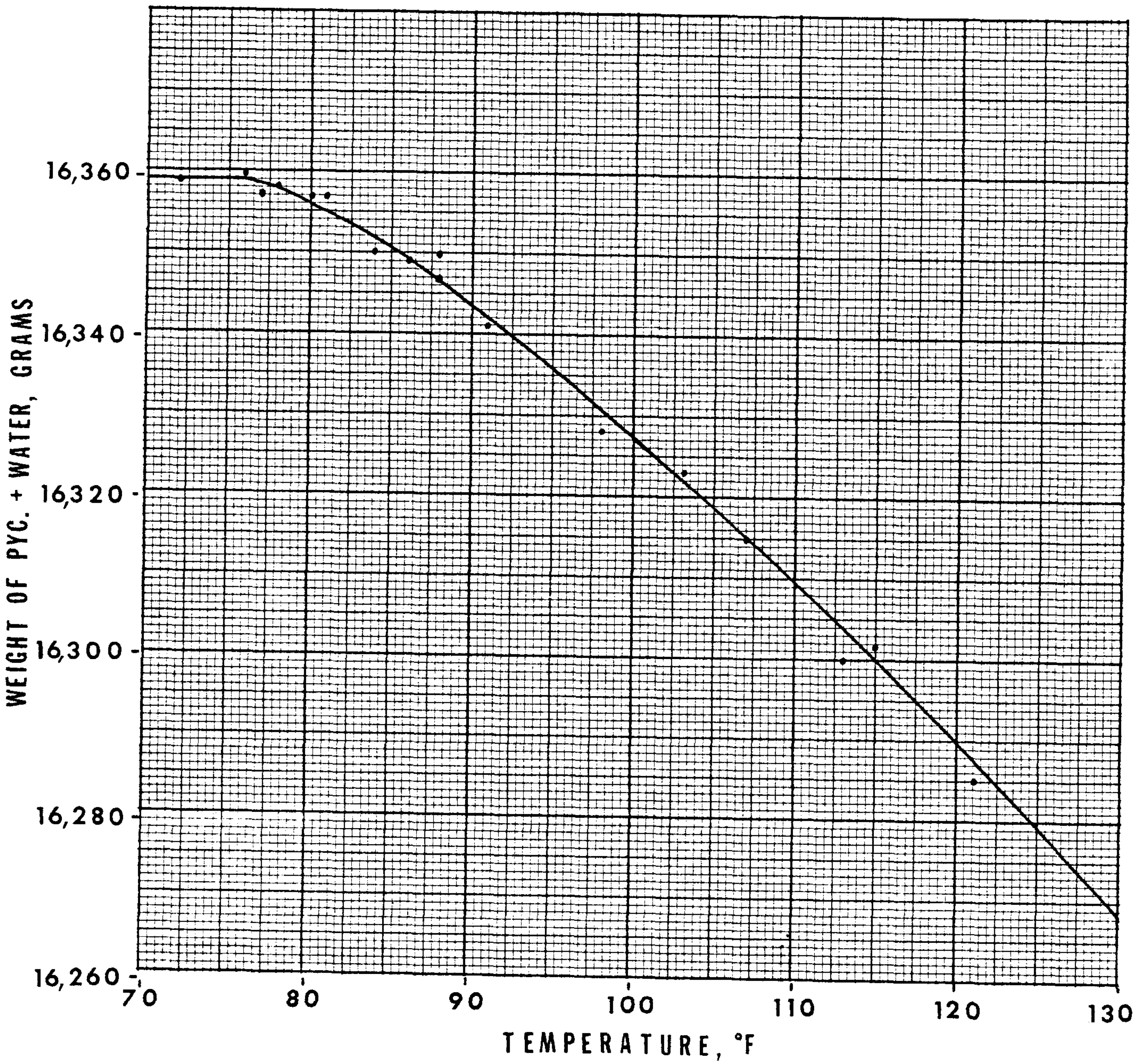

Figure 2: Calibration Curve for Particular Yale Pycnometer Used

aggregate. Both of these sheets are included in Appendix A. Except for lines 9 and 11 on Sheet 1, the forms are self-explanatory. The correction factors called for on lines 9 and 11, and reasons for their use, can be found in a paper (2) by the developer of the Yale pycnometer, Mr. Warren Warden.

