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SUBJECT:

CHANGE THREE (3) to the OCTOBER 2013 EDITION,
PUBLICATION 19 - FIELD AND LABORATORY TESTING MANUAL

INFORMATION AND SPECIAL INSTRUCTIONS:

CHANGE THREE (3) OF THE OCTOBER 2013 EDITION OF PUBLICATION 19 REPLACES THE OCTOBER 2013 EDITION CHANGE TWO (2) OF PUBLICATION 19. CHANGE THREE (3) INCLUDES REVISIONS TO THE FOLLOWING SECTIONS OF PUBLICATION 19:

1. TABLE OF CONTENTS (REVISED)

2. PTM NO. 606 - Method of Test for OBTAINING AND TESTING DRILLED CORES OF CONCRETE

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FIELD AND LABORATORY TESTING MANUAL

October 2013 Edition, Change 3

Bureau of Project Delivery
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PENNSYLVANIA TEST METHODS (PTM'S)

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THE FOLLOWING ARE FORMER PENNSYLVANIA TEST METHODS. PENNSYLVANIA HAS ADOPTED THE FOLLOWING ASTM TEST STANDARDS FOR THESE FORMER TEST METHODS. THE FULL STANDARD FOR EACH TEST IS AVAILABLE FROM THE AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL, 100 BARR HARBOR DRIVE, PO BOX C700, WEST CONSHOHOCKEN, PA 19428-2959, (610) 832-9585, www.astm.org.

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LABORATORY TESTING SECTION

Method of Test for

PROBABILITY SAMPLING

1.   SCOPE

        1.1   This method of test outlines the procedures for selecting sampling sites in accordance with accepted probability sampling techniques. It is intended that all Department samples, regardless of size, type or purpose shall be selected in an unbiased manner, based entirely on chance.

2.   SECURING SAMPLES

        2.1   Department samples shall be taken as directed by the engineer or his authorized representative.

        2.2   Sample location and sampling procedure are as important as testing. It is essential that the sample location be chosen in an unbiased manner and the sample taken precisely as directed by the appropriate PTM.

3.   RANDOM NUMBER TABLE

        3.1   For test results or measurements to be meaningful, it is necessary that the SUBLOTS to be sampled or measured be selected at random, which means using a table of random numbers. The following table of random numbers has been devised for this purpose. To use the table in selecting sample locations, proceed as follows.

        3.2   Determine the LOT size and the number of SUBLOTS Per LOT by referring to the PTM for the material being sampled.

        3.3   For each LOT, use five consecutive two-digit random numbers from Table I. For example, if the PTM for a particular material specifies 5 sublots per LOT and the number 15 is randomly selected as the starting point from Column X (or Column Y) for the first LOT, numbers 15-19 would be the five consecutive two-digit random numbers. For the second LOT, another random starting point, number 91 for example, is selected and the numbers 91 through 95 are used for the five consecutive two-digit random numbers. The same procedure is used for additional LOTS.

        3.4   For samples taken from the roadway, use the decimal values in Column X and Column Y to determine the coordinates of the sample locations as specified in the appropriate PTM.

3.5   In situations where coordinate locations do not apply (i.e., plant samples, stockpile samples, etc.), use only those decimal values from Column X <u>or</u> Column Y as specified in the appropriate PTM.

4.   SAMPLING PROCEDURE

4.1   After the appropriate number of random locations has been determined, refer to the proper PTM for special sampling procedure instructions and examples.

5.   DEFINITION OF TERMS

5.1   <u>LOT</u> - an isolated quantity of a specified material from a single source or a measured amount of specified construction assumed to be produced by the same process. The LOT size is specified in the PTM for the material being sampled.

5.2   <u>SUBLOT</u> - a portion of a LOT; the actual location from which a sample is taken. The size of the sublot and the number of sublots per LOT are specified in the PTM for the material being sampled.

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TABLE I
RANDOM POSITIONS IN DECIMAL FRACTIONS (2 PLACES)

	X		Y		X		Y		X		Y
1.	0.29	R	0.66	34.	0.61	L	0.87	67.	0.93	R	0.17
2.	0.74	R	0.49	35.	0.76	R	0.16	68.	0.40	R	0.50
3.	0.89	L	0.79	36.	0.87	L	0.10	69.	0.44	R	0.15
4.	0.60	R	0.39	37.	0.41	L	0.10	70.	0.03	L	0.60
5.	0.88	R	0.31	38.	0.28	R	0.23	71.	0.19	L	0.37
6.	0.72	L	0.54	39.	0.22	L	0.18	72.	0.92	L	0.45
7.	0.12	R	0.08	40.	0.21	L	0.94	73.	0.20	L	0.85
8.	0.09	L	0.94	41.	0.27	L	0.52	74.	0.05	R	0.56
9.	0.62	L	0.11	42.	0.39	R	0.91	75.	0.46	R	0.58
10.	0.71	R	0.59	43.	0.57	L	0.10	76.	0.43	R	0.91
11.	0.36	L	0.38	44.	0.82	L	0.12	77.	0.97	L	0.55
12.	0.57	R	0.49	45.	0.14	L	0.94	78.	0.06	R	0.51
13.	0.35	R	0.90	46.	0.50	R	0.58	79.	0.72	L	0.78
14.	0.69	L	0.63	47.	0.93	L	0.03	80.	0.95	L	0.36
15.	0.59	R	0.68	48.	0.43	L	0.29	81.	0.16	L	0.61
16.	0.06	L	0.03	49.	0.99	L	0.36	82.	0.29	R	0.47
17.	0.08	L	0.70	50.	0.61	R	0.25	83.	0.48	R	0.15
18.	0.67	L	0.68	51.	0.87	L	0.36	84.	0.73	R	0.64
19.	0.83	R	0.97	52.	0.34	L	0.19	85.	0.05	L	0.94
20.	0.54	R	0.58	53.	0.37	R	0.33	86.	0.43	L	0.05
21.	0.82	R	0.50	54.	0.97	L	0.79	87.	0.87	R	0.98
22.	0.66	R	0.73	55.	0.13	R	0.56	88.	0.37	L	0.71
23.	0.06	L	0.27	56.	0.85	R	0.64	89.	0.94	L	0.26
24.	0.03	L	0.13	57.	0.14	L	0.04	90.	0.57	L	0.63
25.	0.55	L	0.29	58.	0.99	R	0.74	91.	0.26	R	0.80
26.	0.64	L	0.77	59.	0.40	L	0.76	92.	0.01	L	0.79
27.	0.30	R	0.57	60.	0.37	L	0.09	93.	0.83	R	0.59
28.	0.51	R	0.67	61.	0.90	R	0.74	94.	0.71	L	0.21
29.	0.29	R	0.09	62.	0.09	L	0.70	95.	0.65	L	0.63
30.	0.63	R	0.82	63.	0.66	L	0.97	96.	0.65	L	0.87
31.	0.53	L	0.86	64.	0.89	L	0.55	97.	0.72	R	0.92
32.	0.99	R	0.22	65.	0.67	L	0.44	98.	0.85	L	0.78
33.	0.02	R	0.89	66.	0.02	R	0.65	99.	0.04	L	0.46
								100.	0.29	L	0.95

X =   Decimal fraction of the total length measured along the road from the starting point.
Y =   Decimal fraction measured across the road from either outside edge towards the centerline of the paved lane.
R =   Indicates measurement from the right edge of the paved lane.
L =   Indicates measurement from the left edge of the paved lane.

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LABORATORY TESTING SECTION

Method of Test for

TREATMENT OF EXTREME VALUES

1.   SCOPE

        1.1   The purpose of this test method is to outline a procedure for dealing with extreme values when doing computations for quality control or acceptance testing. An extreme value or "outlier" is one that appears to deviate markedly from other increments of the sample in which it occurs. An extreme value is a value from a collection of measurements that varies greatly from the average, $\bar{x}$. This method indicates whether or not the outlier is beyond the normal distribution.

        1.1.1   An extreme value may be merely a manifestation of the random variability inherent in the data (chance cause variation). If this is true, the value should be discarded and another value substituted, when practical. If it is not practical to substitute another value, the extreme value should be discarded and the sample evaluated on the basis of the reduced observations.

        1.1.2   An extreme value may be the result of gross deviation from prescribed construction procedure and/or materials quality control, a calculation error, or negligence in recording numerical data (assignable cause variation). In such cases, it is necessary to institute an investigation to ascertain the reason(s) for the extreme value. When the investigation deems poor construction and/or materials quality control, the extreme value shall be retained and processed in the same manner as the other observations in the sample. Calculation or recording errors shall be corrected and the sample observations re-analyzed.

2.   PROCEDURE

        2.1   Calculate the average of the lot measurement values by:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Where:

        $\bar{X}$ = Average lot measurement value

        X_i = Individual measurement

        n   = Number of measurements

$$\sum_{i=1}^{n} = \text{Sum of "n" measurements } (X_1 + X_2 + X_3 \dots + X_n)$$

2.2   Calculate the standard deviation, s, of the lot measurement values by:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}$$

Where:

s   = Sample standard deviation

$\overline{X}$ = Average lot measurement value

X_i = Individual measurement

$\sum_{i=1}^{n}$ = Sum of the squares deviation from the average

n   = Number of measurements

2.3   Calculate the T value by:

$$T = \frac{\left|\overline{X} - X_{suspected}\right|}{s}$$

Where:

T   = Number of deviation units the suspected value is from the average lot measurement value

$\overline{X}$ = Average lot measurement value

X   = The suspected extreme value

s   = Sample standard deviation

2.4   Compare the result obtained in 2.3 above with the value shown in Table I for the number of observations (n) at the specified significance level. (The significance level will be given in the relevant specification).

2.5   On a LOT basis, when the value obtained in Section 2.3 exceeds the Table I value, the extreme value shall be investigated in accordance with Sections 1.1.1 and 1.1.2 above.

2.6   On a LOT to LOT basis, the concept of extreme values considers that when a large number of measurements are taken, it is highly probable that there will be at least one measurement that will vary greatly from the average of all the measurements. When there are only a few measurements the chance that one of them will vary greatly from the average is very small. When the 5% significance level is used, it means that one should not expect to find more than five extreme values per hundred or a ratio of 1:20, considering chance variation (Table II). If the ratio is exceeded, when the measurements from all LOTS on the project are combined, the extreme values are attributable to an assigned cause. If the construction and/or material process has not changed, the extreme values are no longer considered as outliers. The values shall be investigated in accordance with Sections 1.1.1 and 1.1.2 above.

3.   EXAMPLE

3.1   Five bitumen content determinations were made by the extraction method on a lot of bituminous concrete. The material was an ID-2 wearing course mixture with a design specifying 6.0% bitumen. The results were as follows: (1) 6.0, (2) 5.8, (3) 5.7, (4) 6.1, and (5) 5.4.

It is desired to know if test #5 (5.4%) constitutes an outlier.

3.2   First obtain the average, $\overline{X}$

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{29.0}{5} = 5.8\%$$

3.3   Calculate the standard deviation, s

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}} = \sqrt{\frac{0.29}{4}} = 0.27$$

3.4   Calculate the T value

$$T = \frac{\left|\overline{X} - X_{suspected}\right|}{s} = \frac{5.8 - 5.4}{0.27} = 1.48$$

3.5   Compare the T value (1.48) with the value (1.67) shown in Table I for n=5 and a significance level of 5%.

3.6   The value of T (1.48) does not exceed the T value (1.67) in Table I , therefore, the value of 5.4% bitumen is not considered an outlier.

TABLE I
CRITICAL VALUES OF T (ONE-SIDED TEST) WHEN THE STANDARD DEVIATION IS
CALCULATED FROM THE SAME SAMPLE

NUMBER OF OBSERVATIONS n	5 PERCENT SIGNIFICANCE LEVEL	2.5 PERCENT SIGNIFICANCE LEVEL	1 PERCENT SIGNIFICANCE LEVEL
3	1.15	1.15	1.15
4	1.46	1.48	1.49
5	1.67	1.71	1.75
6	1.82	1.89	1.94
7	1.94	2.02	2.10
8	2.03	2.13	2.22
9	2.11	2.21	2.52
10	2.18	2.29	2.41
11	2.23	2.36	2.48
12	2.29	2.41	2.55
13	2.33	2.46	2.61
14	2.37	2.51	2.66
15	2.41	2.55	2.71
16	2.44	2.59	2.75
17	2.47	2.62	2.79
18	2.50	2.65	2.82
19	2.53	2.68	2.85
20	2.56	2.71	2.88

TABLE II
ALLOWABLE NUMBER OF EXTREME VALUES FOR CHANCE CAUSES

NUMBER OF TESTS	ALLOWABLE NUMBER OF EXTREME VALUES *
1 - 20	1
21 - 40	2
41 - 60	3
61 - 80	4
81 - 100	5

*   When the value in this column is exceeded, the extreme values shall be considered attributable to assignable causes.

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LABORATORY TESTING SECTION

Method of Test for

EVALUATING TESTING REPEATABILITY

1.   SCOPE

1.1   The purpose of this test method is to outline a procedure for evaluating testing repeatability between samples obtained from a lot. Repeatability is the range within which repeated measurements are made by the same or different operator on the same apparatus. Essentially, repeatability refers to the consistency of test method's pattern of variation and may be regarded as the test precision.

1.1.1   In quality-control work and acceptance testing in connection with highway construction, it is important to obtain reliable tests results. A test result is reliable only if a decision based on the result can be considered correct with a certain degree of confidence. In addition, a test result is reliable if the same result (within reasonable specified limits) can be obtained when the test is performed more than once either by the same person or different person.

1.1.2   A sample or test must be obtained and tested in such a way that the results shall be practically the same when the sampling and testing are repeated under similar conditions. In order that test method may be reliable, it is necessary to select the initial sample for the test by a random method and to adopt a standard procedure for making the test.

2.   PROCEDURE

2.1   Perform the required tests on the initial samples from the lot submitted. Remaining material shall be adequately stored for retesting when required to evaluate repeatability.

2.2   When evaluation of testing repeatability is required, perform the appropriate tests on the stored material, preferably by the same operator, utilizing the same equipment used for the initial tests.

2.3   Calculate the difference between each original test value and its associated retest value.

2.4   Calculate the average difference, $\overline{X}_d$, by:

$$\overline{X}_d = \frac{\sum_{i=1}^{n}(X_{t_i} - X_{r_i})}{n}$$

Where:

$\overline{X}_d$ = Average difference

X_{ti} = Individual measurement of the original test

X_{ri} = Individual measurement of the retest

n   = number of paired measurements

$\sum_{i=1}^{n}$ = sum of "n" measurements $\{(X_{t1} - X_{r1}) + (X_{t2} - X_{r2}) + ... + (X_{ti} - X_{ri})\}$

2.5   Calculate the standard deviation, s_d, of the differences between the original test values and their retest values by:

$$s_d = \sqrt{\frac{\sum_{i=1}^{n} X_{d^2_i}}{n} - \overline{X}_{d^2}}$$

Where:

s_d = Standard deviation of the differences

X_{d_i} = Individual differences between the original test values and retest values

$\overline{X}_d$ = Average difference

n   = Number of paired measurements

$\sum_{i=1}^{n}$ = Sum of the squares of the differences between the original test values and retest values

2.6   Calculate the T value by:

$$T = \frac{|\overline{X}_d - \overline{X}_p| \sqrt{n-1}}{s_d}$$

Where:

T   = Number of deviation units the average difference is from the population mean, X_p

$\overline{X}_d$ = Average difference

$\overline{X}_p$ = The population average difference, X_p is always equal to zero

s_d = Standard deviation of the differences

n   = Number of paired measurements

2.7   Compare the result obtained in Section 2.6 above with the value shown in Table I for the number of paired differences at the 5 % significance level.

2.8   If the value obtained in Section 2.6 is less than or equal to the tabular value in Table I, the original test values are considered as repeatable and shall be used for analysis purposes.

2.9   When the value in Section 2.6 exceeds the tabular value in Table I, a lack of repeatability is highly probable and the original test results shall be discarded. The retest values shall be retained and used for analysis purposes.

3.   EXAMPLE

3.1   Five bitumen content determinations were made by the extraction method on a lot of bituminous concrete. The mixture was an ID-2 wearing course with a design specifying 5.7% bitumen. The results were as follows:

(1) 6.0, (2) 6.1, (3) 5.2, (4) 5.9, and (5) 6.2

The contractor requested a retest of the lot and the following results were obtained:

(1) 6.2, (2) 6.0, (3) 5.6, (4) 5.8, and (5) 6.3

It is desired to evaluate the repeatability of the testing.

3.2   Arrange the original test values and their associated retest value in tabular form.

3.3   Determine the difference between each original test value and it associated retest value.

<u>EVALUATION TABLE</u>

<u>Sublot Number</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Original Test Value	6.0	6.1	5.2	5.9	6.2
Retest Value	6.2	6.0	5.6	5.8	6.3
Difference	-0.2	+0.1	-0.4	+0.1	-0.1

3.4   Calculate the average difference, $\overline{X}_d$.

$$\overline{X}_d = \frac{\sum_{i=1}^{n}(X_{t_i} - X_{r_i})}{n} = \frac{(-0.2) + (+0.1) + (-0.4) + (+0.1) + (-0.1)}{5} = -0.1$$

3.5   Calculate the standard deviation, s_d, of the differences between the original test values and their associated retest values.

$$s_d = \sqrt{\frac{\sum_{i=1}^{n}X_{d^2_i}}{n} - \overline{X}_{d^2}} = \sqrt{\frac{(-0.2)^2 + (0.1)^2 + (-0.4)^2 + (0.1)^2 + (0.1)^2}{5} - (-0.1)^2}$$

$$s_d = 0.19$$

3.6   Calculate the T value.

$$T = \frac{|\overline{X}_d - \overline{X}_p|\sqrt{n-1}}{s_d} = \frac{|-0.1 - 0.0|\sqrt{4}}{0.19} = \frac{|-0.1|2}{0.19} = \frac{0.20}{0.19}$$

$$T = 1.05$$

3.7   Compare the T value (1.05) with the value (1.67) shown in Table I for n=5 and a significance level of 5%.

3.8   The value of T (1.05) does not exceed the T value (1.67) in Table I, therefore, the testing shall be considered as repeatable and the original test values are considered valid.

TABLE I
Critical Values of T at the 5%
Level of Significance

Number of Observations n	Tabulated T value
3	1.15
4	1.46
5	1.67
6	1.82
7	1.94
8	2.03
9	2.11
10	2.18
11	2.23
12	2.29
13	2.33
14	2.37
15	2.41
16	2.44
17	2.47
18	2.50
19	2.53
20	2.56

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF PERCENT WITHIN LIMITS (PWL) FOR CONSTRUCTION AGGREGATE

1.   SCOPE

        1.1   For determination of Construction Percent Within Limits (PWL) using Statistical Method as in CAMMS.

2.   DEFINITION OF A MAJOR/MINOR DEVIATION

        2.1   Major Deviation - When a sample PWL is less than 90%.

        2.2   Minor Deviation - When a sample PWL is greater than 90%, but less than 100%.

3.   GENERAL STATEMENTS ABOUT PWL CALCULATIONS

        3.1   If all results on a particular sieve or wash test are within the specification limits, then the construction PWL for that result is 100.

        3.2   If one or more results of three are outside the specification range for a particular sieve the statistical PWL on the report is used to calculate the total sample PWL based on construction specifications.

        3.3   On specification sieves that have an upper limit of 100, Q_U is not calculated. Q_L is the only value calculated and used to represent the PWL for that sieve.

        3.4   On specification sieves that have a lower limit of 0, Q_L is not calculated. Q_U is the only value calculated and used to represent the PWL for that sieve.

        3.5   On specification sieves that have both limits as 100, only use the upper limit and calculate only the upper Quality Index to represent the PWL for that sieve.

4.   CALCULATIONS

        Note: The following calculations are from the #4 sieve on the CAMMS report on page 5.