Asphalt Content Determinations

For this study, the asphalt content of bituminous mixtures was determined from numerous plant samples. Each plant sample was quartered and split. Half of each sample was used to determine the asphalt content using the Yale vacuum pycnometer method; the asphalt content of the remaining half of the sample was determined by the reflux extraction method (ASTM D-2172, Method B). The actual, or known, asphalt content for each sample was taken as the plant print-out for the particular batch sampled. In all, 52 asphalt content comparisons were made on bituminous mixtures representing four different aggregate materials and asphalt contents.

At each of the four plants included in the study, the Yale vacuum pycnometer was used to first determine the effective specific gravity of the mix aggregate. This was done by taking samples of plant-produced mix and determining the maximum specific gravity of the mix, which was then used with the known asphalt content of the mix (plant print-out) to calculate the effective specific gravity of the aggregate. Appendix B, pages 27 and 28, contains the calculations used to arrive at the effective specific gravity (2.730) of one of the aggregate types evaluated in the study. Once an average effective specific gravity of the combined aggregates was determined for each mix type, that value was then used to calculate asphalt contents of subsequent mix samples. Appendix B, pages 29 and 30, gives an example of the asphalt content calculations used for one of the mix types studied.

RESULTS

The asphalt contents determined by each test method (reflux extraction and vacuum pycnometer) are given for all four mix types in Table 1. A statistical analysis of the differences between the asphalt contents determined by each method and the actual asphalt content was used to compare the methods for accuracy and precision. Table 2 shows an example of this anaylsis for one of the mix types included in the study. A summary of the results of such an analysis for all the mix types is given in Table 3.

TABLE 1: ASPHALT CONTENT COMPARISONS

TYPE 3 BINDER (Sand-Shell)			TYPE 1 WEARING (Sand-Gravel)		
Actual*	Extraction	Pycnometer	Actual*	Extraction	Pycnometer
5.25	5.22	5.23	4.51	4.63	4.41
5.30	5.35	5.42	4.45	4.70	4.26
5.31	5.31	5.42	4.49	4.51	4.62
5.31	5.49	5.55	4.49	4.97	4.39
5.30	5.18	5.57	4.48	4.44	4.74
5.31	5.31	5.31	4.51	4.23	4.32
5.10	4.92	5.20	4.99	5.05	4.96
5.10	5.23	5.05	4.97	5.01	4.53
5.10	5.37	5.47	4.99	5.12	4.90
5.10	5.15	5.08	5.00	5.03	5.11
5.10	5.08	5.08	4.97	5.03	4.50
5.20	4.88	5.13	4.97	4.95	4.96
			5.00	4.93	4.93
			5.04	5.25	4.99

*Plant print out for the particular batch sampled.

TABLE 1: ASPHALT CONTENT COMPARISONS (CONTD.)

Friction Course (Slag)			Friction Course (Expanded Clay)		
Actual*	Extraction	Pycnometer	Actual	Extraction	Pycnometer
6.76	7.20	6.87	13.98*	19.6	14.82
6.77	6.66	6.78	13.87*	20.8	9.41
6.78	6.72	6.72	13.90*	19.8	13.63
6.77	6.82	6.87	13.95*	18.9	17.21
6.75	6.73	6.25	13.93*	20.1	12.91
6.78	6.92	6.99	13.96*	19.4	14.82
6.73	6.41	6.48	13.91*	18.8	16.97
6.78	——	7.02	14.02*	20.3	12.19
6.78	7.28	6.87	13.95*	18.3	18.44
6.77	7.07	6.78	13.86*	19.6	14.11
			13.99**	14.2	14.36
			13.99**	14.4	13.24
			13.99**	13.2	18.27
			13.87**	13.7	17.73
			13.87**	14.3	13.81
			13.87**	13.9	15.18

*First-day sample

**Second-day sample

TABLE 2: STATISTICAL ANALYSIS OF DIFFERENCES

(Slag Friction Course)