        4.1   The lot (X) measurements are averaged to find $\overline{X}$.
        $$\overline{X} = \sum_{i=1}^{n} \frac{Xi}{n}$$

Where:

$\overline{X}$ = Average or mean value of the number of tests to the nearest whole number

n   = Size of the sample in whole number increments

X_i = The ith value in a series of observations in whole numbers

Example: Calculations for the #4 sieve for 3 test results (See an example of a test report on page 5).

$$\overline{X} = \frac{28 + 22 + 33}{3} = \frac{83}{3} = 27.7 = 28$$

4.2   The standard deviation "s" of the sample increments for each sieve is calculated using whole numbers. The calculated value is to the nearest tenth.

$$s = \sqrt{\frac{\sum_{i=1}^{n} (Xi - \overline{X})^2}{n-1}}$$

Where:

$\overline{X}$ = Average or mean value of the number of tests to the nearest whole number

n   = Size of sample in whole number increments

X_i = The ith value in a series of observations in whole numbers

s   = The Standard Deviation of the lot of measurements

Example: With the $\overline{X}$ calculated to be 28, "s" would be calculated.

$$s = \sqrt{\frac{(28-28)^2 + (22-28)^2 + (33-28)^2}{3-1}} = \sqrt{\frac{61}{2}} = 5.522 = 5.5$$

4.3   The Quality Index (Q_U) is found by subtracting the average ($\overline{X}$) of the measurements from the upper specification limits (U) and dividing the result by "s" and is expressed to the nearest ten thousandth.

$$Q_U = \frac{(U - \overline{X})}{s}$$

Where:

$\overline{X}$ =   Average or mean value of the number of tests

s   =   The Standard Deviation of the lot of measurements

U   =   Upper Specification Limit

Q_U =   Quality Index of the upper specification limit

P_U =   Estimate of the percentage of a lot which has values equal to or less than the upper specification limit

Example: With the upper specification limit equal to 50, Q_u would be calculated.

$$Q_U = \frac{50 - 28}{5.5} = \frac{22}{5.5} = 4.0000 \qquad P_U = 100$$

NOTE - P_U was found in Table A of Publication 408, Section 106 for n=3.

4.4   The Quality Index (Q_L) is found by subtracting the lower specification limit (L) from the average (X) and dividing the result by "s". This value is expressed to the nearest ten thousandth.

$$Q_L = \frac{(\overline{X} - L)}{s}$$

Where:

L   =   Lower Specification Limit

$\overline{X}$ =   Average or mean value of the number of tests

s   =   The Standard Deviation of the lot of measurements

Q_L =   Quality Index of the lower specification limit

P_L =   Estimate of the percentage of a lot which has values equal to or greater than the lower specification limit

Example: With the lower specification equal to 24, Q_L is calculated.

$$Q_L = \frac{28 - 24}{5.5} = \frac{4}{5.5} = 0.7272 \qquad P_L = 72$$

NOTE: P_L was found in Table A of Publication 408, Section 106 for n=3.

4.5   The percentage of material that will fall within the upper tolerance limit (U) is estimated by entering Table A in Publication 408 Section 106, with Q_u, using the column appropriate to the total number of measurements (n).

4.6   The percentage of material that will fall within the lower tolerance limit (L) is estimated by entering Table A in Publication 408 Section 106 with Q_L, using the column appropriate to the total number of measurements (n).

4.7   In cases where both upper (U) and lower (L) tolerance limits are considered, the percentage of material that will fall within tolerance limits is found by adding the percent (P_U) within the upper tolerance limit (U) to the percent (P_L) within the lower tolerance limit (L) and subtracting 100 from the sum.

Example:
    Percent within limits $= (P_U + P_L) - 100$

    Percent within limits $= (100 + 72) - 100 = 72$

Below is an example of how individual PWL's are calculated to determine the construction aggregate specification PWL on a CAMMS report. (See the CAMMS report on page 5.)

Sieve Size	Statistical PWL on Report	Internal Construction PWL Calculations
2"		+100
3/4"	100	+100
3/8"	100	+100
#4	72	+72
#16	30	+30
Wash Test	100	+100
		502/6
		results=83.5=84

Note - If all the test results on the #4 sieve were within the specification limits, it is possible that the statistical PWL on the report will be below 100%. If all the test results for the #4 sieve are within the specification limits, the construction PWL calculations will be 100%.

4.8   To determine the percentage within tolerance when the calculated Quality Index (Q.I.) value is between two tabular values in Table A, the following procedure is used.

4.8.1   The difference between the tabular Q.I. values on either side of the calculated Q.I. value will be determined.

4.8.2   The difference will be divided by 2 and the quotient added to the lower tabular Q.I. value, resulting in the interpolated Q.I. value.

4.8.3   If the calculated Q.I. is equal to or greater than the interpolated value, the higher listed percent within tolerance will be used.

4.8.4   If the calculated Q.I. is less than the interpolated value, the lower listed percent within tolerance will be used.

Note - When percent loss by wash is required, the (X) and ($\overline{X}$) calculations are rounded to the nearest hundredth. The standard deviation(s) is rounded to the nearest tenth.

```
REPORT: CA~LR510                  AGGREGATE                    13:20:59
FINAL REPORT     Ref#:        Lab#:       Pass/Fail: F   CAMSPROD
----------------------------------------------------------------------
 Cont #:                      QA Rtug: MAJOR      Cntrctr:
 Pr O #:                      Orgnztn:            Lctn Cd:
 Mtl Ds: AGGRGT,COARSE        Section:            L/C XRf:
 408Y/S: 90 703               Station:            Prt Tkt:
 Supl #:                      Colcted:            Lot Nbr:
 Plc Cl:                      Receivd:            # Incrm: 3
 Smp By:                      Releasd:            447 XRf:
----------------------------------------------------------------------
TR-447 Remarks: SUBBASE
----------------------------------------------------------------------
SCREEN  LIMITS R(L) -1-    -2-    -3-     AVG ST DEV R(S) PWL
2 1/2n              100    100    100     100   .0   0
1 1/2"              100    100    100     100   .0   0
3/4"    52  100 48  88     84     89      87   2.6   5    100
3/8"    36   70 34  49     42     57      49   7.5  15    100
#4      24   50 26  28     22-    33      28   5.5  11     72
#8               15  12     20     16   4.0   8
#16     10   30 20   9-     8-     11      9-N 1.5   3     30
#30               6   5      6      6   .6    1
#50               4   4      4      4   .0    0
#100              3   3      3      3   .0    0
#200              2   2      2      2   .0    0


LIMITS      R(L)  -1-    -2-    -3-     AVG ST DEV R(S) PWL
PERCENT LOSS BY WASH
  0          10  6.82   4.94   7.06    6.27  1.2  2.12 100

TOTAL SAMPLE PWL BASED ON CONSTRUCTION SPECIEICATIONS:  84 J
```

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LABORATORY TESTING SECTION

Method of Test for

AMOUNT OF MATERIAL FINER THAN
75 μm (NO. 200) SIEVE IN AGGREGATE

This PTM is a modification of AASHTO T-11. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to AASHTO T-11 are as follows:

1.   SCOPE

        1.2   Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75 μm (No. 200) sieve from the coarser material.

5.   APPARATUS AND MATERIALS

        5.4   Oven- An oven of sufficient size, capable of maintaining a uniform temperature of $110 \pm 5°C$ ($230 \pm 9°F$). Hot plates either electric or gas, maybe used when test results must be obtained quickly in the field. When test results are disputed, referee samples shall be tested using ovens as described above.

6.   SAMPLING

        6.1   Sample the aggregates in accordance with PTM 607.

        6.2   Obtain a sample in accordance with PTM 607. Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in AASHTO T248. The sample for test shall not be less than the appropriate mass dried material as shown in the following table:

AASHTO / PA Number	Minimum Mass of Sample	
	Kg	lb
# 3	5.0	10.0
# 5	5.0	10.0
# 57	3.5	7.7
# 67	2.5	5.0
# 7	2.5	5.0
# 8	1.0	2.0
2A	4.0	8.8
OGS	4.0	8.8
Type A Fine Aggregate	0.5	1.0

11.   REPORT

11.1   Report the percentage of material finer than the 75 μm (No. 200) sieve by washing to the nearest 0.01%.

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LABORATORY TESTING SECTION

Method of Test for

THE MOISTURE-DENSITY RELATIONS OF SOILS
(Using a 2.5 kg (5.5-lb.) Rammer and a 305 mm (12") Drop)

1.   SCOPE

1.1   This method of test, which is a modification of AASHTO T-99 is intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 2.5 kg (5.5 lb.) rammer dropped from a height of 305 mm (12"). Method A is used when the test is run on the portion of the soil sample passing the 19.0 mm (3/4") sieve, the material retained on the sieve being discarded. Method B is used when the test is run on a compensated sample of soil passing the 19.0 mm (3/4") sieve, by replacing the amount retained on the sieve with an equal weight of material passing the 19.0 mm (3/4") and retained on the 4.75 mm (No. 4) sieve, taken from the remaining portion of the sample.

2.   APPARATUS

2.1   Molds - The mold shall be cylindrical in shape, made of metal, and shall have the capacity and dimensions indicated in Section 2.1.1. It shall have a detachable collar assembly approximately 60.3 mm (2-3/8") in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold may be of the "split" type, consisting of two half-round sections, or a section of pipe split along one element, which can be securely locked in place to form a cylinder. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base place.

2.1.1   A 102.0 mm (4.0") mold having a capacity of $9.43 \times 10^{-4} \pm 8.0 \times 10^{-6}$ m^3 (1/30 ± 0.0003 cu. ft.), with an internal diameter of 101.60 ± 0.41 mm (4.0 ± 0.016") and a height of 116.43 ± 0.13 mm (4.584 ± 0.005") (Figure 1).

2.1.2   Molds shall be checked for adherence to tolerances annually. Molds may remain in use after continued service provided the original tolerances (Section 2.1.1) are not exceeded by more than 50 percent. Molds meeting this stipulation shall be calibrated for volume according to Section 8 (Calibration of Measure) of AASHTO T-19, for Unit Mass of Aggregates, and the found volume used in all subsequent calculations.

2.2   Rammer - A manually operated metal rammer 50.8 mm (2") in diameter having a flat circular face and weighing 2.5 kg (5.5 lb.). The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 305 mm (12") above the elevation of the soil.

2.3   Sample Extruder (optional) - A jack, lever, frame or other device adapted for the purpose of extruding compacted specimens from the mold.

2.4 Balances - A balance or scale of at least 10 kg (25 lb.) capacity sensitive to 5 g (0.01 lb), and a balance of at least 1000 g (2.2 lbs.) capacity sensitive to 0.1 g (0.002 lbs).

2.5 Drying Equipment - Stove, oven, hot plate or other suitable equipment for drying moisture content samples.

2.6 Straight Edge - A steel straightedge 300 mm (12") in length and having one beveled edge.

2.7 Sieves - 50.0 mm, 19.0 mm, and 4.75 mm (2", 3/4", and No. 4) sieves conforming to the requirements of the Specifications for Sieves for Testing Purposes, AASHTO M-92.

2.8 Mixing Tools - Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3. METHOD A

3.1 Sample

3.1.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 60°C (140°F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the individual particles.

Note - When the material is granulated slag, the sample should be dried to approximately 4 percentage points below optimum moisture content.

3.1.2 Sieve an adequate quantity of the representative pulverized soil over the 19.0 mm (3/4") sieve. Discard the coarse material, if any, retained on the 19.0 mm (3/4") sieve.

3.1.3 Select a representative sample, weighing approximately 5.0 kg (12 lb.), or more, of the soil prepared as described in Sections 3.1.1 and 3.1.2.

4. METHOD B

4.1 Sample

4.1.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus such that the temperature of the sample does not exceed 60°C (140°F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

Note - When the material is granulated slag, the sample should be dried to approximately 4 percentage points below optimum moisture content.

4.1.2   Sieve an adequate quantity of the representative pulverized soil over a 19.0 mm (3/4") sieve. Discard any large oversized pieces. Weigh the material retained on the 19.0 mm (3/4") sieve and replace it with an equal mass of material passing the 19.0 mm (3/4") sieve and retained on the 4.75 mm (No. 4) sieve. Take the material for replacement from the remaining portion of the sample.

4.1.3   Select a representative sample, weighing approximately 5 kg (12 lb) of the soil prepared as described in Sections 4.1.1 and 4.1.2.

(A) WING NUT (4)
(B) STUD (2)
(C) HANGER (4)
(D) WELD (Top and bottom of each hanger)
(E) COLLAR (1)
(F) MOLD (1)
(G) BASE PLATE (1)

LOCATION OF STUDS IN BASE PLATE
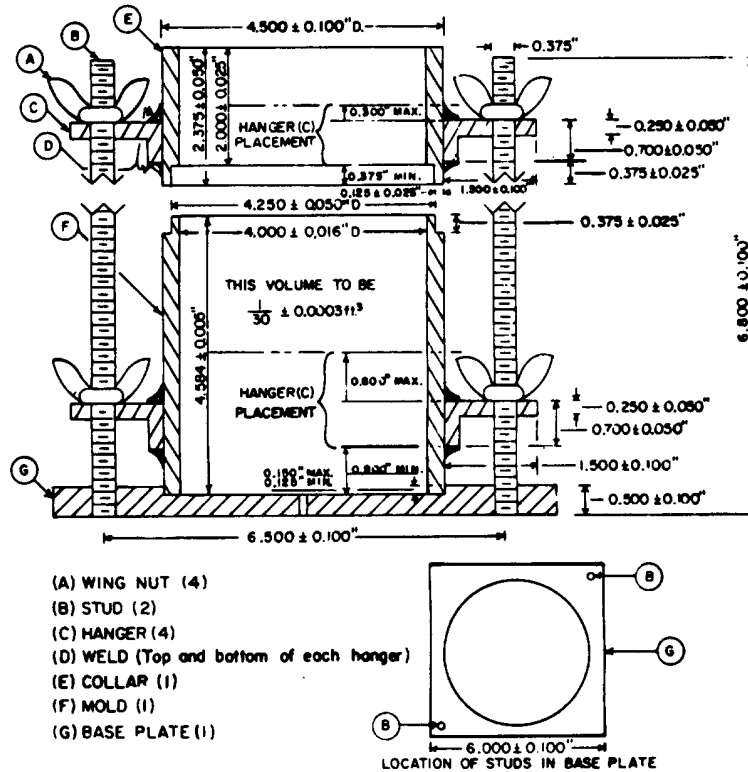
Fig. I—Cylindrical Mold and Base Plate
101.60 mm (4") Mold

Metric Equivalents

5. PROCEDURE

5.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

5.2 Form a specimen by compacting the prepared soil in the 102.0 mm (4") mold (with collar attached) in three equal layers to give a total compacted depth of about 125.0 mm (5"). Compact each layer by using 25 uniformly distributed blows from the rammer, dropping free from a height of 305.0 mm (12") above the elevation of the soil when a sleeve type rammer is used, or from 305.0 mm (12") above the approximate elevation of each finally compacted layer when a stationary mounted type of rammer is used. During compaction, the mold shall rest on a uniform, rigid foundation, such as is provided by a cube of concrete weighing not less than 90 kg (200 lb). Following compaction, remove the extension collar, and carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller sized material. Weigh the mold and moist soil. Multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 1059.32 (30), and record the result as the wet mass per cubic meter (foot) of the compacted soil.

5.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5ºC (230 ± 9ºF) for at least 12 hr., or to constant weight, on a hot plate or in accordance with PTM 123 to determine the moisture content. The moisture content sample shall weigh not less than 200 g (0.5 lbs).

5.4 Thoroughly break up the remainder of the material until it will pass a 19.0 mm (3/4") sieve and 90 percent of the soil aggregations will pass a 4.75 mm (No 4) sieve as judged by eye, and add this material to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass per cubic meter (foot) of the compacted soil.

> NOTE - Another procedure is by the use of separate samples. In instances where the soil material is fragile in character and will be reduced significantly in grain size due to repeated compaction, and in cases where the soil is heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture contents selected shall bracket the optimum moisture content, thus providing samples which, when compacted, will increase in mass to the maximum density and then decrease in mass.

6.   CALCULATIONS AND REPORT

6.1   Calculations

6.1.1   Calculate the moisture content and the dry mass of the soil as compacted for each trial, as follows:

$$M = \frac{W_1 - W_2}{W_2 - P} X100$$

and

$$D = \frac{D_w}{M + 100} X\ 100$$

Where:

M	=	Percentage of moisture in the specimen, based on dry mass
W_1	=	Moist mass of sample including pan, in grams
W_2	=	Dry mass of sample including pan, in grams
P	=	Mass of pan in grams
D_W	=	Wet density of compacted soil specimen, in kilograms per cubic meter (pounds per cubic foot)
D	=	Dry density of compacted soil specimen, in kilograms per cubic meter (pounds per cubic foot)

7.   MOISTURE-DENSITY RELATIONSHIP

7.1   The calculations in Section 6.1.1 shall be made to determine the moisture content and corresponding oven-dry mass (density) for each of the compacted soil samples. The oven-dry masses per cubic meter (foot) (densities) of the soil shall be plotted as ordinates and corresponding moisture contents as abscissas.

7.2   Optimum Moisture Content - When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in Section 7.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture content" of the soil under the above compaction. The smooth curve should be a free-hand approximation of a parabola. The use of a straightedge in drawing the curve is discouraged. A zero air voids line may be added to the graph only when it is appropriate to the measured specific gravity of the sample.

7.3   Maximum Density - The oven-dry mass per cubic meter (foot) of the soil at optimum moisture content shall be termed "maximum density" under the above compaction.

8. REPORT

    8.1   The report shall include the following:

          8.1.1   The optimum moisture content

          8.1.2   The maximum density

          8.1.3   Indicate if Method A or Method B was used

9. REFERENCES

          AASHTO T-99
          ASTM D-698
          PENNDOT Bulletin 39

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LABORATORY TESTING SECTION

Method of Test for

SAMPLE PREPARATION OF FILL MATERIAL
FOR
MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALL SYSTEMS

1.   SCOPE

   1.1   This method of test is the procedure required to correct for oversized
         particles of granular MSE wall backfill material samples prior to
         electrochemical and shear strength testing. This PTM is a supplement to the
         following test methods:

Material Property	Test Method	
Chlorides	AASHTO T 291	Determining Water-Soluble Chloride Ion Content in Soil
Sulfates	AASHTO T 290	Determining Water-Soluble Sulfate Ion Content in Soil
pH	AASHTO T 289	Determining pH of Soil for Use in Corrosion Testing
Resistivity	AASHTO T 288	Determining Minimum Laboratory Soil Resistivity
Internal Friction	AASHTO T 236	Direct Shear Test of Soils Under Consolidated Drained Conditions

NOTE: The above AASHTO Standard Method of Tests use only particles passing
the 2.00 mm (No. 10) sieve. This PTM modifies this to allow material passing the
2.36 mm (No. 8) sieve for all tests.

   1.2   Oversize particle correction is considered necessary to yield representative
         test results when sampling material that contains particles coarser than the
         2.36 mm (No. 8) sieve. Accordingly, oversize particle correction is required
         for samples having material retained on the 2.36 mm (No. 8) sieve.

2.   PROCEDURE

The following shall apply to the preparation of samples prior to electrochemical and shear strength testing:

2.1 Obtain randomly selected backfill samples for testing, representative of the material as to be placed during construction. Determine the particle size distribution in accordance with AASHTO T 27 using, at a minimum, the following succession of sieves:

75 mm (3 in.)
19 mm (3/4 in.)
2.36 mm (No. 8)
1.16 mm (No.16)
425 µm (No. 40)
150 µm (No. 100)
75 µm (No. 200)

NOTE: This is the determination of the grain size distribution of the bulk sample, not the companion sample minus 2.36 mm (No. 8) material sample, if supplied.

2.2 Determine the percent (by weight) of the sample passing the 2.36 mm (No.8) sieve and corresponding fraction of particles larger than the 2.36 mm (No. 8) sieve. If material is retained on the 2.36 mm (No. 8) sieve or a sieve above the 2.36mm (No.8) sieve (a sieve with a larger sieve opening), a corrected sample must be prepared.

2.3 Prepare a "corrected sample" by substituting the fraction of material retained on and above the 2.36 mm (No. 8) sieve with an equivalent percent of material that passes the 2.36 mm (No. 8) sieve but is retained on the 1.18 mm (No. 16) sieve. The remainder of the corrected sample shall be prepared by matching the gradation of the bulk sample for material passing the 2.36 mm (No.8) sieve. DO NOT use the companion sample 2.36 mm (No.8) material to prepare the test sample if the companion sample gradation does not match the gradation of the minus 2.36 mm (No.8) portion of the bulk sample. It is required that the portion of minus 2.36 mm (No.8) material in the test sample, match the minus 2.36 mm (No.8) fraction of material placed as backfill for construction of the MSE wall.

2.4 The minus 2.36 mm (No. 8) to plus 1.16 mm (No. 16) sieve fraction material used in the substitution shall be obtained according to the following steps:

    2.4.1 If the sample is NOT of uniform mineralogy, crush oversized (> 2.36 mm (No. 8) sieve) particles from the original sample.

    2.4.2 If the sample is of uniform mineralogy, sieve additional sample sufficient to produce the required amount.

    2.4.3 If the uniformity of the mineralogy is uncertain, then follow what is written in Section 2.4.1.

2.5 Thoroughly mix the graded fractions to the correct proportions to prepare a quantity of corrected sample sufficient to perform the required electrochemical and shear strength testing methods listed in Section 1.1.