Actual A.C. Percent	Pycnometer A.C. Percent	Difference =D	Actual Percent	Extraction A.C. Percent	Difference =D
6.76	6.87	+0.11	6.76	7.20	+0.44
6.77	6.78	+0.01	6.77	6.66	-0.11
6.78	6.72	-0.06	6.78	6.72	-0.06
6.77	6.87	+0.10	6.77	6.82	+0.05
6.75	6.25	-0.50	6.75	6.73	-0.02
6.78	6.99	+0.21	6.78	6.92	+0.14
6.73	6.48	-0.25	6.73	6.41	-0.32
6.78	7.02	+0.24	6.78	——	——
6.78	6.87	+0.09	6.78	7.28	+0.50
6.77	6.78	+0.01	6.77	7.07	+0.30

	n	$\bar{D}$	S_D	$S_{\bar{D}}$	t	$t_{0.05}$	Significant Difference	95% Confidence Limits
Pycnometer	10	-0.004	0.223	0.071	0.056	2.262	NO	+0.157 & -0.165
Extraction	9	+0.102	0.282	0.094	1.085	2.306	NO	+0.319 & -0.115

Where

$\bar{D}$ = mean difference = $\Sigma D/n$

S_D = standard deviation of individual differences = $\left[\frac{\Sigma(D - \bar{D})^2}{n - 1}\right]^{0.5}$

$S_{\bar{D}}$ = standard error of mean difference = $S_D / n^{0.5}$

$t = \bar{D}/S_{\bar{D}}$

$t_{0.05}$ = 2.262(D.F. = 9) and 2.306(D.F. = 8)

95% Confidence Limits = $\bar{D} \pm t_{0.05} (S_{\bar{D}})$

TABLE 3: SUMMARY OF DIFFERENCE ANALYSIS

Mix Type	Method	Known A.C. Range	$\bar{D}$	$S_{\bar{D}}$	t	$t_{0.05}$	Significant Difference	95 percent Confidence Limits	
1 W. C. (Sand-Gravel)	Pyc	4.45-5.04	-0.088	0.053	1.660	2.160[a]	NO	+0.03	-0.20
	Extract	4.45-5.04	+0.071	0.046	1.543	2.160	NO	+0.17	-0.03
3 B. C. (Sand-Shell)	Pyc	5.10-5.31	+0.086	0.041	2.098	2.201[b]	NO	+0.18	0.00
	Extract	5.10-5.31	+0.001	0.046	0.022	2.201	NO	+0.10	-0.10
Friction Course (Slag)	Pyc	6.73-6.78	-0.004	0.071	0.056	2.262[c]	NO	+0.16	-0.16
	Extract	6.73-6.78	+0.102	0.094	1.085	2.306[d]	NO	+0.32	-0.12
Friction Course (Expanded Clay)	Pyc	13.86-14.02	+0.888	0.609	1.458	2.131[e]	NO*	+2.19	-0.41
	Extract	13.86-14.02	+3.520	0.720	4.890	2.131	YES	+5.05	+1.99

a: 13 degrees of freedom

b: 11 degrees of freedom

c: 9 degrees of freedom

d: 8 degrees of freedom

e: 15 degrees of freedom

*This conclusion is misleading, since the large standard deviation of the mean difference ($S_{\bar{D}}$) is masking the findings.

DISCUSSION OF RESULTS

Table 3 indicates that the asphalt content as determined by both the Yale vacuum pycnometer and the reflux extraction is not significantly different from the actual asphalt content for three of the mix types studied (sand-gravel, sand-shell, and slag). For these mixes, the precision of each method is approximately the same; the pycnometer being more precise in two of the three cases. The accuracy of the reflux extraction was better for the sand-shell mix. (An inaccurate determination of the average effective specific gravity of this mix most probably was the cause of the less accurate pycnometer values.) The accuracy of the pycnometer was better for the slag mix. (The uniformity of the pre-graded, one cold feed, slag aggregate apparently enabled a very accurate calculation of the effective specific gravity of this material.) In general, the 95 percent confidence limits show both methods to be equally acceptable.

The fourth type of mix included in this study was an expanded clay (lightweight) open-graded friction course. The mix was sampled and tested on two consecutive days. The asphalt content results obtained with either method for the first day's samples were neither accurate nor precise. It is felt that the very high water absorptive characteristic of this particular aggregate (greater than 20 percent) was the cause of the poor results. As these high asphalt content friction courses, yielding thick asphalt coatings on the mix aggregate, are produced at lower than normal mix temperatures ($220^{\circ}F$ to $250^{\circ}F$) ($104.4^{\circ}C$ to $121.1^{\circ}C$), it is entirely possible for internal aggregate moisture to be entrapped in the final mix. Varying amounts of such retained aggregate moisture are also possible. The positive bias (see Table 1) obtained on the first day's samples with the reflux extraction method substantiates the presence of such varying amounts of retained moisture. A comparison between the actual asphalt content and the reflux asphalt determination would indicate an entrapped water content ranging from approximately 4 to 7 percent. The actual water content of each mix sample, per ASTM D-95, was not determined. This retained aggregate moisture also seriously affected the results obtained with the vacuum pycnometer. As was discussed earlier, the pycnometer method relies upon a precise knowledge of the effective specific gravity of the mix aggregate. For cases where the moisture content of the final mix is varying, there is no consistent effective specific gravity of the aggregate. Appendix B, page 31, gives an example of how, for this particular type mix, 1 or 2 percent difference in moisture content between samples* (regardless of sample size) can produce a significant difference in a calculated asphalt content. The reasoning here is that the moisture content of the lightweight can increase without decreasing the amount of asphalt absorption. This being the case, the final volume of the tested mix would remain constant, although the weight of the mix would increase. The poor accuracy and precision of the vacuum pycnometer for this 4th mix type are believed to have been caused by this inability to measure the effective specific gravity of an aggregate whose final moisture content varied.

The samples taken during the second day represent mix produced with pre-dried lightweight aggregate. The reflux results for these samples (see Table 1) were more accurate than those of the previous day, indicating a substantial reduction in retained aggregate moisture. However, the pycnometer results were still neither accurate nor precise. Although a new effective specific gravity for this drier aggregate had been determined, the still present fluctuations in retained mix moisture affected the asphalt content calculations in a manner similar to the first day's samples.

*The sample sizes used in the study for this lightweight mix were approximately 2,000 grams. This would be the equivalent volume sample of a 4,000-gram hard rock mix.

CONCLUSIONS

(1) The Yale vacuum pycnometer is appropriately designed to handle large sample sizes and to test such samples under plant conditions.

(2) The pycnometer test procedure is extremely sensitive to weight measurements. Frequent zeroing of the balance, an occasional check of the pyc calibration curve, and constant care in all weighings are necessary.

(3) The accuracy and precision of the Yale pycnometer in determining asphalt content was equivalent to that of the reflux extraction for 3 of the 4 mix types tested.

(4) In comparison to the reflux method, the pycnometer method is quicker and less expensive (20 minutes, with no solvent expense).

(5) The use of the pycnometer with a highly porous, (water absorption greater than 20 percent) expanded clay aggregate was not successful. Inherent plant fluctuations in the effective specific gravity of the aggregate (due to variations in internal moisture of the heated aggregate) was believed to be the cause of the poor findings.

RECOMMENDATIONS

In keeping with Louisiana's end result specifications, the Yale vacuum pycnometer is recommended as a valuable tool for our state contractors in fulfilling their responsibility for good plant production control. A reliable knowledge of any significant change in maximum specific gravity of a "lined-out" mix (indicating a problem in production control) can quickly lead to either the cause of the problem or, at least, to the initiation of normal plant "trouble-shooting" methods to find the cause.

Additionally, it is recommended that the Yale pycnometer be investigated as a means of compaction control for Louisiana Type 4 mixes. Currently the fluctuations in individual core densities of these mixes, due to variations in the percent lightweight aggregate present in each field core, makes referencing to a lab briquette density impossible. Once densities of the field cores have been determined in a normal manner, it may be appropriate to determine the maximum specific gravity (zero air voids) of each individual core by the pycnometer "cold method" procedure. Compaction control and acceptance could then be referenced against a zero air voids density.