3. REFERENCES

AASHTO T-27
AASHTO T-236
AASHTO T-288
AASHTO T-289
AASHTO T-290
AASHTO T-291

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LABORATORY TESTING SECTION

Method of Test for

EVALUATION OF POTENTIAL EXPANSION OF STEEL SLAGS

1.   SCOPE

1.1   This method of test covers the determination of the rate of expansion of steel slags where compacted and tested in the laboratory. Steel slags, produced in steel making processes such as open hearth, open oxygen, and electric arc furnaces are generally expansive with volume changes of up to 10% attributable to the hydration of calcium and magnesium oxides.

1.2   This method is also applicable to any particulate material suspected of having expansive characteristics.

2.   APPARATUS

2.1   Mold - The mold (see Fig. 1) shall be of metal, cylindrical in shape, with an inside diameter of 6 ± 0.026", and a height of 7 ± 0.018". It shall be provided with a metal extension collar 2.0" in. in height, and a perforated metal base plate 3/8" in height. The perforations in the base plate shall not exceed 1/16" in diameter. The mold apparatus shall be well coated with a rust preventative or constructed of stainless steel.

2.2   Spacer Disk - A circular metal spacer disk (see Figure 1) 5 15/16" in diameter and 2.416" in height.

2.3   Rammer - A metal rammer as specified in Section 2.2, PTM 106.

2.4   Expansion Measuring Apparatus- An adjustable metal stem and perforated plate, with perforations in the plate not exceeding 1/16" in diameter, and a metal tripod to support the dial gage for measuring the amount of vertical expansion (see Figure 1).

Thickness to give 5 LBS.

M

ELEVATION

L

PLAN

SURCHARGE WEIGHT

Weld

Drill 0.375" With 0.001" Shim Between Clamp and Frame

C

PLAN
Dial Not Shown For Clarity

6.5"

0.125" Machine Screw (Typ.)

Dial

A
B
D
A
B
E
Clamp
F
B
G
H

ELEVATION

Dial
Weld
E
E
I
I
K
J

SIDE VIEW

K I

STEEL TRIPOD FOR DETERMINING EXPANSION

N

PLAN

P

ELEVATION

STEEL SPACER DISC

0.0625"
Hole (Typ.)

PLAN

42-0.0625" Drilled Holes equally spaced

W
V
X
A
G
Z
Extension Collar
Y
Mold
O
Q
P
Spacer Disc
E
F
0.375" 16 NC-2
T
U

ELEVATION

STEEL MOLD WITH EXTENSION COLLAR

C
g
d
k
f
h
m
0.75" HEX
M10x1.5-6g
Knurl
0.25"
n
g
M10x1.5-6g
p
s
t

Elevation

Bronze Adjustable Stem and Plate

NOTE:
Where no Dimension Tolerances are given the Dimension shown is Approximate.

LEGEND:
* Diameters
** Other Suitable Metal to be used
*** Plate may be Square

TABLE OF MEASUREMENTS (in.)														
TRIPOD FOR DETERMINING EXPANSION												SURCHARGE	SPACER DISC	
MATERIAL	STEEL **													STEEL **	
DIMENSION	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P
INCHES	0.250	0.500	2.500	4.750	0.375	0.0625	6.00	7.500	3.00	3.750	0.750	2.125	5.875	5.9375	2.416
TOLERANCE (in.)														0.03125	0.005
MOLD WITH EXTENSION COLLAR															
MATERIAL	STEEL **														
DIMENSION	A	E	F	G*	O	P	Q	T*	U***	V*	W	X	Y	Z	
INCHES	0.250	0.375	0.063	6.00	7.00	2.416	3.500	6.21875	9.375	6.50	8.375	0.9375	1.3125	2.00	
TOLERANCE (in.)				0.026	0.018	0.005									
ADJUSTABLE STEM AND PLATE															
MATERIAL	BRONZE														
DIMENSION			c	d	e*	f	g	h	k	m	n*	p*	r	s	t
INCHES			0.21875	0.46875	0.125	1.8125	2.00	2.750	2.96875	0.750	1.125	0.375	0.250	4.250	5.875

FIGURE 1 – Epansion Test Apparatus

2.5   Weight - Two annular metal weights or four slotted metal weights totaling 10 lbs., 5 7/8" in diameter, with a center hole 2 1/8" in diameter (see Figure 1).

2.6   Gauge - Dial gauge reading to 0.001".

2.7   Miscellaneous Apparatus - Other general apparatus such as a mixing bowl, straightedge, scale, submersion tank or bucket, filter paper, dishes, and a 160 ± 5ºF oven.

3.   STOCKPILE SAMPLING

3.1   Three representative samples, two sample bags or approximately 100 pounds of material per sample, shall be obtained from each stockpile or sublot. One sample shall be obtained at a random location from each of three separate faces of the stockpile.

3.2   Since aggregate segregation usually occurs when the material is stockpiled, with the coarser particles rolling to the outside base of the pile, it is necessary to excavate into the base of the stockpile with power equipment to obtain a representative sample. At least two scoop loads of the representative material shall be thoroughly mixed on a separate pile by the power equipment and then "backbladed" to form a level surface. The sample shall then be obtained by channeling in one direction across the middle of the level surface. If additional material is needed, another channel may be made at approximately right angles to the first near the middle of the level surface.

3.3   Identification

3.3.1   The following identification shall accompany each sample:

3.3.1.1 Sample number - each sampled stockpile shall have three separate samples numbered 1, 2 and 3

3.3.1.2 Name of owner or seller

3.3.1.3 Stockpile identification or designation

3.3.1.4 Date the stockpile was sealed to start the cure period

3.3.1.5 Approximate quantity available in the stockpile

4.   SAMPLE PREPARATION FOR DENSITY

4.1   Prepare the sample in accordance with PTM 106, Section 4 (Method B).

4.2   Select and maintain separate representative samples of slag passing the No. 4 sieve and the 3/4" sieve but retained on the No. 4 sieve so that the total sample will weigh approximately 14 lbs. or more for the moisture-density relationship and 12 lbs. or more for the molding of the test specimen. Set aside the portion of the sample to be used in the expansion test and store so as to minimize loss of natural moisture. The percentage, by oven-dry mass, of aggregate passing the 3/4" sieve and retained on the No. 4 sieve shall be the same as the total percentage larger than the No. 4 sieve in the original sample when the material is recombined at the time the moisture-density curve is determined.

4.3   Determine the optimum moisture content and maximum dry density in accordance with PTM 106, Section 5 except that the 6" diameter mold depicted in Figure 1, with the spacer disc in place, is used and that the soil shall be compacted in 3 equal layers with 56 blows per layer. That portion of material passing the 3/4" sieve and retained on the No. 4 sieve is used in the surface-dry condition.

5.   PREPARATION OF TEST SPECIMEN FOR EXPANSION

5.1   Using the 12 lbs. or more portion of unprepared sample at approximately the natural stockpile moisture (undried), compensate for the aggregate larger than 3/4" as stated in Section 4.2 except the weights of the plus No. 4 sieve and minus No. 4 sieve material used in the procedure shall be adjusted for their respective natural moisture.

5.2   Clamp the well-lubricated mold (with extension collar attached) to the base plate. Insert the spacer disc over the base plate and place a disc of coarse filter paper on top of the spacer disc. Compact the slag-water mixture into the mold in accordance with Section 4.3 above, except the amount of water added shall be adjusted downward to compensate for the approximate natural moisture content. Compact the sample at maximum density and optimum moisture as determined in Section 4.3. If other densities and moisture contents are desired, they may be used if indicated in the report.

5.3   Remove the extension collar and carefully trim the compacted soil even with the top of the mold by means of a straightedge. Patch with smaller size material any holes that may have developed in the surface by the removal of coarse material. Remove the perforated base plate and spacer disc, weigh and record the weight of the mold and compacted slag. Place a disc of coarse filter paper on the perforated base plate, invert the mold and compacted slag, and clamp the perforated base plate to the mold with the compacted slag in contact with the filter paper.

5.4   Place the adjustable stem and perforated plate on the compacted slag specimen in the mold and apply weights to produce a 10 lb. surcharge. Submerge the mold and weights in water, which have been preheated to approximately 100ºF, allowing free access of water to the top and bottom of the specimen.

5.5   Place the submerged sample in a level position in a controlled oven at 160 ± 5ºF.

5.6   Seat the tripod on the extension collar and adjust the dial gage to a zero reading. The dial gage shall be set so that its piston is not fully extended. This will allow for measurement of initial sample settlement or consolidation.

6.   PROCEDURE

6.1   Record an initial gage measurement taken 30 minutes after the sample was placed in the 160 ± 5°F oven. This measurement is the base reading and allows for thermal expansion of the test apparatus.

6.2   Dial measurements shall be recorded a minimum of once daily (preferably the same time each day) thereafter for a period of at least one week.

6.3   Sufficient water shall be added each day so that the test specimen remains fully submerged. Water shall not be added within 2 hrs. of the time for dial measurement readings.

6.4   After a period of one week, the test specimen shall be removed from the tank or bucket and placed in the 160 ± 5°F oven in an unsubmerged but saturated condition for an additional one week period.

6.5   Dial measurements for the unsubmerged sample shall be continued as stated in Section 6.2. Measurements shall not be obtained within 2 hours of the time of addition of water to the specimen.

6.6   A minimum of 500 milliliter (500 cc) of water shall be added to the top of the sample each day so that the test specimen remains fully saturated.

6.7   Carefully dismantle the test specimen after the two-week expansion period, and visually inspect it for crystalline growth on the slag particle surfaces.

7.   CALCULATIONS

7.1   Percent Volumetric Expansion - Calculate the percent expansion by dividing the dial gage measurement (A) minus the base gage measurement (B) by the initial sample height of 4.584".

$$\frac{(A - B)}{4.584} X \ 100$$

7.2   Rate of Expansion - The rate of expansion is the slope of the plot of time in days (x-axis) versus the percent expansion (y-axis) shown in Fig. 3. Those parts of the curve developed during submerged and unsubmerged conditions shall be clearly indicated and separate rates of expansion shall be calculated for each of the two parts.

7.3　　　Percent Total Volumetric Expansion - The dial gage measurement after fourteen days of combined submerged and unsubmerged conditions (A^1) minus the base dial gage measurement (B) divided by the initial sample height of 4.584".

$$\frac{(A^1 - B)}{4.584} X\ 100$$

8.　　　REPORT

8.1　　　The report shall include the following:

8.1.1　　Particle size distribution curve of the original sample

8.1.2　　Particle size distribution curve of the prepared sample before testing

8.1.3　　The optimum moisture content and maximum dry density of the slag specimens as per Section 4.3 herein.

8.1.4　　The moisture content and dry density of the molded specimens used in the expansion tests.

8.1.5　　The expansion curve as depicted in Figure 3 to include the total percent volumetric (one dimensional) expansion after 14 days and rate(s) of expansion.

8.1.6　　The average of the 3 total volumetric expansions for the 3 material samples representing each stockpile.

8.1.7　　Determination of the pH of the sample leachate and x-ray diffraction of the sample, if specified
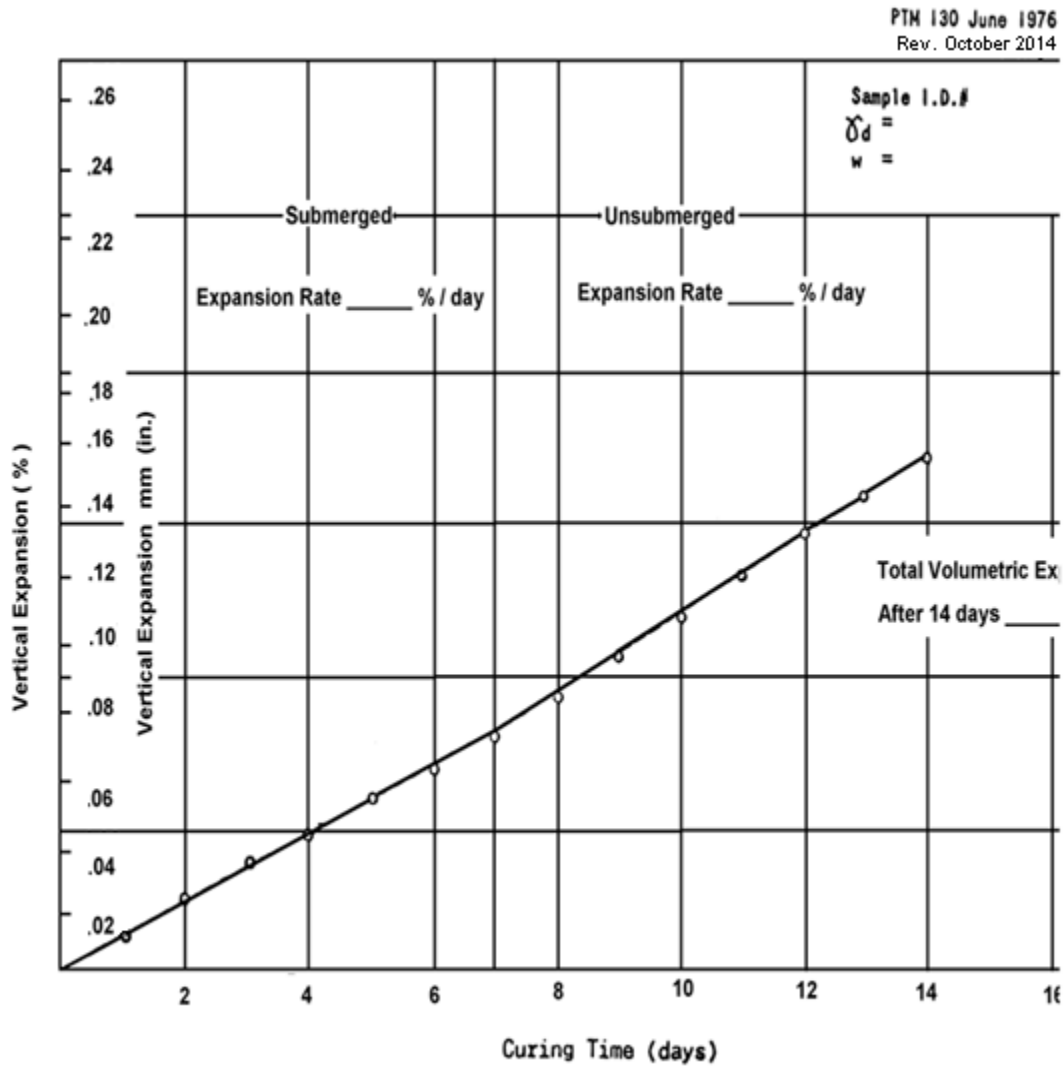
Fig. 3 - Typical Slag Expansion Curve

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF COEFFICIENT OF UNIFORMITY

1.   SCOPE

1.1   This method describes a procedure to determine how well graded a material is from the top to the bottom sieve size by calculating a coefficient of uniformity. This coefficient is defined in ASTM D-653, and is important for determining the acceptability of open graded material. This coefficient is a measure of how the material will compact and how stable it will be in place.

2.   OUTLINE OF METHOD

2.1   The ratio D_{60}/D_{10}, where D_{60} is the particle diameter corresponding to 60% finer on the cumulative particle-size distribution curve, and where D_{10} is the particle diameter corresponding to 10% finer on the cumulative particle-size distribution curve, is determined.

3.   PROCEDURE

3.1   Plot the grading on a gradation chart as shown on Page 3. A blank copy of the chart is provided with this PTM that may be photocopied for use by those performing the test. A similar chart may be produced from a standard to division x 3 cycle log paper.

3.1.1   Take the percent passing values for at least six sieve sizes from the gradation analysis and plot them on the gradation chart.

3.1.2   Connect the points with straight lines.

3.2   From the gradation chart, at the 10% passing point, draw a vertical line to the millimeter scale and record the number (D_{10}).

3.3   From the gradation chart, at the 60% passing point draw a vertical line to the millimeter scale and record the number (D_{60}).

4.   CALCULATIONS

    4.1   Coefficient of Uniformity - Calculate as follows using the gradation curve:

        4.1.1   Formula:

        $D_{60}/D_{10} = C$

    Where:

        $D_{10} = 10\%$ of the sample is passing the 1.4 millimeter size

        $D_{60} = 60\%$ of the sample is passing the 11.8 millimeter size

        C = Coefficient of Uniformity

    Therefore, from the example:

        $D_{60}/D_{10} = 11.8/1.4 = 8.4$

5.   REPORT

    5.1   The report shall include the gradation chart with D_{10} and D_{60} marked and the coefficient of uniformity indicated.

GRADATION CHART

SIEVE SIZES RAISED TO 0.45 POWER
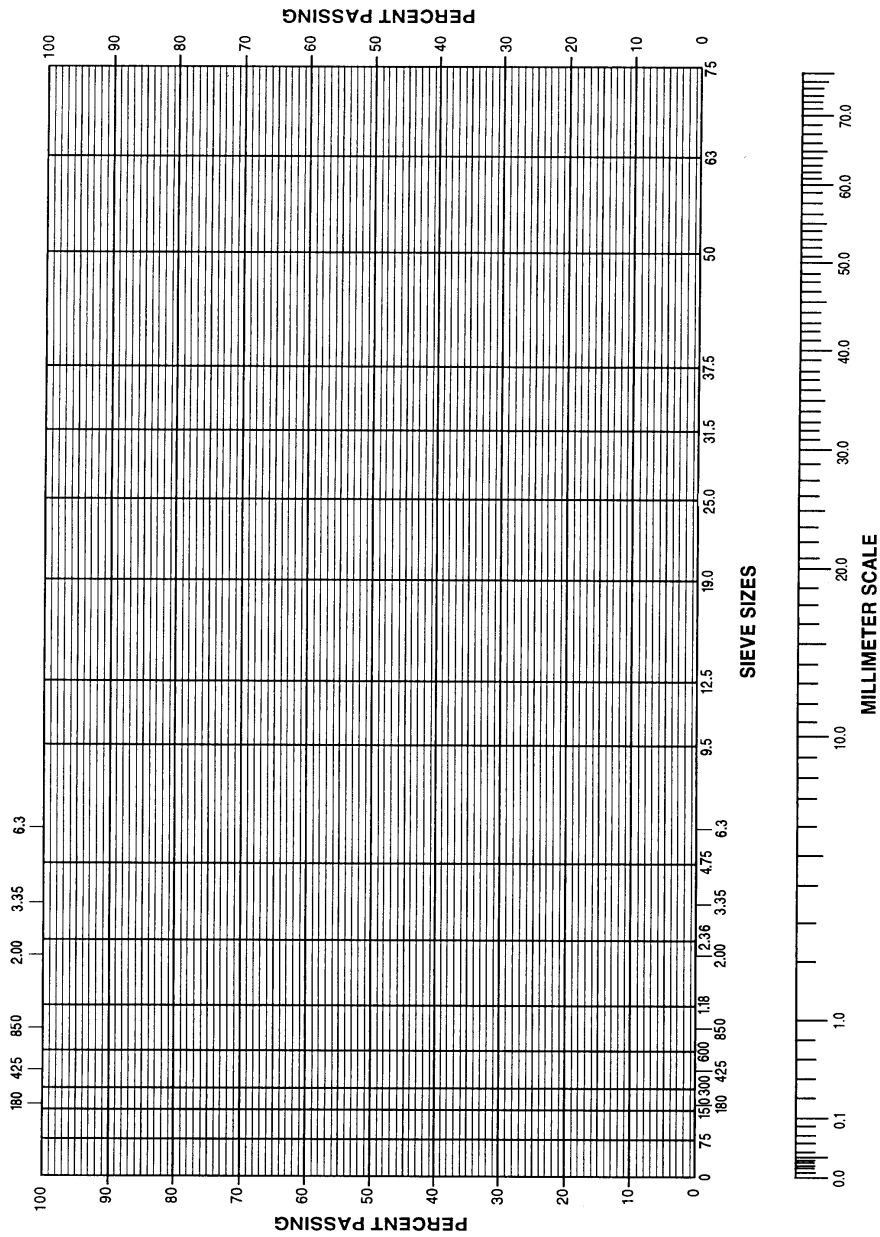
Maximum Density Gradation = Straight Line Connecting 100% Passing Given Sieve and 0% Passing 0 Sieve.

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LABORATORY TESTING SECTION

Method of Test for

FIELD SAMPLING OF COATED FILMS FOR LABORATORY
ANALYSIS OF TOXIC METAL CONTENT

This PTM is a modification of ASTM D 5702. The full standard is available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428 (www.astm.org).

The modifications to ASTM D 5702 are as follows:

5.   PROCEDURE

5.3   Use a clean knife and straight edge to scribe the perimeter of a square that measures approximately 2.5 to 5.0 cm (1" to 2") on each side. The scribed lines should extend through the paint film to the substrate. For some types of analysis, it may be desirable to obtain a larger sample.

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LABORATORY TESTING SECTION

Method of Test for

WEIGHT PER-LITER OF PAINT

This PTM is a modification of ASTM D 1475. The full standard is available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428 (www.astm.org).