REFERENCES

(1) Steele, G. W. and Hudson, S. B., "A Pycnometer Test Procedure for Determining Asphalt Content of Paving Mixture," ASTM STP 461, July 1969.

(2) Warden, W. B., "Evaluation of a Large-Sized Vacuum Pycnometer for Maximum Specific Gravity Determinations," Proceedings of the Association of Asphalt Paving Technologists, Vol. 43 (1974).

APPENDIX A

Volume Calibration Procedure

The first step is to calibrate the pycnometer (pyc) by measuring its weight, full of water, over a range of temperatures from about 70°F. to 150°F. (21.1°C to 65.6°C). The weight versus temperature curve can be defined mathematically, so it is more important to verify a few good repeat readings particularly at 77°F. (25°C), than it is to get a lot of points. The domed lid is latched in place and the pyc nearly filled with water up to about 2" (5.08cm) from the top. Some small air bubbles will hang up on the interior surfaces. Their release may be facilitated by applying vacuum and by jarring (dropping first one side and then the other of the pyc about 1/2" (1.27cm) on the bench surface). It is not necessary to remove all of the bubbles, but it is important to use the same technique when running the rest so the degree of small bubble retention is about the same. This vacuum application and bubble release procedure should take about 10 minutes so that the temperature equilibrium between the pycnometer and the water approximates that attained when running a test.

A final water is then poured in gently (to minimize introduction of new bubbles) until the level is about one-half way up into the neck, and the pyc vented stopper inserted. The bottom of the plastic stopper is concave, which forces the last remaining free air out of the small vent hole. Only enough force to just seat the stopper need be applied, and the excess water is wiped off the top with one swipe of a towel. The outside of the pyc is then wiped dry, taking care to wipe out the water trapped in the latch ring. Ordinary absorptive paper towels work very nicely. The full pyc is weighed and the temperature of the water taken. A plywood balance pan extender is supplied so that the weight is carried by the skirt of the pyc. The pyc should be lowered onto the pan extension slowly so that any water displaced through the plastic stopper is caught in the latch ring for weighing.

While this calibration need only be done once, it should be checked occasionally. It is particularly important to zero the balance frequently. Also, it is obvious that the equipment must be kept clean and free of any accumulation that would change weight, if the volume calibration is to remain constant. The pyc should be kept clean (outside and inside) by wiping with a rag dampened with kerosene or mineral spirits or similar aliphatic solvent. However,

DO NOT CLEAN pyc with chlorinated solvents (carbon tetrachloride, trichloroethylene, etc.), as they will damage the polycarbonate plastic.

DO NOT CLEAN pyc with aromatic solvents (benzene, zylol, etc.). While slower, they too are damaging.

Pycnometer Test Procedure

In brief, the procedure consists of sucking all of the free air out of a 6,000-gram sample of bituminous mixture under water, then measuring the volume of the voidless mass by water displacement. The steps are:

1. Weigh and break up the sample so that air is not trapped within lumps of the mixture. Two of the various techniques which have been used are given below:

   (a) Cold Method. The simplest and most accurate way is to part the sample into discrete particles by hand, and cool and weigh them separately before adding them to about 3" (7.62cm) of water in the pyc. The water helps to keep the coated particles from reconglomerating. Pavement core samples must be dried and broken up before testing. This cold method is recommended for referee work.

   (b) Hot Method. A time saving alternate that is surprisingly accurate is to add the hot sample, directly from the oven or truck, into water in the pyc and shake vigorously. Enough heat is retained so that the sample can be effectively dispersed by shaking, after the dome has been latched in place, using a back-and-forth rolling motion with the pyc tipped up about 30° and with the skirt still in contact with the bench.

   The objective, in any case, is to avoid lumping of the mix so that entrapped air cannot be sucked out. Measurement of sample weight for either method by weighing the sample container before and after transferring the test portion to the pyc negates possible error due to evaporation loss.

2. Add additional water, if necessary, to cover sample, insert vacuum assembly (No. 4 stopper) in hole, open vent valve and

apply vacuum. Gradually close vent valve to dispel air and pull full vacuum (27" (68.6cm) Hg plus) for 10 minutes. Use the handles to lift and shake the pyc (throw the sample), to aid in displacing air bubbles. If the vacuum capacity is limited (low water pressure, for instance) the water level in the pyc may be increased into the dome, thereby decreasing the total volume of air to be dispelled and making it easier to get the pressure down.

3. When all air has been removed, fill pyc completely with water, insert vented stopper, wipe water off stopper (once), dry outside using same technique as during volume calibration, and weigh.

4. Remove vented stopper and measure temperature of water.

5. Siphon off water, disassemble and clean pyc.

SHEET 1

ASPHALT CONTENT by PYCNOMETER METHOD

Sample Identification:							
Material							
Location							
Date							
Line Test No.							
1 Tare + Mix							
2 Tare	-	-	-	-	-	-	-
3 (1-2) Sample Wt.							
4 Pyc + Water at Temp. 8,	+	+	+	+	+	+	+
5 (3+4) Total							
6 Pyc + Mix + Water	-	-	-	-	-	-	-
7 (5-6) Wt. of Displaced Water							
8 Temp. of Water, °F							
9 Asphalt Correction,							
10 (7-9) Adjusted Wt.							
11 Multiplier, Curve R,							
12 (Line 3 ÷ Line 10)(Line 11) Sp.Gr., M							
13 (A ÷ Line 12) - 1							
14 (D x Line 13) % Asphalt, P.							
A Effective sp.gr.aggregates, A*							
B Sp. Gr. of Asphalt, B							
C (A - B)							
D (100B ÷ C)							

*Line 9 of Sheet 2

SHEET 2
EFFECTIVE SPECIFIC GRAVITY OF ASPHALT COATED AGGREGATE

Sample identification:								
Aggregates - Coarse								
Fine								
Filler								
Asphalt								
How Mixed								
Location								
Date								
Test Number								
Line	**Step**	**Symbol**						
1	Max. Sp. Gr. of Mix*	M						
2	Known % Asphalt**	P						
3	Sp.Gr. of Asphalt at 77°F	B						
4	Line 2 ÷ Line 3	$\frac{P}{B}$						
5	100 - % AC	100-P						
6	Line 1 x Line 4	$\frac{MP}{B}$						
7	Line 1 x Line 5	M(100-P)						
8	100 - Line 6	$100-\frac{MP}{B}$						
9	Line 7 ÷ Line 8 = Effective Sp.Gr. of Aggregate	A***						

*Line 12 of Sheet 1

**Mix of known asphalt content may be prepared in the lab or it may be the mix produced in a closely monitored plant. Averaging a number of plant samples may be more convenient and more representative of actual asphalt absorption.

***
$$A = \frac{M(100-p)}{100-\frac{MP}{B}} = \frac{MB(100-p)}{100 - MP}$$

APPENDIX B

SHEET 1

ASPHALT CONTENT by PYCNOMETER METHOD

Sample Identification:	#1	#2	#3	#4	#5	#6	
Material	Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	
Location	THESE 6 SAMPLES WERE USED TO DETERMINE THE MAXIMUM SPECIFIC GRAVITY FROM WHICH THE EFFECTIVE SPECIFIC GRAVITY OF THE AGGREGATE WAS CALCULATED (SHEET 2, PAGE 28.						
Date							
Line — Test No.							
1 Tare + Mix	7358	10161	10185	10314	10278	10245	
2 Tare	- 2357	- 5106	- 5214	- 5241	- 5173	- 5147	-
3 (1-2) Sample Wt.	5001	5055	4971	5073	5105	5098	
4 Pyc + Water at Temp. 8,	+ 16334	+ 16330	+ 16335	+ 16337	+ 16328	+ 16334	+
5 (3+4) Total	21335	21385	21306	21410.	21433	21432	
6 Pyc + Mix + Water	- 19356	- 19381	- 19337	- 19397	- 19410	- 19409	-
7 (5-6) Wt. of Displaced Water	1979	2004	1969	2013	2023	2023	
8 Temp. of Water, °F	96	98	95	93	100	96	
9 Asphalt Correction,	-0.9	-1.0	-0.8	-0.8	-1.1	-0.9	
10 (7-9) Adjusted Wt.	1979.9	2005	1969.8	2013.8	2024.1	2023.9	
11 Multiplier, Curve R,	.9968	9963	.9970	.9973	.9960	.9968	
12 (Line 3 ÷ Line 10)(Line 11) Sp.Gr., M	2.518	2.512	2.516	2.512	2.512	2.511	
13 (A ÷ Line 12) - 1							
14 (D x Line 13) % Asphalt, P.							
A Effective sp.gr.aggregates, A*							
B Sp. Gr. of Asphalt, B							
C (A - B)							
D (100B ÷ C)							