The modifications to ASTM D 1475 are as follows:

3.   TERMINOLOGY

3.1   Definitions

3.1.1   Density- The mass of a unit volume of a material at a specified temperature. In this method, it is expressed in grams per milliliter (lbs/gal) of the liquid at the specified temperature, 23 ± 0.5 °C (73 ± 1 °F).

4.   SUMMARY OF TEST METHOD

4.1   The accurately known absolute density of distilled water at various temperatures (Table 1) is used to calibrate the volume of a container. The weight of the paint liquid contents of the same container at the standard temperature 23 ± 0.5 °C (73 ± 1 °F) is then determined. The density of the contents is calculated in terms of grams per milliliter, (lbs/gal) at the specified temperature.

7.   APPARATUS

7.1   Recommended test apparatus shall conform to ASTM D 333, Section 6.

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LABORATORY TESTING SECTION

Method of Test for

PATCH TEST FOR ASSESSING COATING COMPATIBILITY

This PTM is a modification of ASTM D 5064. The full standard is available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428 (www.astm.org).

The modifications to ASTM D 5064 are as follows:

1.   SCOPE

1.1   This practice covers the procedures for testing coating compatibility when maintenance of an in-place coating system is being contemplated. It does not cover procedures for assessing the integrity of the existing, coating to determine if it can be repainted, nor does it establish the compatibility of the maintenance coating system with the substrate or corrosion products. The practice is intended for use in the field. Preparation, application, and testing are to be witnessed by the Inspector-in-Charge.

6.   PROCEDURE

6.2   The size of each test patch shall be at least 0.2 m^2 or more (2 ft^2 or more).

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING AND TESTING TREATED WOOD PRODUCTS

1.   SCOPE

        1.1   The purpose of this test is to outline the procedures for sampling and testing treated wood products.

2.   DESCRIPTION OF MATERIAL

        2.1   The procedures, herein, are designed to cover treated wood products for post-mounted sign projects or other highway construction use.

3.   SAMPLING PROCEDURES

        3.1   Test for retention of preservatives shall be made on a sampling consisting of borings from not less that 20 pieces of lumber representative of the lot, but not less than one piece of lumber for each 2.5 m^3 (1,000 board feet) in the lot. When different sizes of lumber are encountered care should be taken to secure samples representative of all sizes in the lot.

        3.2   Borings from southern yellow and ponderosa pine shall be taken from sapwood only. Borings from Douglas fir and the other soft woods shall be taken from heartwood only.

        3.3   No samples shall be taken closer than 0.9 m (3 ft.) from the end of any piece, and the area where the sample is to be taken shall have any encrusted preservative removed. Borings shall be immediately and carefully placed in suitable containers to avoid all losses.

        3.4   Borings shall be obtained using a hand brace and bit. Wood bits shall be 9.52 mm (3/8 in.) in diameter and shall be modified as shown in the drawing to permit a depth penetration of 15 mm (0.6 in). All borings shall be made accurately to 15 mm (0.6 in.) in depth measured from the outside of the treated lumber. All shavings shall be retrieved from the hole and placed in a container.

        3.5   Borings shall be submitted individually for testing. Tests will be conducted on composite samples prepared from the borings.

        3.6   Boring holes shall be plugged immediately using a latex or silicone caulking compound.

4.   TESTING

4.1   Testing shall be performed in accordance with the latest version of AWPA Test Method A ll. All samples shall be tested at the PENNDOT'S Materials Testing Laboratory.

9.5mm (3/8") BIT WITH 15.2mm(0.6") PROJECTION

15.0mm (3/4")

9.5mm (3/8")

19.0mm (3/4")
STANDARD WT. PIPE
(SCHEDULE 40)

WELD TO BIT
ABOVE AUGER

19.0mm (3/4")PIPE
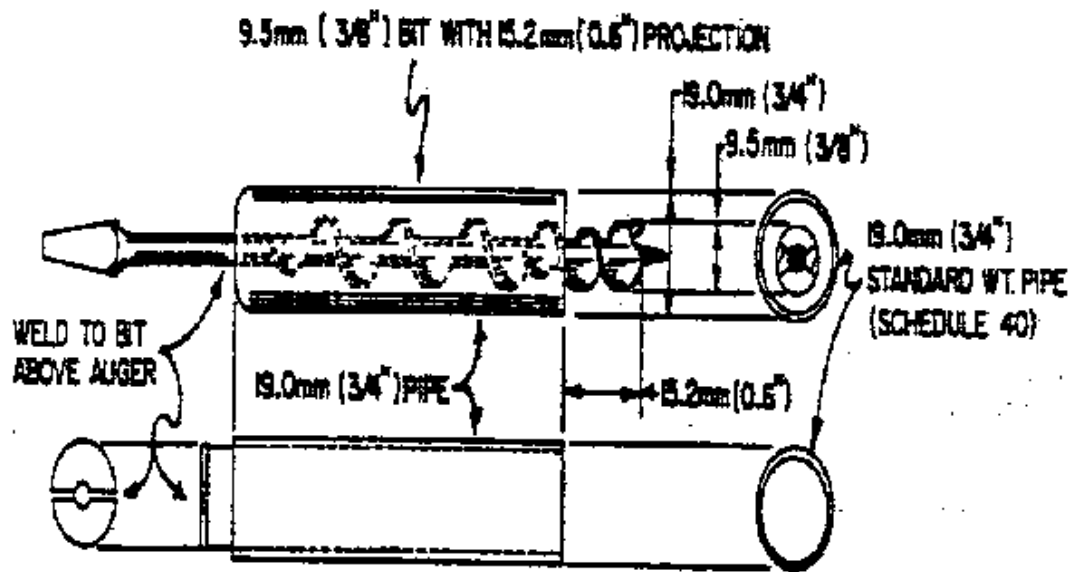
15.2mm (0.6")

15.2mm (0.6") PROJECTION DOES NOT INCLUDE FEED THREADS

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LABORATORY TESTING SECTION

Method of Test for

CLOUD POINT OF DIESEL FUEL

1.   SCOPE

1.1   This method covers the procedure for the testing of diesel fuel for cloud point. This method is a modification of ASTM D 2500.

2.   APPARATUS

2.1   Test jar- Clear glass, cylindrical form, flat bottom, approximately 30 to 35 mm (1 ⅛" to 1⅜") in inside diameter and 115 to 125 mm (4½" to 5") in height. The jar shall be marked with a line to indicate the sample height 54 ± 3 mm (2⅛") above the inside bottom.

2.2   Thermometers-Having ranges as shown below and conforming to the requirements as prescribed in ASTM Specification E1, for ASTM Thermometers or in the specifications for IP Standard Thermometers.

Thermometer	Temperature Range	Thermometer Number	
		ASTM	IP
Cloud & Pour	-38 to +50°C	5°C	1°C
	(-36 to +120°F)	(5°F)	(1°F)
Low Cloud & Pour	-80 to +20°C	6°C	2°C
	(-112 to +70°F)	(6°F)	(2°F)

2.3   Cork- To fit the test jar, bored centrally to take the test thermometer.

2.4   Jacket- 200 ml beaker, tall form.

2.5   Disk, cork or felt- 6 mm (1/4") in thickness with the same diameter as the inside of the jacket.

2.6   Gasket, ring- 5 mm (1/4") in thickness, to fit snugly around the outside of the test jar and loosely inside the jacket. This gasket may be made of cork, felt, or other suitable material, elastic enough to cling to the test jar and hard enough to hold its shape. The purpose of the ring gasket is to prevent the test jar from touching the jacket.

2.7   Cold Chamber- A refrigerated chamber capable of rapid, manual or programmed temperature changes to -1, -18 and -34°C (+30, 0 and –30°F). The chamber shall have a glass viewing area. At this facility a Thermotron unit is used.

3.   PROCEDURE

3.1   Bring the oil to be tested to a temperature at least -4°C (25°F) above the approximate cloud point. Remove any moisture present by any suitable method, such as by filtration through dry lintless filter paper until the oil is perfectly clear, but make such filtration at a temperature of at least -4°C (25°F) above the approximate cloud point.

3.2   Pour the clear oil into the test jar to the level mark.

3.3   Close the test jar tightly by using a cork to carry the test thermometer. Use the high Cloud and Pour Thermometer if the expected cloud point is to be above -38°C (-36°F), and the low Cloud Pour Thermometer if the expected cloud point is to be below -38°C (-36°F). Adjust the position of the cork and the thermometer so that the cork fits tightly, the thermometer and the jar are coaxial, and the thermometer bulb is resting on the bottom of the jar.

NOTE 1 - Since separation of the mercury or toluene thread of Cloud and Pour Thermometers occasionally occurs, and since such separation may otherwise escape immediate detection, it is suggested that the ice points of the thermometers be checked immediately prior to the test. Any thermometer that shows an ice point differing from 0°C (32°F) by more than 1°C (2°F) should be further examined or recalibrated, or both, before use.

3.4   Place the disk in the bottom of the jacket. Place the ring gasket around the test jar. The disk, gasket, and inside of the jacket shall be clean and dry. Insert the test jar in the jacket.

3.5   Maintain the temperature of the chamber at -1 to +2°C (30 to 35°F).

3.6   If the oil does not show a cloud when it has been cooled to 10°C (50°F), lower the chamber temperature to -18 ± 3°C (0 ± 5°F). If the oil does not show a cloud when it has been cooled to -7°C (20°F), lower the chamber temperature to -34 to -32°C (-30 to -25°F).

3.7   When such inspection first reveals a distinct cloudiness or haze in the oil at the bottom of the test jar, record the reading of the test thermometer as the cloud point.

NOTE 2 - A wax cloud or haze is always noted first at the bottom of the test jar where the temperature is lowest. A slight haze throughout the entire sample, which slowly becomes more apparent as the temperature is lowered, is usually due to traces of water in the oil. Generally, this water haze will not interfere with the determination of the wax cloud point. In most cases of interference, filtration through dry lintless filter papers such as described in Section 3.1 is sufficient.

In the case of diesel fuels, however, if the haze is very dense, a fresh portion of the sample shall be dried by shaking 100 ml of the sample with 5 g (0.2 ounces) of anhydrous sodium sulfate for at least 5 min. and then filtering the sample

through dry lintless filter paper. Given sufficient contact time, this procedure will remove or sufficiently reduce the water haze so that the wax cloud can be readily discerned. Drying and filtering shall be done always at a temperature at least 14°C (57°F) above the approximate cloud point, but otherwise not in excess of 50°C (120°F).

4. REPORT

4.1 Report the temperature recorded in Section 3.7 as the Cloud Point.

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LABORATORY TESTING SECTION

Method of Test for

SPONGE ELASTOMERS LOW TEMPERATURE BRITTLENESS

1.   SCOPE

        1.1   This method of test is intended to determine the ability of elastomeric sponges to resist the effect of low temperature embrittlement by determining the resistance of the sponge to cracking or fracture when flexed. Standard test specimens are conditioned at specified test temperatures for pre-determined periods of time after which the specimens are flexed in a prescribed apparatus designed to give a uniform and reproducible flexure pattern. Any cracking or fracture is noted.

2.   APPARATUS

        2.1   The apparatus consists of the following:

        2.1.1   Test Chamber- The test chamber must be of a suitable size to accommodate the flexing apparatus and specimens. The chamber shall be so constructed as to permit unhindered flexing of the specimens without removal from the chamber. The chamber must be of sufficient size to permit adequate insulating of the testing apparatus from the bottom and walls of the chamber. The chamber must be capable of maintaining a uniform atmosphere of cold, dry air at the specified test temperature ±11 °C (±20 °F).

        2.1.2   Flexing apparatus- The flexing apparatus consists of one fixed sample holder and one movable sample holder per sample. Each sample holder is designed to hold a 12.7 mm (1/2") thick sample for a distance of 25.4 mm (1"). The movable holder is mounted in a slide or guide in such a way that its center line and the center line of its movement are the same and are parallel to the center line of the fixed holder. The two center lines are 50.8 mm (2") apart. The two holders are maintained parallel to each other at all times. The fronts and backs of each holder are blocks 12.7 mm (1/2") thick with a 6.4 mm (1/4") radius on their leading edges over which the samples are bent. The back of each holder is rigidly fastened in place while the front is a removable plate to facilitate clamping of the samples. The movable holder is provided with a stop so that the maximum test position allows an overlap of holder positions of 25.4 mm (1"). The balance of the apparatus consists of material to fasten the holders in place and push rods to change the movable clamps from the conditioning to test position. See Figure 1.

  3. SAMPLES

        3.1   Standard test specimens are cut from 12.7 mm (1/2") stock, 19.0 mm (3/4") wide x 152.4 mm (6") ± 2.5 mm (0.1") length.

4.   PROCEDURE

        4.1   Test specimens are securely mounted in the fixed and movable holders with the specimens extending completely to the bottom of each holder. The movable holder is raised to a maximum height that does not stretch the sample. The apparatus and samples are placed in the test chamber and the temperature maintained at the specified temperature for 5 hours. At the end of the conditioning time and while still in the test chamber, the movable holder is forced to the test position as rapidly as possible by means of the push rods. The specimens are then examined for fracture or cracks. All sides of the specimens are examined.

5.   RESULTS

        5.1   The specimen shall exhibit no cracks.

PTM 305

CONDITIONING
POSITION

6.4 mm
$\left(\frac{1"}{4} r\right)$

6.4 mm
$\left(\frac{1"}{4} r\right)$

6.4 mm
$\left(\frac{1"}{4} r\right)$

6.4 mm
$\left(\frac{1"}{4} r\right)$

TEST
POSITION

25.4 mm
$(1")$

| 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ | 12.7 mm $\left(\frac{1"}{2}\right)$ |
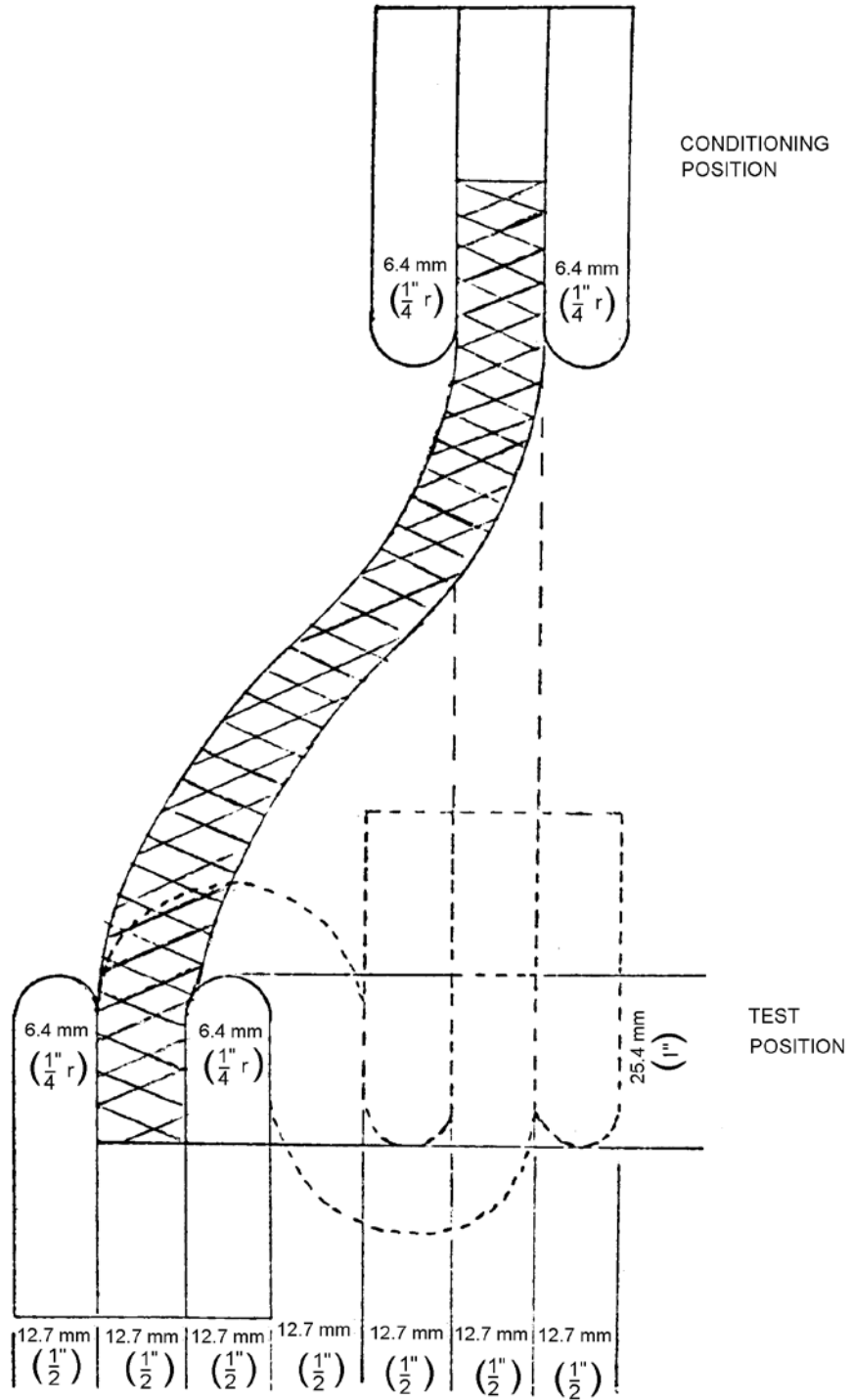
Fig. 1.

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING AND REPORTING NEOPRENE BRIDGE BEARING PADS

1.   SCOPE

        1.1   This method provides guidance for determining the total number of test pads required for a project for both Laminated and Non-Laminated Neoprene Bridge Bearing Pads and reporting test results when test pads are indicated on the approved bridge beam or girder shop drawings (minimum project sampling frequencies for designers are indicated in DM-4, Section 14.7.6.5P).

2.   SAMPLING

        2.1   Laminated Neoprene Bridge Bearing Pads shall be sampled at the rate of one pad for every 50 pads or fraction of pads received. When there is more than one laminated pad thickness used on the project, and more than one sample is required as dictated by the one for 50 requirement, the required number of samples shall be representative of the thickness of the bearing pads being used.

        2.2   Non-Laminated Bridge Bearing Pads shall be sampled at the rate of one pad for every 50 pads or fraction of pads received. When there is more than one pad thickness used on the project, and more than one sample is required as dictated by the one for 50 requirement, the required number of samples shall be representative of the thickness of the bearing pads being used.

        2.3   The samples shall be selected only by Pennsylvania Department of Transportation personnel or their authorized representative. Samples shall be taken in accordance with
PTM No. 1 at the ordering agency's facilities or project site and submitted to the Laboratory Testing Section.

        2.4   Bulk shipments will be tested only if a written request is made to the Division Chief, Bridge Innovation and Support Services Division.

        2.5   It is the responsibility of the ordering agency to provide the required samples as determined by Sections 2.1 and 2.2 above. The ordering agency is responsible for requesting sampling of shipments. This request shall be made to the Chief Structural Materials Engineer or to the Chief, Laboratory Testing Section.

        2.6   The Engineer may increase sampling requirements when found necessary.

        2.7   Sampling Examples. The following are intended to help clarify the sampling requirements:

2.7.1 If 48 laminated bearing pads are required on the project; all the same thickness. The number of required samples shall be one (1).

2.7.2 If 48 laminated bearing pads are required on project; 24 are four inch (4") in thickness and 24 are two inch (2") in thickness. The number of required samples shall be one (1). The sample should be of the largest thickness, therefore, one (1), four inch (4") thick sample pad would be required.

2.7.3 If 60 non-laminated bearing pads are required on the project; all the same thickness. The number of required samples shall be two (2).

2.7.4 If 60 non-laminated bearing pads are required on the project; 20 are four inch (4") in thickness, 20 are three inch (3") in thickness and 20 are two inch (2") in thickness. The number of required samples shall be two (2). The samples should be of the two largest thicknesses, therefore, one (1), four inch (4") sample and one (1), three inch (3") sample would be required.

2.7.5 If 20 laminated and 20 non-laminated pads are required on the project; all the same thickness. Because there are both laminated and non-laminated pads, and each has their own sampling criteria, the number of required samples shall be two (2); one (1) laminated sample and one (1) non-laminated sample.

2.7.6 If 60 laminated and 20 non-laminated are required on the project; 40 of the laminated pads are four inch (4") in thickness and 20 of the laminated pads are two inch (2") in thickness; all the non-laminated are the same thickness. Again, because the laminated and non-laminated have their own sampling requirements, the number of required samples shall be three (3); two (2) laminated and one (1) non-laminated. The two (2) samples of the laminated would consist of one (1), four inch (4") sample and one (1), two inch (2") sample.

3. APPROVAL

3.1 Test results for Neoprene Bearing Pads will be released from CAMMS after testing is completed and a determination is made to whether the tested pads conform to the applicable specification. Testing and reporting of results normally requires 15 working days from the receipt of samples at the Laboratory Testing Section.

3.2 Notification of passing or failing verification sample test results of the bearing pads shall be made by laboratory report.

3.3 The submission of Form CS-4171, Certificate of Compliance, manufacturer's test results and certified mill reports for steel used in laminated pads is required to be submitted with the test pads.

4.   RELEASE OF BEARING PADS FOR PLACEMENT

4.1   When verification samples of bearing pads are indicated on the plans and samples are required for testing, the lot(s) represented by the bearing pad samples shall not be installed until a laboratory report(s) indicating passing results is received, or unless Form TR-455 is completed by the District indicating the terms of acceptance.

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING NEOPRENE COMPRESSION SEALS

1.   SCOPE

1.1   This method covers the sampling of Preformed Neoprene Compression Seals for use in pavements or structures.

2.   SAMPLING

2.1   Preformed Neoprene Compression Seals shall be sampled for approval at the rate of one 1.5 m (5') length for each lot of seal used on a project. Lot numbers are to be repeatedly stenciled on the top of each seal, at 1 m (3') intervals.

2.1.1   At the time of installation an additional 300 mm (1') sample for each 150 m (500') or fraction of seal used shall be taken.

2.1.2   All samples will be taken at the end of a run, or off the end of a reel. Samples will be taken in such a manner as to avoid unnecessary splicing or waste of material.

2.2   The samples shall be taken only by Pennsylvania Department of Transportation representatives. Samples shall be taken at the location where the seal becomes a physical part of the joint. This may be at the project site, fabrication shop, or other purchasing agencies' facilities. This sample shall be submitted to the Laboratory Testing Section for testing.

2.3   It is the responsibility of the purchasing agency to order sufficient material to cover sampling as determined by Section 2.1 above. The purchasing agency is responsible for requesting sampling of shipments.

2.4   The Engineer may increase sampling requirements when found necessary.

3.   APPROVAL

3.1   Approval to use the Preformed Neoprene Compression Seals will be granted after testing is completed and the material is found to conform to the specification requirements. Testing and reporting of results normally will require 15 working days from receipt of samples at the Laboratory Testing Section.

3.2   Notification of approval or rejection of the seal shall be by laboratory report.

4.   RELEASE OF SEAL FOR REPLACEMENT

4.1   Until an acceptable laboratory report is received, the Field Inspector shall not permit the use of any Preformed Neoprene Compression Seals.

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LABORATORY TESTING SECTION

Method of Test for

DETERMINING IN-PLACE DENSITY AND MOISTURE CONTENT OF
CONSTRUCTION MATERIALS BY USE OF NUCLEAR GAUGES

This PTM is a modification of ASTM D 2950 (for Bituminous Concrete) and AASHTO T-310 (for Soils and Granular Material, Type 1). The full standards are available, respectively, from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428 (www.astm.org) and the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to ASTM D 2950 are as follows:

8.   STANDARDIZATION AND REFERENCE CHECK (FOR BITUMINOUS CONCRETE)

    8.2   The gauge standardization procedure shall be conducted and documented on Form TR-4276B before establishing an optimum-rolling pattern.

9.   PROCEDURE- OPTIMUM-ROLLING PATTERN (FOR BITMINOUS CONCRETE)

    9.1   Purpose- The objective of the optimum-rolling pattern is to obtain the maximum density attainable under existing field conditions and to employ this value as a target or standard for measurement of compaction compliance for the specified work.

    9.2   Establishment of Optimum-Rolling Pattern

        9.2.1   Enter into the gauge the theoretical maximum density (pcf) from the job mix formula for the bituminous material being placed.

        9.2.2   The thickness of the course shall be the same as specified in the contract. Select a location that would be a convenient test site between roller passes. During compaction, the nuclear gauge operator shall take a surface density reading and surface temperature at the selected location after each pass of the roller. A pass is defined as one coverage of the entire roller. The counting period for each reading shall be one (1) minute, unless the area is too small to effectively compact without significant delay. In such cases, the readings may be reduced to 1/2 or 1/4 minute. Each roller shall make at least three (3) passes, and compaction with each roller shall continue until the increase of three (3) successive readings is $\leq$ 3.0 pcf. The optimum number of passes for each roller will be either the 2nd or 3rd pass from the three (3) successive readings with the greatest increase in compaction. If a decompaction reading is obtained, the previous pass will be the optimum number of passes for that roller. Then, proceed to the next

roller or temperature range. Record all density values and all surface temperatures and plot the optimum-rolling pattern growth curve for each roller.

> NOTE 8- When a pneumatic-tire roller is used, nuclear density readings shall not be taken until after the second pass with this piece of equipment.

9.3   Summary of Optimum-Rolling Pattern Density

9.3.1   Compact the entire course according to the optimum-rolling pattern. After compaction is complete, select an area of at least 400 square yards, when practical, containing ten (10) random locations selected according to PTM No. 1 within this area. At each location, at least one (1) surface density (backscatter) reading shall be taken and documented. The counting period must be one (1) minute for each of these readings. Determine the average of the ten (10) readings and document this value as the target density.

11.   REPORT

11.1   Complete Form TR-4276B to document an optimum-rolling pattern for bituminous density acceptance by nuclear method.

TR-4276B (3-15)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

OPTIMUM-ROLLING PATTERN FOR BITUMINOUS DENSITY ACCEPTANCE BY NUCLEAR METHOD
(REFERENCE: PTM NO. 402)

ECMS # _____ S.R. _____ Sec. _____ County _____ District _____ Date _____

Material Type _____ JMF # _____ Theoretical Max Density _____ pcf Thickness _____

NUCLEAR GAUGE STANDARDIZATION PROCEDURE

DENSITY Standard Counts	MOISTURE Standard Counts	OPERATING LIMITS Density	Moisture
		to	to

Tested By _____
Gauge Manufacturer _____
Gauge Model No. _____
Calibration Date _____
Remarks:

ESTABLISHMENT OF OPTIMUM-ROLLING PATTERN

Roller No. 1

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____
Surface Temp Range _____

Roller No. 2

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____
Surface Temp Range _____

Roller No. 3

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____
Surface Temp Range _____

OPTIMUM-ROLLING PATTERN GROWTH CURVE

Percent Theoretical Density vs. Roller Passes (0–10), Percent Theoretical Density axis 70–100.

SUMMARY OF OPTIMUM-ROLLING PATTERN DENSITY

	Location	Offset	Density
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

TARGET DENSITY _____

Each roller should make at least three (3) passes, and compaction with each roller shall continue until the increase of three (3) successive readings is ≤ 3.0 pcf. The optimum number of passes will be either the 2nd or 3rd pass from the three (3) successive readings with the greatest increase in compaction. If a decompaction reading is obtained, the previous pass will be the optimum number of passes for that roller. Then, proceed to the next roller or temperature range.

The modifications to AASHTO T-310 are as follows:

8.   STANDARDIZATION (FOR SOILS AND GRANULAR MATERIAL, TYPE 1)

      8.2.4   The gauge standardization results shall be documented on Form TR-4276A.

9.   PROCEDURE

      9.5.9   Secure and record three (3) one (1) minute readings. Rotate the gauge about the axis of the probe 90° in the same direction between readings. Average the three (3) readings to obtain an average density value for the test location.
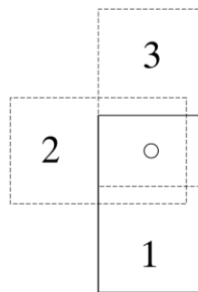
11.   REPORT

      11.1   Complete Form TR-4276A to document all compaction density tests by nuclear method.

TR-4276A (3-15)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

REPORT ON COMPACTION DENSITY BY NUCLEAR METHOD

(Reference: PTM No. 402)

Fill Out Completely. Original to be retained with project records. Remit copy to District Office

ECMS # _____ S.R. _____ Sec. _____ County _____ District _____ Date _____

TYPE OF CONSTRUCTION: ☐ Embarkment ☐ Subgrade ☐ Pipe Backfill ☐ Other _____
(check one type only)

1. Test No.						
2. Time of Test						
3. Type of Material						
4. Source of Material						
5. Specific Gravity of Material (SG)						
6. Station						
7. Offset						
8. Subgrade Elevation, ft.						
9. Test Elevation, ft.						
10. Lift Height, in.						
11. Source Rod Position						
12. Target Density (Proctor), pcf						
13. Optimum Moisture, %						
14. % Passing 3/8" Sieve						
15. % Passing No. 200 Sieve						
16. Minimum % Compaction Required						
17. % of Compaction of Test						
18. Dry Density, pcf (DD)						
19. Wet Density, pcf (WD)						
20. Moisture, pcf (M)						
21. % Moisture (M%)						
22. Density Count (Shift + Counts)						
23. Moisture Count (Shift + Counts)						
24. Zero Air Voids Formula Check (Y/N)						
25. (P)ASS or (F)AIL						

DENSITY Standard Counts	MOISTURE Standard Counts	OPERATING LIMITS	
		Density	Moisture
		_____ to _____	_____ to _____

Tested By _____
Gauge Manufacturer _____
Gauge Model No. _____
Calibration Date _____
Remarks:

Zero Air Voids Formula

$$\frac{62.4}{DD} - \frac{1}{SG} \geq M\%$$

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LABORATORY TESTING SECTION

Method of Test for

DETERMINING IN-PLACE DENSITY OF BITUMINOUS CONCRETE
USING ELECTRICAL IMPEDANCE MEASUREMENT METHODS

This PTM is a modification of AASHTO T-343. The full standard is available from the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to AASHTO T-343 are as follows:

3.   SIGNIFICANCE

        3.2   The density results obtained by this test method are relative and require a screed calibration method according to Section 7.4.

4.   INTERFERENCES

        4.2   This test method exhibits spatial bias in that the instrument is most sensitive to the density of the material in closest proximity to the center of the instrument sensor. Oversized aggregate particles in the center of the sensor path may cause variations in density readings. The average of at least 5 measurements at each test location is required.
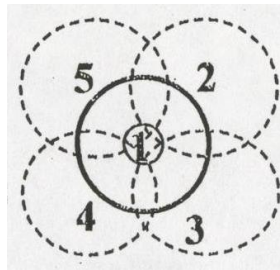
5.   APPARATUS

        5.4   The device shall include the internal circuitry suitable for automatically averaging a number of individual measurements to obtain a mean value.

7.   CALIBRATION PROCEDURE

        7.2   The device shall be calibrated on the bituminous mat at compaction temperature ranges allowing subsequent readings to be taken as paving progresses at this temperature range.

        7.4   All data used for calibration shall be documented on Form TR-4276C before establishing an optimum-rolling pattern. Calibrate the device following the screed calibration method outlined below:

        7.4.1   This screed calibration method utilizes the percent compaction obtained by the screed to calculate a starting density. This method requires the operator to estimate the percent compaction obtained by the screed; routinely this number is 75 to 85 percent of the theoretical maximum density (pcf). Operator experience will contribute to the accuracy of the compaction estimate and the success of this method.

        7.4.2   Enter into the device the theoretical maximum density (pcf) from the job mix formula for the bituminous material being placed.

        7.4.3   Estimate the percent compaction obtained by the screed.

        7.4.4   Multiply the estimated percent compaction obtained by the screed, in decimal form by the theoretical maximum density of the material. Example: The estimated screed compaction is 81%, 0.81; the theoretical maximum density is 154 pcf. The gauge should read 124.7 pcf behind the screed (0.81 × 154 pcf = 124.7 pcf).

        7.4.5   Compute the average of five (5) density readings of the mixture exiting the screed and offset the device to obtain the reading calculated in Section 7.4.4. Follow the manufacturer's specific recommendations to input the offset.

8.   PROCEDURE OF OPERATION

        8.4   The objective of the optimum-rolling pattern is to obtain the maximum density attainable under existing field conditions and to employ this value as a target or standard for measurement of compaction compliance for the specified work.

        8.5   Establishment of Optimum-Rolling Pattern

        8.5.1   The thickness of the course shall be the same as specified in the contract. Select a location that would be a convenient test site between roller passes. During compaction, the operator shall take a surface density reading and surface temperature at the selected location after each pass of the roller. A pass is defined as one coverage of the entire roller. Each roller shall make at least three (3) passes, and compaction with each roller shall continue until the increase of three (3) successive readings is ≤ 3.0 pcf. The optimum number of passes for each roller will be either the 2nd or 3rd pass from the three (3) successive readings with the greatest increase in compaction. If a decompaction reading is obtained, the previous pass will be the

optimum number of passes for that roller. Then, proceed to the next roller or temperature range. Record all density values, all surface temperatures, and plot the optimum-rolling pattern growth curve for each roller.

> NOTE 1- When a pneumatic-tire roller is used, density readings shall not be taken until after the second pass with this piece of equipment.

8.6   Summary of Optimum-Rolling Pattern Density

8.6.1   Compact the entire course according to the optimum-rolling pattern. After compaction is complete, select an area of at least 400 square yards, when practical, with ten (10) random locations being selected according to PTM No. 1 within this area. At each location, at least one (1) surface density reading shall be taken and documented. Determine the average of the ten (10) readings and document this value as the target density.

9.   RECORDING RESULTS

9.1   Complete Form TR-4276C to document an optimum-rolling pattern for bituminous density acceptance by the electrical impedance measurement method.

TR-4276C (3-15)

pennsylvania
DEPARTMENT OF TRANSPORTATION
www.dot.state.pa.us

OPTIMUM-ROLLING PATTERN FOR BITUMINOUS DENSITY ACCEPTANCE BY ELECTRICAL IMPEDANCE MEASUREMENT METHOD
(Reference: PTM No. 403)

ECMS # _____ S.R. _____ Sec. _____ County _____ District _____ Date _____

Material Type _____ JMF # _____ Theoretical Max Density _____ pcf Thickness _____

ELECTRICAL IMPEDANCE GAUGE CALIBRATION PROCEDURE

Gauge Operator _____ Manufacturer _____ Model No. _____

Screed Density = Estimated Screed Density (As Decimal) _____ × Theoretical Max Density _____ = _____ pcf

Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Total	Average	Screed Density	Offset Value

Screed _____ + _____ + _____ + _____ + _____ = _____ ÷ 5 = _____ - _____ = _____

ESTABLISHMENT OF OPTIMUM-ROLLING PATTERN

Roller No. 1

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____

Surface Temp Range _____

Roller No. 2

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____

Surface Temp Range _____

Roller No. 3

Type _____

	Density, pcf	% Density	Temp, °F
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Optimum No. Passes _____

Surface Temp Range _____

OPTIMUM-ROLLING PATTERN GROWTH CURVE

SUMMARY OF OPTIMUM-ROLLING PATTERN DENSITY

	Location	Offset	Density
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

TARGET DENSITY _____

Each roller should make at least three (3) passes, and compaction with each roller shall continue until the increase of three (3) successive readings is ≤ 3.0 pcf. The optimum number of passes will be either the 2nd or 3rd pass from the three (3) successive readings with the greatest increase in compaction. If a decompaction reading is obtained, the previous pass will be the optimum number of passes for that roller. Then, proceed to the next roller or temperature range.

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LABORATORY TESTING SECTION

Method of Test for

CHECKING THE ACCURACY OF BIN SCALES
USED FOR PROPORTIONING

1.   SCOPE

        1.1   This method of test covers the procedures for checking the accuracy of bin scales used for proportioning of bituminous and concrete materials and is applicable to bin scales of all capacities.

2.   APPARATUS

        2.1   Weights- A minimum of ten 20 kg, (50 pound) weights meeting the National Institute of Standards and Technology Class F requirements.

3.   PROCEDURE

        3.1   Preliminary Inspection. This procedure shall be conducted prior to all scale checks.

                3.1.1   Check the hopper to insure that it is empty and clean.

                3.1.2   Check the scales weigh beam to insure that it is clean and that its movement is not restricted.

                3.1.3   Check the zero reading of the scale.*

        * The scale dial or reading may not be altered or adjusted either mechanically or electrically.

        3.2   Complete Scale Check. This method shall be performed at the start of the season and after any significant modification of the weight system, or as deemed necessary by the Engineer.

                3.2.1   Load the scale with the test weights without exceeding 10% of the nominal batch capacity of the scale (The nominal batch capacity shall be established by the Engineer). Record the scale reading and remove the weight.

                3.2.2   Charge the hopper with a test load equal to the previous scale reading and record the reading.

3.2.3   Place an amount of test weights equal to the test weights of Section 3.2.1 on the scale, record the reading, and remove the weights.

3.2.4   Repeat Sections 3.2.2 and 3.2.3 until the approximate midpoint of the nominal batch capacity is reached.

Note 1- Certified Weights may be used in lieu of aggregate test loads in Sections 3.2.2 and 3.3.2.

3.2.5   At the midpoint of the nominal batch capacity, check the repeatability of the scale by placing the test weights on the scale and recording the weight. Compare this reading to the original value obtained in Section 3.2.3 when the test weights were on the scale.

Note 2- If the repeatability check indicates a difference greater than 0.1% of the full scale capacity, the Engineer shall be notified.

3.2.6   Repeat Sections 3.2.2 and 3.2.3 until the nominal batch capacity is reached.

3.2.7   The scale shall be considered accurate if the total error produced by the addition of the test weights is 0.5% or less of the nominal batch capacity.

3.2.8   In the event that this tolerance is not met, the Engineer shall be notified and the appropriate corrective measure(s) taken.

3.3   Incremental Scale Check

3.3.1   Incremental scale checks shall be performed at random intervals of the nominal batch capacity (i.e., 10%, 20%, 30%,...,100%) at the frequency of one different interval for each check as directed.

3.3.2   Aggregate Scales:

After assuring that the scale reads zero*, load the scale with the test weights without exceeding 10% of that portion of the nominal batch capacity represented by the aggregate(s) mass. Record the scale reading. Remove the test weights. The scale should again read zero. Charge the hopper with a load equal to the selected percentage of Section 3.3.1. Again add the test weights. Record the scale reading. Remove the weights. The scale shall meet the required accuracy of the incremental check if the total error produced by the addition of the test weights does not exceed 0.5% of that portion of the nominal batch capacity represented by the aggregates.

3.3.3   Cement scales:

If a separate system is used to weigh cement, the system shall be checked in accordance with the procedure outlined above under "aggregate scales". Again, the number of test weights used shall not exceed 10% of that portion of the nominal batch capacity represented by the cement. Again, the total error produced by the cement scale shall not exceed 0.5% of that portion of the nominal batch capacity represented by the cement, or 5 kg (10 lbs.), whichever is greater.

Example 1:   Metric:

Incremental Scale Check (Aggregate Scale)

An aggregate scale having a nominal capacity of 2500 kg is due for the bi-weekly metric scale check. 20% of the nominal capacity is selected at random (500 kg). The total error is computed by dividing the total error in kilograms (25 kg) by the nominal capacity for the scale.

Mat'l WT	Test WT	True WT	Scale Reading	Error
0	200	200	210	+10
500	200	700	715	+15
			Total Error:	+25

Percent Error:

$$(25/2500) \times 100 = 1.0\%$$

Example 1:   English:

Incremental Scale Check (Aggregate Scale)

An aggregate scale having a nominal capacity of 5500 lbs is due for the bi-weekly incremental scale check. 20% of the nominal capacity is selected at random (1100 pounds). The total error is computed by dividing the total error in pounds (25 lbs.) by the nominal capacity for the scale.

Mat'l WT	Test WT	True WT	Scale Reading	Error
0	500	500	505	+5
1100	500	1600	1620	+20
			Total Error:	+25

Percent Error:

$$(25/5500) \times 100 = 0.45\%$$

Example 2:

Attached are actual examples of complete scale checks entered on Form CS-4211C and performed on a scale having a full capacity of 4500 kg (10,000 lbs.) and a nominal batch capacity of 4000 kg (8,500 lbs). Scale increments are 5 kg (10 lbs).

CS-4211C (2-81)   **SCALE CHECK**

Reference: P.T.M. 410

	TYPE
A —	Aggregate Scale
B —	Bitumen or Asphalt Scale
C —	Cement Scale

TYPE	MATL. WT.	TEST WT.	TRUE WT.	SCALE READING	ERROR	% ERROR	SIGNATURE	DATE
	0	500	500	500	0			
	510	500	1010	1010	0			
	1000	500	1500	1490	−10			
	1550	500	2050	2040	−10			
	2010	500	2510	2500	−10			
	2490	500	2990	2970	−20			
	3010	500	3510	3510	0			
	3500	500	4000	4010	+10			
	4020	500	4520	4510 4510	−10	Repeatability check 0.0 Deviation		
	4550	500	5050	5040	−10			
	5000	500	5500	5480	−20			
	5510	500	6010	5990	−20			
	6020	500	6520	6520	0			
	6500	500	7000	7000	0			
	7020	500	7520	7500	−20			
	7510	500	8010	8020	+10			
	8000	500	8500	8500	0			
			TOTAL	ERROR	−110#	−1.3%		

CS-4211C
M (1-96)

SCALE CHECK

Reference: P.T.M. 410

	TYPE
A — Aggregate Scale
B — Bitumen or Asphalt Scale
C — Cement Scale

TYPE	MATL. MASS	TEST MASS	TRUE MASS	SCALE READING	ERROR	% ERROR	SIGNATURE	DATE

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING AND TESTING RIGHT-OF-WAY AND
PROTECTIVE FENCING

1.   SCOPE

        1.1   The purpose of this test method is to outline procedures for sampling and testing Right-of-Way and Protective Fence in accordance with PTM No. 1 and Publication 408, PENNDOT Standard Drawings, and any other applicable drawings or specifications currently used by the Pennsylvania Department of Transportation. The following is designed as a supplemental procedure for the references mentioned above, and not as a replacement.