*Line 9 of Sheet 2

SHEET 2

EFFECTIVE SPECIFIC GRAVITY OF ASPHALT COATED AGGREGATE

Sample identification:

Aggregates - Coarse
Fine
Filler

Asphalt

How Mixed

Location

Date

NOTE THE AVERAGE EFFECTIVE SPECIFIC GRAVITY OF THE SIX SAMPLES BELOW IS 2.730.

Test Number

Line	Step	Symbol						
1	Max. Sp. Gr. of Mix*	M	2.518	2.512	2.516	2.512	2.512	2.511
2	Known % Asphalt**	P	5.13	5.13	5.13	5.30	5.30	5.31
3	Sp.Gr. of Asphalt at 77°F	B	1.030	1.030	1.030	1.030	1.030	1.030
4	Line 2 ÷ Line 3	$\frac{P}{B}$	4.981	4.981	4.981	5.146	5.146	5.154
5	100 - % AC	100-P	94.87	94.87	94.87	94.70	94.70	94.69
6	Line 1 x Line 4	$\frac{MP}{B}$	12.54	12.51	12.53	12.93	12.93	12.94
7	Line 1 x Line 5	M(100-P)	238.9	238.3	238.7	237.9	237.9	237.8
8	100 - Line 6	$100-\frac{MP}{B}$	87.46	87.49	87.47	87.07	87.07	87.06
9	Line 7 ÷ Line 8 = Effective Sp.Gr. of Aggregate	A***	2.732	2.724	2.729	2.732	2.732	2.731

*Line 12 of Sheet 1

**Mix of known asphalt content may be prepared in the lab or it may be the mix produced in a closely monitored plant. Averaging a number of plant samples may be more convenient and more representative of actual asphalt absorption.

***
$$A = \frac{M(100-p)}{100-\frac{MP}{B}} = \frac{MB(100-p)}{100 - MP}$$

SHEET 1

ASPHALT CONTENT by PYCNOMETER METHOD

Sample Identification:	#1	#2	#3	#4	#5	#6	
Material	Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	
Location							
Date							
Line — Test No.							
1 Tare + Mix	10042	10211	10085	10103	10281	10108	
2 Tare	- 5197	- 5223	- 5207	- 5183	- 5174	- 5118	-
3 (1-2) Sample Wt.	4845	4988	4878	4920	5107	4990	
4 Pyc + Water at Temp. 8,	+ 16335	+ 16329	+ 16340	+ 16332	+ 16335	+ 16330	+
5 (3+4) Total	21180	21317	21218	21252	21442	21320	
6 Pyc + Mix + Water	- 19259	- 19335	- 19277	- 19292	- 19406	- 19340	-
7 (5-6) Wt. of Displaced Water	1921	1982	1941	1960	2036	1980	
8 Temp. of Water, °F	95	99	92	97	95	98	
9 Asphalt Correction,	-0.8	-1.0	-0.7	-0.8	-0.8	-0.9	
10 (7-9) Adjusted Wt.	1921.8	1983.0	1941.7	1960.8	2036.8	1980.9	
11 Multiplier, Curve R,	0.9970	0.9961	0.9975	0.9966	0.9970	0.9963	
12 (Line 3 ÷ Line 10)(Line 11) Sp.Gr., M	2.513	2.506	2.506	2.501	2.500	2.510	
13 (A ÷ Line 12) - 1	0.0864	0.0894	0.0894	0.0916	0.0920	0.0876	
14 (D x Line 13) % Asphalt, P.	5.23	5.42	5.42	5.55	5.57	5.31	
A Effective sp.gr.aggregates, A*	2.730	2.730	2.730	2.730	2.730	2.730	
B Sp. Gr. of Asphalt, B	1.030						
C (A - B)	1.70						
D (100B ÷ C)	60.59	Same	Same	Same	Same	Same	