2.   DESCRIPTION OF MATERIALS

        2.1   The procedures herein are designed to cover all Right-of-Way and Protective Fencing components described in Sections 624 and 1110 of Publication 408, Specifications of the Commonwealth of Pennsylvania, Department of Transportation.

3.   SAMPLING PROCEDURES

        3.1   Samples shall be randomly secured in accordance with PTM No. 1, Section 2. Except for fabric, wire, and posts, 3 samples of each item shall be secured. Since the size of each lot will vary considerably, the particular sampling procedure under PTM No. 1, Section 2 shall be left to the discretion of the Field Engineer. Sample selection, however, shall be based on Table No. 1, "Random Positions in Decimal Fractions".

        3.2   All component parts and accessories for a particular job operation shall be in compliance with the appropriate specifications before field installation.

        3.3   In instances where all component parts are not submitted for test, the Field Engineer shall be responsible for assurance of a proper fit of the component parts.

        3.4   Samples submitted for test shall conform to the following appropriate sizes.

        a.   Fabric- a full height sample, 600 mm (2 feet) wide.
        b.   Post samples shall be 900 mm (3 feet) in length.
        c.   Samples of wires shall be 900 mm (3 feet) in length.
        d.   For caps, clamps, fasteners and all other accessories, 3 samples of each item shall be submitted.

4.   TEST PROCEDURE

4.1   Physical testing shall be performed in accordance with the references listed in Section 1.1 of this PTM. Identification Form TR-447 shall indicate the type of fence submitted.

In the case of an item comprised of 3 samples, the physical measurement shall be an average of the 3 individual measurements, but no particular item shall be outside the specified tolerance.

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LABORATORY TESTING SECTION

Method of Test for

OBTAINING SAMPLES OF PULVERIZED CONCRETE
FOR CHLORIDE ANALYSIS

This PTM is a modification of AASHTO T-260. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to AASHTO T-260 are as follows:

4. METHOD OF SAMPLING

4.1 Concrete Sample:

4.1.3 Pulverizing Method:

4.1.3.1 The number of samples taken in each lane shall be computed, in accordance with PTM No. 415, "Method of Sampling Miscellaneous Materials", as the cube root of the length of the lane in meters (feet). Not less than five (5) samples per lane shall be taken.

4.1.3.2 The location of the samples shall be determined in accordance with PTM No. 1, "Probability Sampling".

4.1.3.3 An approximate five (5) gram (0.2 oz.) sample shall be taken 13 mm (1/2") directly above a rebar as follows:

4.1.3.3.1 Determine bar location and depth according to PTM No. 419, "Depth of Steel Embedded in Concrete Using The Pachometer Method".

NOTE- When bituminous concrete overlays are present, a section of the overlay large enough to effectively accommodate the pachometer probe shall be removed prior to application of this test method.

4.1.3.3.2 Set the rotary hammer's depth indicator so that it will drill to 13 mm (1/2") above the rebar.

4.1.3.3.3 Use a 19 mm (3/4") drill bit. Drill until the depth indicator seats itself on the concrete surface.

4.1.3.3.4   Thoroughly clean the drilled hole and surrounding area utilizing the "blow out" bulb or other suitable means.

4.1.3.3.5   Reset the depth indicator to permit 13 mm (1/2") of additional drilling.

4.1.3.3.6   Place the 85g (3 oz.) sample tin over the hole and pulverize the concrete until the depth indicator again seats itself on the concrete. Remove the drill. Empty the "blow out" bulb of previously collected pulverized concrete powder.

4.1.3.3.7   Collect the pulverized concrete by using the "blow out" bulb to blow out the sample by placing a hand over the sample tin and blowing out the sample by using the "blow out" bulb nozzle.

4.1.3.4   Chloride ion samples shall be identified as to location and depth (from-to) and forwarded with Form TR-447 to the Laboratory Testing Section for analysis.

4.1.3.5   Care shall be taken to patch all holes with a material similar to and compatible with the roadway surface being patched.

5.   PROCEDURE

5.4   Four alternate methods are available to determine the Cl^- content of the solution. The first three methods utilize Cl^- or Ag^+ as an ion selective electrode. The fourth method utilizes Cl^-. All methods for the purpose of this analysis give results of essentially equal accuracy and precision,

5.4.4   Method IV: Specific Ion Electrodes- Follow procedures outlined in Document No. CHP20 of the Laboratory Testing Section, Bureau of Project Delivery, Pennsylvania Department of Transportation.

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING MISCELLANEOUS MATERIALS

1.   SCOPE

        1.1   This method of sampling outlines the procedures for selecting quantities of miscellaneous materials for quality assurance testing. Miscellaneous Materials shall be considered as those materials not covered by any other PTM.

2.   SAMPLE SECTION

        2.1   Samples shall be selected in a random manner in accordance with PTM No.1.

        2.2   The number of samples constituting a lot shall be computed as the cube root of the number of units or quantity of miscellaneous material to be used on the project.

        Example - If 27,000 miscellaneous bolts of a given size were to be used on a structure, the total number of samples to be taken in accordance with PTM # 1 would be the cube root of 27,000 or 30 bolts.

        2.3   If material is sent to a project site in packaged groups (i.e. cartons or kegs), the number of samples computed in Section 2.2 shall be chosen from the cube root of the number of packaged groups.

        Example - If the 27,000 bolts in Section 2.2 were shipped in 27 cartons, the 30 bolts would be selected from the cube root of 27 or from 3 cartons; thus, 10 bolts would be chosen from each of 3 cartons in a random fashion described in PTM # 1.

        2.4   Dimensions or masses of miscellaneous units shall be checked for compliance with plans and specifications at the sampling site. Material requiring physical or chemical testing should be sampled in accordance with Sections 2.1 and 2.2 above and forwarded to the Laboratory Testing Section identified on Form TR-447 as "Verification Samples".

USE OF CUBE ROOT TABLES

# of Items to a Samples is	n =	Answer in Column #	Remarks
1 - 100	# of items	1	Use answer as is stated in the table
100 - 1,000	$\dfrac{\text{\# of items}}{10}$	2	Use answer as is stated in the table
1,000 - 10,000	$\dfrac{\text{\# of items}}{100}$	3	Use answer as is stated in the table
10,000 - 100,000	$\dfrac{\text{\# of items}}{1,000}$	1	Multiply answer as is stated in the table by 10
100,000 - 1,000,000	$\dfrac{\text{\# of items}}{10,000}$	2	Multiply answer as is stated in the table by 10

Example:

27,000 items:

Since the # of items lies between 10,000 and 100,000

$$n = \frac{27,000}{1,000} = 27$$

Using column 1, $\sqrt[3]{27} = 3$

Multiplying by 10, $\sqrt[3]{27,000} = 3 \times 10 = 30$

Table of Cube Roots

n	1	2	3	n	1	2	3
n	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$	**n**	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$
1	1.000	2.154	4.641	**50**	3.684	7.937	17.09976
2	1.259	2.714	5.848	**51**	3.708	7.989	17.21301
3	1.442	3.107	6.694	**52**	3.732	8.041	17.32478
4	1.587	3.419	7.368	**53**	3.756	9.092	17.43513
				54	3.779	8.143	17.54411
5	1.709	3.684	7.937	**55**	3.802	8.193	17.65174
6	1.817	3.914	8.434	**56**	3.825	8.242	17.75808
7	1.912	4.121	8.879	**57**	3.848	8.291	17.86316
8	2.999	4.308	9.283	**58**	3.870	8.339	17.96702
9	2.080	4.481	9.654	**59**	3.892	8.387	18.06969
10	2.154	4.641	10.00000	**60**	3.914	8.434	18.17121
11	2.223	4.791	10.32280	**61**	3.936	8.480	18.27160
12	2.289	4.932	10.62659	**62**	3.957	8.527	18.37091
13	2.351	5.065	10.91393	**63**	3.979	8.572	18.46915
14	2.410	5.192	11.18689	**64**	4.000	8.617	18.56636
15	2.466	5.313	11.44714	**65**	4.020	8.662	18.66256
16	2.519	5.428	11.69607	**66**	4.041	8.706	18.75777
17	2.571	5.539	11.93483	**67**	4.061	8.750	18.85204
18	2.620	5.646	12.16440	**68**	4.081	8.793	18.94536
19	2.668	5.748	12.38562	**69**	4.101	8.836	19.03778
20	2.714	5.848	12.59921	**70**	4.121	8.879	19.12931
21	2.758	5.943	12.80579	**71**	4.140	8.921	19.21997
22	2.802	6.036	13.00591	**72**	4.160	8.962	19.30979
23	2.848	6.126	13.20006	**73**	4.179	9.004	19.39877
24	2.884	6.214	13.38866	**74**	4.198	9.045	19.48695
25	2.924	6.299	13.57209	**75**	4.217	9.085	19.57434
26	2.962	6.382	13.75069	**76**	4.235	9.125	19.66095
27	3.000	6.463	13.92460	**77**	4.254	9.165	19.74681
28	3.036	6.542	14.09460	**78**	4.272	9.205	19.83192
29	3.072	6.619	14.26043	**79**	4.290	9.244	19.91632

Table of Cube Roots (continued)

n	1	2	3	n	1	2	3
n	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$	**n**	$\sqrt[3]{n}$	$\sqrt[3]{10n}$	$\sqrt[3]{100n}$
30	3.107	6.694	14.42250	**80**	4.308	9.283	20.00000
31	3.141	6.767	14.58100	**81**	4.326	9.321	20.8299
32	3.174	6.839	14.73613	**82**	4.344	9.359	20.16530
33	3.207	6.910	14.88806	**83**	4.362	9.397	20.24694
34	3.239	6.979	15.03695	**84**	4.379	9.435	20.32793
35	3.271	7.047	15.18294	**85**	4.396	9.472	20.40828
36	3.301	7.113	15.32619	**86**	4.414	9.509	20.48800
37	3.332	7.179	15.46680	**87**	4.431	9.546	20.56710
38	3.361	7.243	15.60491	**88**	4.447	9.582	20.64560
39	3.391	7.306	15.74061	**89**	4.464	9.619	20.72351
40	3.419	7.368	15.87401	**90**	4.481	9.654	20.80084
41	3.448	7.428	16.00521	**91**	4.497	9.690	20.87759
42	3.476	7.488	16.13429	**92**	4.514	9.725	20.95379
43	3.503	7.547	16.26133	**93**	4.530	9.761	21.02944
44	3.530	7.605	16.38643	**94**	4.546	9.795	21.10454
45	3.556	7.663	16.50964	**95**	4.562	9.830	21.17912
46	3.583	7.719	16.63103	**96**	4.578	9.864	21.25317
47	3.608	7.774	16.75069	**97**	4.594	9.898	21.32671
48	3.634	7.829	16.86865	**98**	4.610	9.932	21.39975
49	3.659	7.883	16.98499	**99**	4.626	9.966	21.47229
50	3.684	7.937	17.09976	**100**	4.641	10.000	21.54435

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LABORATORY TESTING SECTION

Method of Test for

NUCLEAR GAUGE CALIBRATION

1.   SCOPE

1.1   This method of test covers the calibration of nuclear gauges.

2.   APPARATUS

2.1   Density Calibration

2.1.1   Nuclear gauge and accompanying accessories necessary for calibration.

2.1.2   Three Reference Calibration Blocks: Magnesium, Magnesium-Aluminum, and Aluminum.

2.2   Moisture Calibration

2.2.1   Nuclear gauge and accompanying accessories necessary for calibration.

2.2.2   One Reference Calibration Block for moisture.

2.3   Post Calibration Check

2.3.1   Nuclear gauge and accompanying accessories.

2.3.2   Magnesium, Magnesium-Aluminum, Aluminum, Granite, and Limestone calibration blocks.

3.   GAUGE STANDARDIZATION PROCEDURE

3.1   Prepare the Reference Calibration Block by cleaning the block so that the block is free of dust and foreign matter.

3.2   Allow critical circuits to stabilize during a warm up period with the gauge in the safe position and the battery fully charged. Gauges require at least a five-minute warm up period.

3.3   Check the accuracy of the gauge timer by comparison with a stopwatch.

3.4   Begin the standardization process by taking a standard count with the gauge on the reference standard block. The standardization shall take place at least 1.8 m (6 feet) from any building or structure, and a minimum of 9.1 m (30 feet) from any other radioactive source. The standardization shall take place on any surface with a density of at least 1,601 kg/m^3 (100 lbs./cu ft.). Do not perform the standardization on truck beds, tailgates, etc. Place the source rod in the safe position and begin taking the four-minute standard count. If there were no problems with the conditions under which the standard count was taken and the standard count passes, accept the new standard count into memory. If the standard count fails and there were no problems with the conditions under which the standard count was taken, do not accept the standard count. Perform a second standard count. If the second standard count passes and there were no problems with the conditions under which the second standard count was taken, accept the new standard count and enter into memory. If the second standard count fails, erase all of the old standard counts. Four new sets of standard counts shall be taken and entered into memory. Record the standard counts.

3.5   If the gauge has not been standardized within the past three months, perform at least four new standardization checks.

3.6   If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

4.   GAUGE CALIBRATION PROCESS

4.1   Perform the statistical stability test (Stat Test) to validate the normal operation of the gauge, i.e. to check for erratic readings or readings that may indicate a problem with the gauge. Place the gauge on the reference standard block with the source rod in the safe position. Perform the Stat Test by using the Stat Test function on the gauge, taking twenty one minute counts. If the results of the Stat Test pass, print out the Stat Test results. If the results of the Stat Test fail, perform the Stat Test a second time. The ratio for the density and moisture results from the Stat Test shall range between 0.17 and 0.33. Values outside this range indicate a problem with the gauge. No further calibration under this procedure can occur if the values obtained by the Stat Test are outside the range of values mentioned above after the second Stat Test. If the results from the Stat Test fall within the range indicated but gauge readings continue to fluctuate from test to test, perform the Drift Test later in the procedure to determine the long-term drift of the gauge. Perform the Drift Test 3-4 hours after the Stat Test has been performed without turning the gage off in between the Stat and Drift Tests.

4.2   Place the gauge on the Magnesium block and put the source rod in the backscatter position. Take a 4-minute measurement. Record the count for both moisture and density.

4.3   With the gauge still on the Magnesium block align the source rod over the hole and adjust the source rod to 50 mm (2"), 100 mm (4"), 150 mm (6"), 200 mm (8"), and 250 mm (12") depths and take 4-minute readings at each depth. Record the density count for each depth.

4.4   Place the gauge on the Magnesium/Aluminum block and align the source rod over the hole and take 4-minute readings at the backscatter position, at depths of 50 mm (2"), 100 mm (4"), 150 mm (6"), 200 mm (8"), and 250 mm (12"). Record the density counts for each depth.

4.5   Place the gauge on the Aluminum block and align the source rod over the hole and take 4-minute readings at the backscatter position, at depths of 50 mm (2"), 100 mm (4"), 150 mm (6"), 200 mm (8"), and 250 mm (12") depths. Record the density counts for each depth.

4.6   Place the gauge on the Magnesium/Poly block and with the gauge in the backscatter position. Take a 4-minute reading. Record the moisture count.

4.7   With the gauge still in the backscatter position and on the Magnesium/Poly block, place 4 shims under each corner of the gauge (simulates surface roughness) and take a 4-minute reading. Record the moisture count.

4.8   Without turning off the gauge from the time the Stat Test was taken, wait 3-4 hours after performing the Stat Test and start the Drift Test. Place the gauge on the reference standard block with the source rod in the safe position. Perform the Drift Test using the Drift Test function on the gauge by taking five 4 minute counts. If the Drift Test results pass, print out the Drift Test results. If the Drift Test results fail, perform the Drift Test a second time. If the Drift Test fails the second time, retake the Stat test. If the Stat test passes retake the Drift Test. If the Drift test fails again terminate the calibration process.

4.9   Place all standard counts taken during the calibration process (Sections 4.2-4.7) into the Troxler software program to compute the individual calibration constants.

4.10   Type the individual calibration constants taken from the Troxler software program into the nuclear gauge under the calibration constants function.

4.11   Check the density of the Magnesium, Aluminum, and Magnesium/Aluminum Standard Blocks. All density values from the nuclear gauge after calibration shall

be within 16.02 kg/m^3 (1 lb./cu. ft.) of the values on the side of the standard calibrated blocks.

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LABORATORY TESTING SECTION

Method of Test for

DEPTH OF STEEL EMBEDDED IN CONCRETE
USING THE PACHOMETER METHOD

1.   SCOPE

        1.1   The purpose of this test method is to supply personnel in the field with an accurate and dependable means of determining the depth of steel reinforcing bars in concrete by utilizing a Pachometer.

2.   EQUIPMENT

        2.1   A pachometer equal to the capabilities of the James Instruments Pachometer or models approved by the Innovation and Support Services Division will be utilized.

        2.2   These types of pachometers are capable of measuring the depth of reinforcing steel of 125 mm (5") or more within ± 3 mm (± 1/8") overall accuracy. These are portable units that measure steel reinforcing bar depth by means of magnetic detection of ferrous metal.

        2.3   These devices, like all devices using magnetic detection systems, are affected by ferrous materials, including any contained within the concrete. Flyash and slag often contain ferrous materials and will affect the readings of the instrument. When using pachometers to determine depth or location of reinforcement in concrete suspected of containing ferrous material, refer to the operator's manual of the model of equipment being used.

        2.4   By manufacturer's recommendation, each Pachometer Model C-4974 is to be sent to the manufacturer's lab for re-calibration every two years.

3.   TEST SITE LOCATIONS

        3.1   Bridge Decks

                3.1.1   When possible the entire bridge shall be tested as one area. On large bridges, the data from areas between expansion devices shall be recorded on separate data sheets.

                3.1.2   The bridge deck area shall be marked in a grid pattern such that readings are taken approximately every 1.5 m (5 feet) transversely and longitudinally over the entire deck area. The starting point should be indicated on the data sheet sketch.

                3.1.3   Record every meter reading and/or corresponding depth in the appropriate space on the data sheet, Form TR-4344.

3.2   All other test site locations - For all other pachometer testing, develop a testing pattern particular to the condition at that location that represents the area in question and provides the information needed.

4.   TEST PROCEDURES

4.1   The instrument shall be turned on for several minutes prior to making depth measurements. This allows the battery output to stabilize.

4.2   After warm-up, adjust the meter pointer to exactly full-scale deflection. This adjustment must be made initially and checked frequently during testing to avoid meter drift.

4.3   Place the probe on the concrete at the chosen location so that the probe is parallel to the reinforcing bar of the main steel.

4.4   Slide the probe back and forth over the concrete until the meter indicates a minimum reading (i.e., maximum deflection to the left or minimum depth reading). Record this reading on the data sheet.

4.5   To determine the depth of the bar below the pavement surface, read the depth corresponding to the recorded meter reading from the appropriate calibration curve or the depth reading given by the instrument used. Record the depth on the data sheet.

5.   REPORT

5.1   The final report will include both the data sheet and Bridge Description Supplement Sheet.

5.2   The data sheet sketch should include the following:

1.   General shape of the bridge or area tested

2.   Direction of traffic flow (if applicable) and an arrow indicating North

3.   Location of the starting point

4.   Location and orientation of the expansion devices

5.   Direction in which the main steel lies

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PACHOMETER DATA SHEET

State

County

S.R. No.

Direction of lane

Pach serial no.

Date

Operator

Reinforcement type

#	STATION NUMBER	LANE	METER READING	BAR DEPTH
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

REMARKS:

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LABORATORY TESTING SECTION

Method of Test for

RETRO-DIRECTIVE REFLECTIVITY OF
REFLECTIVE MATERIALS

1.   SCOPE

        1.1   This method of test covers a procedure and the apparatus used to determine the
                reflectance of retro-directive reflective materials. The units of measurements are
                the Candela returned per incident Lux per square meter of material (sign sheeting
                materials) and milli-Candela returned per incident Lux (raised pavement
                markers).

2.   APPARATUS

        2.1   Test Corridor- Sealed against outside light with all interior surfaces painted flat
                black and of sufficient length to accommodate a test distance of 30.24 ± 0.03
                meter (100 ± 0.1 feet).

        2.2   Gamma Scientific Photometer, Model 940

        2.3   Light Source of sufficient intensity to illuminate the test sample at a 15.24 meters
                (50 feet) test distance.

        2.4   Goniometer

        2.5   Computer and operating software

3.   START UP AND ALIGNMENT OF THE GONIOMETER

        3.1   Turn on power to the following devices:
                -   Photometer (Switch on the back of the Control box)
                -   Light Source (Press the "Power" then "Lamp" buttons on the front of the
                    control box).
                -   OAP Control box (Typically is on all the time. Verify that the power is on).
                -   Computer

        3.2   Allow a minimum of 15 minutes for the light source to warm up before starting to
                take any measurements. While waiting for the light source to warm up you may
                proceed with the Goniometer alignment.

3.3   Open the light tunnel equipment software program "**GS940D5 (2)"**.

3.4.   Once the software program is open hit the "Connect Goniometer" and "Connect Detector" buttons.

3.5   In the software program using the "Goniometer Position Control" move the Photometer to the 0.5 observation angle "α". Press the "Enter" key on keyboard to execute the move.

3.6   Place the alignment mirror in the center of the Goniometer and secure with mounting brackets.

3.7   Place the alignment panel over the light source.

3.8   Turn off all lights in the light tunnel and locate the position of the alignment mirror "X".

3.9   In the software program using the "Goniometer Position Control" adjust the entrance angle components "β_1" and "β_2" until the alignment mirror "X" is centered on the alignment panel. Typically only small movements (0.02 – 0.10 degrees) are required.

3.10   Once the alignment mirror "X" is centered on the alignment panel hit the "Zero Indexer" buttons next to the "β_1" and "β_2" angle to save the adjustments (computer software program).

3.11   Turn on the lights and remove the alignment mirror and panel.

4.   CALIBRATION OF THE LIGHT SOURCE AND THE PHOTOMETER

4.1   Place a sign sheeting sample on the Goniometer and select the appropriate size apertures for both the Photometer and Light source. Apertures shall be large enough to completely cover the samples being tested with a minimum amount of background.

4.2   To view sign sheeting samples through the Photometer eyepiece follow the following steps:
- Hit the menu button on the "Photometer Control Box"
- Using the black knob scroll until you see the "Shutter" option
- Hit the menu button again
- Using the black knob scroll to the "Closed/View" option. Listen for the shutter to click.
- You should be able to see through the eyepiece

4.3   Use the thumb wheel on the front of the photometer to select the appropriate sized aperture.

4.4   Use the lever toward the bottom of the light source to select the appropriate sized aperture.

4.5   Remove the sign sheeting sample from the Goniometer.

4.6   Take the Photometer and Control box down to the Goniometer.

4.7   Put the Photometer in the middle of the mounting plate facing toward the light source.

4.8   From the "Setup" drop down menu select "Calibration" in the computer software program.

4.9   Make sure all lights within the light tunnel are turned off before proceeding.

4.10   In the computer software program under "Procedure A" hit "Recalibrate" and follow the on-screen instructions.

4.11   Once the light source reading is taken, save the light source reading value when prompted using the date and aperture size as the file name (computer software program).

4.12   Write the measured light source value in the light source value notebook.

4.13   Compare the measured light source value to the previously measured light source value.

4.14   If the values are within 1% of each other, return the Photometer and Control box to their original positions and proceed with taking measurements. If values differ by more than 1% check for any potential problems. Repeat Steps 4.6 through 4.13. If values differ by 1% or less proceed to Step 4.15.

4.15   In the computer software program under the "Calibration" window hit the "Done" button.

4.16   Turn on the light tunnel lights.

5.   MEASURING BACKGROUND LIGHT AND THE CALIBRATION CHECK FOR SIGN SHEETING AND RAISED PAVEMENT MARKERS

5.1   Before any sign sheeting or raised pavement marker samples can be tested a background measurement shall be taken and the sign sheeting color standards shall be measured to verify calibration.

5.2   Select sign sheeting color standards that match the color of samples to be tested that day.

5.3   Before starting the background measurement check, make sure that the appropriate "Macro File" (ASTM E810 Pro A.csv), "Sample Area" and "Color" is being used (computer software program).

5.4   In the computer software program under "Goniometer / Lab background subtract" select the "Retake" option. This only needs to be done for the first measurement of the day and can be set to "Last Value" once the background light measurement has been collected and saved.

5.5   Turn off all lights inside the light tunnel.

5.6   Press the "Start Measurement" button (computer software program).

5.7   In the "Dark Current Subtract" window select "Yes" (computer software program).

5.8   In the "Background Subtract" window select "Yes" (computer software program).

5.9   Once the background light measurement is collected place a colored sign sheeting standard on the Goniometer.

5.10   Make sure all lights inside the light tunnel are off.

5.11   In the "Background Subtract Completed" window select "Yes" (computer software program).

5.12   After the measurement is completed turn on the light tunnel lights.

5.13   In the "Save Background Subtract" window select "Yes" (computer software program).

5.14   Set the "Goniometer/Lab background subtract" to "Last Value" (computer software program).

5.15   In the "Calibration Check" folder located on the computer desktop open the "Our Standards" Excel file.

5.16   Insert a blank worksheet.

5.17   Copy and paste the previous date's measurement information for the sign sheeting color standard being measured into the blank Excel worksheet.

5.18   Clear all old measurements from the "Actual Reading" column of the Excel worksheet.

5.19   Copy and paste today's measurements into the appropriate spot in the "Actual Reading" column of the Excel worksheet.

5.20   Check that today's measurements when compared with the tested color standard measurements are within the following tolerances:
+/- 5 %: White, Yellow, Orange
+/- 7 %: Green, Red
+/- 10%: Blue

5.21   If measurements fall outside of the range in Step 5.20 check for any problems. Repeat Steps 5.3 through 5.20.

5.22   If measurements are within the range in Step 5.20, proceed to measure any other color standards that are needed to be tested.

5.23   Copy and paste results into the appropriate spot in the "Actual Reading" column of the Excel worksheet.

5.24   Save and close the "Our Standards" Excel file.

6.   TAKING A RETRO-DIRECTIVE MEASUREMENT FOR SIGN SHEETING

6.1   Before starting sample measurements check that the appropriate "Macro File" (ASTM E810 Pro A.csv), "Sample Area" and "Color" is being used (computer software program).

6.2   In the "Measurement Description" field write "Lab Number XX-XXXXXX" placing the appropriate lab number in place of the X's (computer software program).

6.3   Place the sample to be tested in the center of the Goniometer.

6.4   Look into the eyepiece to insure that sample is inside of the photometer aperture.

6.5   Turn off all lights inside the light tunnel.

6.6   Press the "Start Measurement" button (computer software program).

6.7   In the "Dark Current Subtract" window select "Yes" (computer software program).

6.8   When the measurement is completed the results will be displayed as an Excel worksheet.

6.9   Turn on the light tunnel lights.

6.10   In the results Excel worksheet do the following:

> - Expand Column A to 120 pixels and Columns E, F and G to 90 pixels.
> - Center justify Columns A through G and Rows 13 through 22.
> - In Columns E, F and G, Row 13, write Increment 1, Increment 2 and Increment 3 respectively.
> - Format the results in Rows 15 through 22 and Columns E, F and G to one decimal place.

6.11   Click on the circular button located in the top left corner of the Excel worksheet.

6.12   From the pull down menu select "Save As" "Excel Workbook".

6.13   In the "Save As" window select "Desktop" from the left column.

6.14   Open the "Samples" folder.

6.15   Save the Excel file using an appropriate lab number.

6.16   Repeat Steps 6.1 through 6.9 as necessary to complete all increments of the same lab number.

6.17   Copy results from Columns E, F, and G into the Excel worksheet.

6.18   Paste results into the appropriate column of the previously saved Excel sheet.

6.19   When finished with all increments of a lab number print out a copy of the completed Excel worksheet results. These results are then to be entered into the CAMMS computer system.

6.20   Save the Excel file before closing it.

7.   TAKING A RETRO-DIRECTIVE MEASUREMENT FOR RAISED PAVEMENT MARKERS

7.1   Replace the sign sheeting mounting plate with the pavement marking mounting plate.

7.2   Before any samples can be measured a background light measurement shall be taken (Section 5).

7.3   Before starting the background measurement check make sure that the appropriate "Macro File" (RPM Pro A.csv) and "Color" is being used (computer software program).

7.4   In the computer software program under "Goniometer / Lab background subtract" select the "Retake" option. This only needs to be done for the first measurement of the day and can be set to "Last Value" once the background light has been collected and saved.

7.5   Turn off all lights inside the light tunnel.

7.6   Press the "Start Measurement" button (computer software program).

7.7   In the "Dark Current Subtract" window select "Yes" (computer software program).

7.8   In the "Background Subtract" window select "Yes" (computer software program).

7.9   Once the background light measurement is collected place a raised pavement marker sample on the Goniometer

7.10   In the "Background Subtract Completed" window select "Yes" (computer software program).

7.11   After the measurement is completed turn on the light tunnel lights.

7.12   In the "Save Background Subtract" window select "Yes" (computer software program).

7.13   Set the "Goniometer/Lab background subtract" to "Last Value" (computer software program).

7.14   Save the test values to the "Our Standards" Excel file.

8.   SHUTTING DOWN THE EQUIPMENT

8.1   After all measurements have been completed shut down the system.

8.2   In the computer software program hit the "Disconnect Goniometer" and "Disconnect Detector" buttons.

8.3   Close the software program and turn off the computer.

8.4   Turn off power to the following devices:
             - Photometer (Switch on the back of the Control box)
             - Light Source (Press the "Lamp" button, wait for the light to turn off.
                Then press the "Power" button).

8.5   Do not turn off power to the OAP Control Box.

9.   CALCULATIONS

9.1   For each of the Retroreflective sheeting specimens and each combination of entrance and observation angles, calculate the coefficient of retroreflection of the retroreflective sheeting using the following equation:

$$R_A = [(m_1 - m_b)d^2/m_2A]$$

Where:

$R_A =$ Coefficient of retroreflection, in candelas per lux per square meter.
$m_b =$ Background light measurement (candelas)
$m_1 =$ Measurement of Retroreflective test specimen measured at the observation position (candelas).
$m_2 =$ Mean measurement of the light source measured normal to the source at the specimen position (lux).
$d =$ Test distance, in meters
$A =$ Area of sample, in square meters

9.2 For each Raised Pavement Marker specimen and each combination of entrance and observation angles, calculate the coefficient of retroreflection of the retroreflective sheeting using the following equation:

$$R_I = m_1'd^2/m_2$$

Where:

$R_I =$ Coefficient of luminous intensity (mcd/lux).
$m_1' =$ Photometer reading (minus stray light) used to measure reflected illuminance at the observation position (mcd).
$d =$ Test distance, in meters.
$m_2 =$ Photometer reading used to measure normal illuminance (lux).

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LABORATORY TESTING SECTION

Method of Test for

MEASURING PAVEMENT PROFILE USING A PROFILOGRAPH

1.   SCOPE

        1.1   This test method covers the measurement of pavement profile using an articulated multi-wheeled profilograph at least 7.6 m (25') long by moving the profilograph longitudinally over the pavement at less than 5 km/hr (3 mph).

        1.2   This test method covers the determination of the pavement ride quality as the pavement profile index from the longitudinal profile for acceptance and payment and describes the procedure for location of individual high points.

        1.3   Either metric or English units may be used, but units must be used consistently and not mixed.

2.   REFERENCED DOCUMENT

        2.1   ASTM Adjunct:

        E- 1274 Test Method for Measuring Pavement Roughness Using a Profilograph

3.   TERMINOLOGY

        3.1   Description of terms specific to this PTM:

        3.1.1   Must Correct Area- A 10 mm (0.4") deviation of the pavement surface record from a chord representing 7.5 m (25') on the longitudinal scale. The chord may represent less than 7.5 m (25') if it is from the lows on each side of the high. A deviation greater than 10 mm (0.4") over the 7.5 m (25') is considered a high point or low point requiring correction (Figure 1).
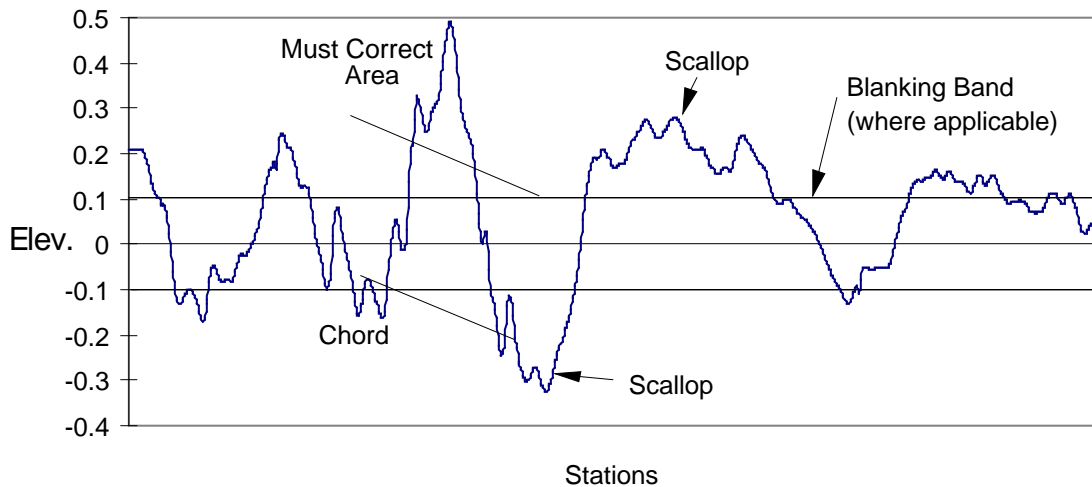
FIGURE 1.   EXAMPLE PROFILE TRACE

3.1.2 Scallops- Excursions of the surface record above and below the mathematically established baseline or band representing the digitized profile's central tendency (Figure 1).

3.1.3 Blanking Band- A band of uniform height with its longitudinal center positioned optimally between the highs and lows of the pavement surface profile. The width of band is specified, typically 0 or 5 mm (0 or 0.2"). Only scallops that extend above or below the specified band are measured.

3.1.4 Profile Index (PRI)- The sum of the scallops divided by the longitudinal distance over which the profile is measured.

3.1.5 Excluded Area - An area that is not included in the measurement of profile used to determine lot payment.

4.   APPARATUS

4.1   Profilographs:

4.1.1   With Non-Uniformly Spaced Wheels- California type profilograph. A reference platform comprised of dollies articulated by rigid members or trusses so that all the wheels are supporting the profilograph. There must be at least twelve reference platform wheels. The wheels must be arranged in a staggered position (axles must be spaced at least 0.3 m (1') apart) such that no two wheels cross the same bump at the same time. The profilograph shall be hand propelled of aluminum construction, on a frame at least 7.6 m (25') in length. The profilograph must be equipped with a recorder capable of recording the profile trace either graphically or digitally. The recorder must produce a trace at a scale of 1:1 vertically and 1: 300 longitudinally (1 mm = 0.3 m; 1" = 25'). Any analog display must have the same scales as the recorder. The digital recorder must sample the longitudinal surface every 5 mm (0.2") and record

the relative height of the surface to at least the nearest 0.25 mm (0.01"). The surface sensing wheel shall be located at the center of the reference platform. The diameter of the surface sensing wheel shall be at least 150 mm (6").

4.1.2 The profile trace must be interpreted automatically. Automated profilographs must provide smoothing of the trace using a third order Butterworth lowpass filter. The following models and software versions and specified data filter settings are acceptable for automated interpretation:

Table 1: Approved Profilograph Models, Software and Data Filter Settings

Manufacturer	Model/Serial No.	Software Version or Revision Date	Data Filter Setting
McCraken	111002	3/93	2.0
	111006	3/93	2.0
	111007	N.A.	2.0
	111009	N.A.	2.0
Cox	All Units	2.23	2.0
Ames	4000	3.29B	3.0

4.2 Calibration Blocks- Three steel calibration blocks with dimensions of 6.00 ± 0.25 mm, 12.00 ± 0.25 mm, and 25.00 ± 0.25 mm (0.25 ± 0.01 ", 0.50 ± 0.01" and $1.00 \pm .01$") are used for calibration checks on the vertical displacement mechanism.

4.3 Optical Scanner and Reduction Software (optional)- A graphic trace may be digitized by use of an optical scanner. The scanner must digitize at uniform intervals not exceeding 50 mm (2") of the profilographs longitudinal travel, and must record with a resolution of 0.25 mm (0.01").

4.4 Computers - Digital recording and profile analysis are performed by the use of computers. All computer software must be approved by the Department.

5. SAMPLING

5.1 Pavement profiles will be taken 1 m (3') from and parallel to each edge of the pavement for pavement placed at a 4 m (12') width or less. When pavement is placed at any other width, the profile will be taken 1 m (3') from and parallel to each edge and from the approximate location of each planned longitudinal joint, or as directed by the Project Engineer. Measure profiles on pavement areas, as specified. Terminate profile measurements fifteen feet from excluded areas. As per Specifications, Publication 408, sampling areas will be designated as lots, and excluded areas shall be defined and measured separately.

6.   CALIBRATION

6.1   Height recording:

6.1.1   Prior to testing, place three calibration blocks on the pavement at the job site. With the profilograph in the operational mode, push the profilograph at a walking pace so that the surface sensing wheel passes directly over the calibration blocks. The entire bearing surface of the wheel shall be on the calibration block. The record must indicate the height of each calibration block. The vertical displacement is recorded on a scale of 1 mm equals 1 mm (one inch equal to one inch) or full scale. If the measured displacement deviates from the calibrated block thickness by more than 5%, the equipment shall not be used until satisfactory corrections have been made.

6.1.2   Verify the accuracy of the height recording before any week of use, whenever the profilograph is re-assembled, and whenever there is evidence of possible inaccuracy.

6.2   Distance Recording:

6.2.1   Mark a distance of 30.00 m (100.00') on reasonably even pavement. Move the profilograph forward until a particular point on the profilograph is at the begin point and mark this event on the record. Move the profilograph forward again until the point is at the end point and mark this event on the record. The record must indicate 30.0 ± 0.3 m ($100 \pm 1'$) between the two events ($4.00 \pm 0.04"$ on graphic record).

6.2.2   Verify the accuracy of the distance recording before any week of use, whenever the profilograph is re-assembled and whenever there is evidence of possible inaccuracy.

7.   PROCEDURE

7.1   Clear the intended profilograph path of all loose material and foreign objects.

7.2   Move the profilograph to the start position using the center wheel as the reference wheel. Once at the start position, initialize the recorder and make the beginning notations.

7.3   Perform the testing by moving the profilograph forward, no faster than 5 km/hr (3 mph), steering it to stay within the prescribed sampling path. Pertinent observations about surveyed locations or unusual conditions may be made on the record only as they occur. Observe the recorder for any unusual operation.

7.4   Upon completion of a sampling path, make ending notations and review the recording for reasonableness. Repeat the procedure, moving the profilograph in the same direction for successive sampling paths for a given section of pavement. Test each sampling path

only once. Additional profiles may be taken to define the limits of an out-of-tolerance surface variation.

8.   AUTOMATED INTERPRETATION

8.1   If the profile trace for each wheelpath has been digitized directly at the time of measurement, interpret it by automated means as follows:

8.1.1   To remove the effects of extraneous chatter caused by pavement texture or profilograph vibration, filter the surface record using a digital third-order Butterworth lowpass filter with a cutoff wavelength of 0.6m (2.0'). Use the smoothed surface record for all calculations.

8.1.2   Mathematically establish the position of a baseline representing the profile's central tendency. Apply the specified blanking band.

8.1.3   Measure and record, to the nearest 0.2 mm (0.01"), the height of each scallop extending above or below the blanking band, except those less than 0.8 mm (0.03") vertically and 2 mm (0.08") longitudinally on the trace. If a scallop spans two pavement sections, include it in the section where its height is the greatest.

8.1.4   Compute the Profile Index for the wheelpath as the sum of the scallops' heights divided by the length of the sampling path.

8.1.5   Identify the areas of deviations with high or low points; a portion of the trace that extends more than 10 mm (0.4"), above or below the baseline.

8.2   If the profile trace is produced graphically by a profilograph without an automated interpretation the profile must be optically scanned, digitized, and analyzed using Department approved scanning and reduction software. Analyze the trace the same as described in Section 8.1 except that the scanner must provide smoothing by using a eight point moving average of the graphic trace.