*Line 9 of Sheet 2

SHEET 1

ASPHALT CONTENT by PYCNOMETER METHO

Sample Identification:		#7	#8	#9	#10	#11	#12	
Material		Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	Shell Mix	
Location								
Date								
Line	Test No.							
1	Tare + Mix	10056	10019	10316	10155	10166	10159	
2	Tare	- 5170	- 5191	- 5207	- 5238	- 5229	- 5188	-
3	(1-2) Sample Wt.	4886	4828	5109	4917	4937	4971	
4	Pyc + Water at Temp. 8	+ 16345	+ 16343	+ 16335	+ 16330	+ 16337	+ 16348	+
5	(3+4) Total	21231	21171	21444	21247	21274	21319	
6	Pyc + Mix + Water	- 19292	- 19260	- 19411	- 19303	- 19320	- 19348	-
7	(5-6) Wt. of Displaced Water	1939	1911	2033	1944	1954	1971	
8	Temp. of Water, °F	89	90	95	98	93	87	
9	Asphalt Correction,	-0.6	-0.6	-0.9	-0.9	-0.7	-0.5	
10	(7-9) Adjusted Wt.	1939.6	1911.6	2033.9	1944.9	1954.7	1971.5	
11	Multiplier, Curve R,	0.9981	0.9978	0.9970	0.9963	0.9973	0.9984	
12	(Line 3 ÷ Line 10)(Line 11) Sp.Gr., M	2.514	2.520	2.504	2.519	2.519	2.517	
13	(A ÷ Line 12) - 1	0.0859	0.0833	0.0903	0.0838	0.0838	0.0846	
14	(D x Line 13) % Asphalt, P	5.20	5.05	5.47	5.08	5.08	5.13	
A	Effective sp.gr.aggregates, A*	2.730	2.730	2.730	2.730	2.730	2.730	
B	Sp. Gr. of Asphalt, B	1.030						
C	(A - B)	1.70						
D	(100B ÷ C)	60.59	Same	Same	Same	Same	Same	

*Line 9 of Sheet 2

SHEET 1

ASPHALT CONTENT by PYCNOMETER METHOD

Sample Identification:	$X\%\ H_2O$	$X+2\%\ H_2O$	$X+3\%\ H_2O$		$X\%\ H_2O$	$X+2\%\ H_2O$	$X+3\%\ H_2O$
Material	Light-weight				Light weight		
Location							
Date							
Line Test No.							
1 Tare + Mix							
2 Tare	-	-	-	-	-	-	-
3 (1-2) Sample Wt	2000	2040	2060		3000	3060	3090
4 Pyc + Water at Temp. 8,	+16358	+16358	+16358	+	+16358	+16358	+16358
5 (3+4) Total	18358	18398	18418		19358	19418	19448
6 Pyc + Mix + Water	-16798	-16838	-16858	-	-17018	-17078	-17108
7 (5-6) Wt. of Displaced Water	1560	1560	1560		2340	2340	2340
8 Temp. of Water, °F	77	77	77		77	77	77
9 Asphalt Correction,	0		0		0	0	0
10 (7-9) Adjusted Wt.	1560	1560	1560		2340	2340	2340
11 Multiplier, Curve R,	1.0	1.0	1.0		1.0	1.0	1.0
12 (Line 3 ÷ Line 10)(Line 11) Sp.Gr., M	1.282	1.308	1.321		1.282	1.308	1.321
13 (A ÷ Line 12) - 1	0.0413	0.0206	0.0106		0.0413	0.0206	0.0106
14 (D x Line 13) % Asphalt, P	14.00	6.99	3.59		14.00	6.99	3.59
A Effective sp.gr.aggregates, A*	1.335	1.335	1.335		1.335	1.335	1.335
B Sp. Gr. of Asphalt, B	1.031						
C (A - B)	0.304						
D (100B ÷ C)	339.145	Same	Same		Same	Same	Same

*Line 9 of Sheet 2