8.3   Upon completion of the interpretation a report must be given to the inspector for review and acceptance. Any observable differences between the measured profiles of the left and right wheelpaths that cannot be attributed to actual differences in the roadway mandate a repeat measurement. If there is any question about the performance of the test apparatus or the interpretation for the run, make an immediate check by measuring the test section again.

9.   REPORT

9.1   As a minimum, the following information shall be printed for the interpreted output for each wheel path:

9.1.1   Date and time of day

9.1.2   Operator and equipment identification

9.1.3   Weather conditions, principally temperature, cloud cover, and wind

9.1.4   Surface description; type of pavement and condition

9.1.5   Location and description of section; Job ID, lot, lane, wheel path, beginning and ending stationing, and direction measured

9.1.6   Height of blanking band

9.1.7   Must Correct Area to the nearest 1 mm (0.05")

9.1.8   Data filter setting

9.1.9   Length of test for which the Profile Index is calculated

9.1.10 Location of areas by stations of excess height or high points that require correction.

9.1.11 The profile index

9.2   The average of the two wheelpaths for each lot will be the profile index for the lot. This information must also be provided with the printed output.

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LABORATORY TESTING SECTION

Method of Test for

PROOF-LOAD TESTING

1.   SCOPE

1.1   This method of test, which is a modification of AASHTO M-306, outlines the procedures for sampling and testing the covers and frames for buried structures, to include inlet grates, junction boxes, and manholes.

1.2   For purposes of determining actual usage of these types of buried structures, the testing criteria are specified for either traffic or non-traffic conditions.

2.   SAMPLING

2.1   Department Samples shall be taken or requested by the Engineer or his authorized representative.

2.2   Determination of the number of samples to be taken shall be made in conformance with random sampling procedures and in accordance with Pennsylvania Test Method (PTM) No. 415.

2.3   Samples for testing in accordance with this method shall be taken for Bulletin 15 approval, verification testing, or as otherwise deemed necessary by the Engineer.

3.   APPARATUS

3.1   Universal Testing Machine- The compression machine shall be capable of developing and maintaining a minimum of a 142.4 kN (32,000 pound) load to an accuracy of 0.1% of the load.

3.2   A 225 mm x 225 mm x 13 mm (9" x 9" x 1/2") structural steel plate and an equivalent size rubber or neoprene pad to provide bearing for transmission of test loads to the cover or grate.

4.   STRENGTH REQUIREMENTS

4.1   Traffic Loads- The frame and cover or grate shall have a minimum transverse proof-load of 111.20 kN (25,000 pounds), when tested in accordance with Section 5, with no cracks or permanent deformation.

4.2   Non-traffic loads- Frames and covers or grates for non-traffic applications shall have a minimum transverse proof-load strength of 4.45 kN (1,000 pounds), when tested, in accordance with Section 5. No cracks or permanent deformations shall develop under the test.

4.3   Special Load Requirements- Where a proof load in excess of 111.20 kN (25,000 pounds) is expected, special load test requirements shall be specified in the bid proposal.

5.   PROCEDURE

5.1   For the performance of each test, a complete frame and cover or grate assembly shall be centered in the universal testing machine.

5.2   Center the 225 mm x 225 mm (9" x 9") plates on the cover of the frame, with the rubber or neoprene pad placed between the metal surfaces.

5.3   Apply the proof load, as specified in Section 4 at a rate not to exceed 13 mm (0.5") per minute, and hold the load for a period of one minute.

5.4   Upon removal of the load, the frame and the cover or grate shall be examined for cracks or permanent deformation. Any cracks or permanent deformation shall be cause for rejection.

5.5   Each of these assemblies shall be tested according to these procedures. Cracking or permanent deformation on any of the three assemblies shall be cause for rejection.

6.   REFERENCE

6.1   Federal Specification RR-F-621C.

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LABORATORY TESTING SECTION

Method of Test for

ROTATIONAL CAPACITY TEST

1.   SCOPE

1.1   This method of test is in accordance with AASHTO M-164 (ASTM A-325). Additional requirements under the 1993 AASHTO Division II supplement, Section 11.5.6.4, cover the procedures for Rotational-Capacity (R.C.) field testing of black or galvanized bolts, and nut and washer assemblies.

1.2   Perform the test procedure immediately prior to starting installation in the field. The test requires a minimum of two people to conduct.

1.3   Washers or steel spacers are required behind the nut for all tests; even if it is not required on the plan (prevents face plate wear of the testing device).

1.4   Test all the possible combinations of Bolt/Nut/Washer assemblies. Test samples from each bolt lot, nut lot, and washer lot in combination as an assembly.

1.5   Assign an R.C. lot number to each combination of lots in Section 1.4 above.

1.6   Test a minimum of two assemblies per R.C. lot.

2.   EQUIPMENT REQUIRED

2.1   Use a Skidmore- Wilhelm Calibrator (Skidmore) or an acceptable equivalent device (calibrated within the last year). For bolts that cannot be assembled in the Skidmore see Section 4 for the procedure.

2.2   Use a calibrated manual dial torque wrench with a 1355 N·m (1000 Ft.-lb.) capacity or a torque multiplication device (calibrated within the last year).

2.3   Use steel spacers and/or washers with a hole size a maximum 1.59 mm (1/16") greater than the diameter of the bolt to be tested.

2.4   Use a steel section to mount the Skidmore. The flange of the girder or cross frames accessible from the ground is satisfactory for this purpose.

2.5   Bolt, nut and washer assemblies. Check the condition of the assemblies for lubrication and rust. Clean and lubricate all weathered or rusted assemblies prior to testing or installation.

3.   PROCEDURE FOR LONG BOLTS IN THE SKIDMORE

        3.1   Test two bolt, nut, and washer assemblies from each R.C. lot. Install the nut on the bolt and measure the stick out of the bolt when 3 to 5 full threads of the bolt are located between the bearing face of the nut and the bolt head. Measure the bolt length and distance from the end of the threaded shank to the underside of the bolt head.

        3.2   Place the bolt in the Skidmore. Use steel shims or washers to take up space, if necessary, to produce the thread stick out length measured in Section 3.1 above. Tighten the nut to snug tight (10% of required installation tension (RIT), see Table 1 for values).

        3.3   Make reference marks on the face plate of the Skidmore, nut, bolt, and on the wrench socket.

        3.4   Tighten the nut to at least the RIT given in Table 1 using a calibrated manual torque wrench. At some point greater than RIT, record the torque (T) and tension (P) with the nut in motion. These values will be used in the equation $T \leq 0.25$ PD, [D is bolt diameter in meters (feet)]. This equation is discussed below.

> Torque ≤ 0.25 PD
> Torque "Measured Torque", Newton-meters (foot-pounds)
> P = Measured bolt tension, Newtons (pounds)
> D = Bolt Diameter, meters (feet)

        Measure Torque and Tension somewhere between required installation tension and turn test tension, as mentioned in Section 3.4 above. If the maximum torque is exceeded, the assembly fails.

        3.5   Continue tightening the bolt to the required rotation given in Table 2. This rotation is measured from the initial mark in Section 3.3 above. If the bolt breaks or threads strip, the assembly fails.

        3.6   The measured bolt tension on the Skidmore must equal or exceed 1.15 x RIT as shown in Table 1. If it doesn't, the assembly fails.

        3.7   Loosen and remove the nut, and examine the threads on the nut and bolt. No signs of thread shear failure, stripping, or twisting of bolt shall be evident. If such evidence exists, the assembly fails. Following the test if the nut is unable to be removed, the assembly fails.

        3.8   If an assembly fails any of the test criterion as stated in Sections 3.4 through 3.7 above, one of the following steps will be taken by the Engineer:

                3.8.1   The Engineer may reject the lot on the results of the first test, provided failure is not due to the effects of shipment and storage on fastener lubrication.

3.8.2   The Engineer may allow the contractor to relubricate the failed lot, provided failure is due to the effects of shipment and storage on fastener lubrication. The lot will then be retested. If the retest fails, reject the lot.

3.8.3   The Engineer may reject the lot on results of the first test, even if the failure is due to the effects of shipment and storage on fastener lubrication, provided that relubrication is deemed impractical in field.

4.   PROCEDURE FOR BOLTS THAT CANNOT BE ASSEMBLED IN THE SKIDMORE:

Note 1 - Bolt assemblies that cannot be assembled in the Skidmore may be tested in a steel section with the hole size in the plate being a maximum of 1.59 mm (1/16") over the bolt diameter. The Turn Test Tension requirement of Table 1 does not apply.

4.1   Install the nut on the bolt and measure the stick out of the bolt when 3 to 5 full threads of the bolt are located between the bearing face of the nut and bolt head. Measure bolt length and distance from the end of the threaded shank to the underside of bolt head.

4.2   Choose a steel section with a proper size hole to install the bolt. Any available splice hole can be used with a plate thickness that will provide the required number of threads under the nut.

4.3   Install the bolt with appropriate shims to produce the thread stick out measured in Section 4.1 above.

4.4   Install the nut and washer, using a second wrench to prevent the bolt head from turning at all times.

4.5   Tighten the nut snug tight using the same effort (torque) required to reach 10% of RIT. This value can be determined using the equation Torque = 0.25(.10 of RIT)D [Note - D is bolt diameter in meters (feet)].

4.6   Mark reference points on the socket, nut, bolt, and steel plate and turn the nut using a torque wrench to the minimum rotation required for the turn of the nut installation listed below, and record the torque. Torque must be measured with the nut in motion.

Bolt Length (measured in Section 4.1)	≤ 4 x Bolt Diameter	>4 ≤ 8xBolt Diameter	>8&< 12 x Bolt Diameter
Required Rotation	1/3	1/2	2/3

4.7   Torque cannot exceed the torque value calculated from the formula in Section 3.4 above. The P value used in this calculation is the "turn test tension" from Table 1.

4.8   Tighten the bolt to the required rotation past the snug fit value given in Table 2. This rotation is measured from the initial marking in Section 4.6 above. Assemblies that fail prior to this rotation either by stripping or fracture, fail the test.

4.9   The nut and bolt must be free from damage as described previously in Section 3.7.

4.10   Test both sets of samples. Both samples must pass the test.

TABLE 1
Rotational Capacity Test

METRIC

Bolt Diameter		(1) Required Installation Tension (RIT)		(2) Snug Tight Condition		(3) Turn Test Tension	
				0.10 x RIT (-0 Newtons, +10% load)		1.15 x RIT	
		A-325M	A-490M	A-325M	A-490M	A-325M	A-490M
millimeter	meter	kN	kN	kN	kN	kN	kN
16	0.016	94.2	130	10	13	108	150
20	0.020	147	203	15	20	169	233
22	0.022	182	251	19	25	209	289
24	0.024	212	293	22	29	244	337
27	0.027	275	381	28	38	316	438
30	0.030	337	466	33	47	388	536
36	0.036	490	678	50	68	564	780

NOTES:

(1) Values taken from the 1993 AASHTO Division II, Table 11.5A.
(2) This definition of snug tight applies to rotational capacity tests only.
(3) After turning the nut the required rotation, the tension must equal or exceed these values.

TABLE 1
Rotational Capacity Test

ENGLISH

Bolt Diameter		(1) Required Installation Tension (RIT)		(2) Snug Tight Condition		(3) Turn Test Tension	
				0.10 x RIT (-0 KIPS, + 2 KIPS)		1.15 x RIT	
		A-325	A-490	A-325	A-490	A-325	A-490
Inches	Feet	KIPS	KIPS	KIPS	KIPS	KIPS	KIPS
½	0.0417	12	15	1	2	14	17
⅝	0.0521	19	24	2	3	22	28
¾	0.0625	28	35	3	4	32	40
⅞	0.0729	39	49	4	5	45	56
1	0.0833	51	64	5	7	59	74
1⅛	0.0938	56	80	6	8	64	92
1¼	0.1042	71	102	7	10	82	117
1⅜	0.1146	85	121	9	12	98	139
1½	0.1250	103	148	10	15	118	170

Notes:

(1) Values taken from the 1993 AASHTO Division II, Table 11.5A.
(2) This definition of snug tight applies to rotational capacity tests only.
(3) After turning the nut the required rotation, tension must equal or exceed these values.

TABLE 2
Rotational Capacity Test
Required Rotation Past Snug Tight

Bolt Length (1)	≤ 4 x Bolt Diameter	>4 ≤ 8xBolt Diameter	>8&< 12 x Bolt Diameter
Required Rotation (2)	2/3	1	1 1/3

NOTES:
- (1)   The bolt length is the distance from the end of the threaded shank to the underside of the bolt head.
- (2)   These values are 2 times the values required for the turn of the nut method as presented in 1993 AASHTO Division II, Table 11.5B.

TABLE 3
Rotational Capacity Test
METRIC

ROTATIONAL CAPACITY TEST/MAXIMUM TORQUE
0.25(P)(D)

20 MILLIMETER BOLT		22 MILLIMETER BOLT	
TENSION(kN)	TORQUE(N·m)	TENSION(kN)	TORQUE(N·m)
147	735	182	1001
148	740	183	1007
149	745	184	1012
150	750	185	1018
151	755	186	1023
152	760	187	1029
153	765	188	1034
154	770	189	1040
155	775	190	1045
156	780	191	1051
157	785	192	1056
158	790	193	1062
159	795	194	1067
160	800	195	1073
161	805	196	1078
162	810		

TABLE 3
Rotational Capacity Test
ENGLISH

ROTATIONAL CAPACITY TEST/MAXIMUM TORQUE
0.25(P)(D)

3/4 INCH BOLT		7/8 INCH BOLT	
TENSION (KIPS)	TORQUE (FT-LBS.)	TENSION (KIPS)	TORQUE (FT-LBS.)
28	437	39	711
29	453	40	729
30	469	41	747
31	484	42	766
32	500	43	784
33	516	44	802
34	531	45	820
35	547	46	839
36	562	47	857
37	578	48	875
38	594	49	893
39	609	50	911
40	625	51	930
41	641	52	948
42	656	53	966
43	672	54	984
44	688	55	1003

HIGH STRENGTH BOLT
Rotation Capacity Test (R.C. Test)
Publication 408 Section 1105.02(d)5.d

S.R. _____ Section _____Date_____
County: _____ Job Name: _____
Inspector:_____
Passes: _____ Fails: _____

Bolt: _____ A325 _____ A490 Length _____ in.
                                                    Diam._____in._____ ft.
Galvanized: _____ No _____Yes
Stressing Length:_____ in. Stress Ln. =
                                        Diam.   _____

Assembly	Manufacturer	Lot No.	R.C. Lot No.
Bolt			
Nut			
Washer			

Note: Only one R.C. Lot No. is assigned to a bolt-nut-washer assembly

Required Installation Tension (RIT)_____KIPS
  (1993 AASHTO Division II, Table 11.5A)
0.10 x RIT (snug tight)_____KIPS
1.15 x RIT (turn test tension)_____KIPS
Required rotation past snug tight_____TURN
  (2 x value in 1993 AASHTO Division II Table 11.5B)

Measured Values
 T (Torque measured at a value > RIT)_____FT.-Lb.
 P (Bolt tension measured at the above torque)_____Lb.
 Measured bolt tension at required rotation_____KIPS

Check the Following
1) Is T < 0.25 PD = _____Ft.Lb.?_____Yes_____No (assembly fails)
    (Note: D is bolt diam. in feet)
    (Note: For bolts that can not be assembled in Skidmore use P value "Turn
          Test Tension" from Table 1(1.15xRIT).
2) Did assembly break or threads strip before
   reaching required rotation?_____ Yes(assembly fails)_____ No
3) Is the measured bolt tension at required
   rotation > 1.15 x RIT?_____ Yes _____ No (assembly fails)
4) Disassemble and examine threads on bolt and nut
   Signs of shear failure?_____   Yes (assembly fails)_____   No
   Signs of stripping? _____   Yes (assembly fails)_____   No
   Signs of twisting? _____   Yes (assembly fails)_____   No
5) Is bolt rusted?   _____   Yes (assembly fails)_____   No
6) Signs of Lubrication? _____   Yes   _____   No

```
                          HIGH STRENGTH BOLT
                     Rotation Capacity Test (R.C. Test)
                     Publication 408 Section 1105.02(d)5.d
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S.R. _____ Section _____Date_____
County: _____ Job Name: _____
Inspector:_____
Passes: _____ Fails: _____

Bolt: _____ A325M _____ A490M   Length _____ mm
                                                      Diam._____mm_____ m
Galvanized: _____ No _____Yes
Stressing Length:_____mm   <u>Stress Ln.</u>   =
                                     Diam.   _____

Assembly	Manufacturer	Lot No.	R.C. Lot No.
Bolt			
Nut			
Washer			

Note: Only one R.C. Lot No. is assigned to a bolt-nut-washer assembly

Required Installation Tension (RIT)_____kN
  (1993 AASHTO Division II, Table 11.5A)
0.10 x RIT (snug tight)_____kN
1.15 x RIT (turn test tension)_____kN
Required rotation past snug tight_____TURN
  (2 x value in 1993 AASHTO Division II Table 11.5B)

<u>Measured Values</u>
 T (Torque measured at a value > RIT)_____N·m
 P (Bolt tension measured at the above torque)_____kN
 Measured bolt tension at required rotation_____N·m

<u>Check the Following</u>
1) Is T $\leq$ 0.25 PD = _____N·m?_____Yes_____No (assembly fails)
   (Note: D is bolt diam. in meters)
   (Note: For bolts that can not be assembled in Skidmore use P value "Turn
          Test Tension" from Table 1(1.15xRIT).
2) Did assembly break or threads strip before
   reaching required rotation?_____ Yes(assembly fails)_____ No
3) Is the measured bolt tension at required
   rotation $\geq$ 1.15 x RIT?_____ Yes _____ No (assembly fails)
4) Disassemble and examine threads on bolt and nut
   Signs of shear failure?_____   Yes (assembly fails)_____   No
   Signs of stripping? _____   Yes (assembly fails)_____   No
   Signs of twisting? _____   Yes (assembly fails)_____   No
5) Is bolt rusted?   _____   Yes (assembly fails)_____   No
6) Signs of Lubrication? _____   Yes   _____   No

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LABORATORY TESTING SECTION

Method of Test for

MEASURING PAVEMENT PROFILE USING A LIGHT WEIGHT PROFILER

1.   SCOPE

1.1   This test method covers the measurement of pavement profile and roughness using a Light Weight Profiler (LWP) by driving the profiler longitudinally over the pavement.

1.2   This test method covers the determination of the pavement ride quality from the longitudinal profile, in the form of the International Roughness Index (IRI), for acceptance and payment.

2.   REFERENCED DOCUMENTS

2.1   ASTM Adjunct
E950-98 Test Method for Measuring Pavement Roughness Using a Profiler

2.2   NCHRP Report 228

2.3   Light Weight Profiling System Calibration Verification and Operator Certification Program Manual

3.   TERMINOLOGY - DESCRIPTION OF TERMS SPECIFIC TO THIS PTM

3.1   International Roughness Index (IRI) - A scale for roughness based on the response of a generic motor vehicle to roughness of the road surface. IRI was developed as a reference measure by The World Bank, and is based on a quarter-car simulation as described in NCHRP Report 228. IRI is determined by obtaining a suitably accurate measurement of the profile of the road, processing it through an algorithm that simulates the way a reference vehicle would respond to the roughness inputs, and accumulating the suspension travel.

3.2   Excluded Area - An area that is not included in the measurement, used to determine lot payment.

4.   APPARATUS

4.1   The Light Weight Profiling System must be an all-terrain or golf-cart type vehicle equipped with various hardware and software that together allow the measurement and recording of the longitudinal profile of a traveled wheel track and the reference distance traveled along the traveled wheel track. The device must meet the requirements of the "Generic Specification for Light Weight Profiling System," Appendix A. (Disregard Items 11 and 12 of Appendix A, which refer to equipment supplier obligations, and note that Item 13 is optional).

4.2   Acceptance

4.2.1   Prior to testing, the LWP device must be checked to verify that it has have been calibrated and is operating properly. The operator of the LWP device must be certified, by the Bureau of Maintenance and Operations, Pavement Testing Section. Accepted devices will be designated with a decal. Certified operators will receive individual certification cards. Additional re-verification/re-certification of devices or operators may be required, due to repairs, replacements, and/or upgrades to the device's hardware or software, or because of questionable results and/or practices on a construction or maintenance project. Verification/certification will be done in accordance with the Light Weight Profiling System Calibration Verification and Operator Certification Program Manual.

4.3   Software

4.3.1   The test software must activate the testing using the timing and control parameters stored by the test control setup software. The software must monitor the signals to verify that the testing is being performed properly and indicate detectable errors.

4.3.2   The test software must receive, display, and store raw data received from the vehicle mounted transducers at corresponding distances and test speeds.

4.3.3   The system must be capable of meeting the requirements of Appendix A.

5.   SAMPLING

5.1   Pavement profiles must be taken in the wheel paths of each lane. The first profile must be approximately 1 m (3') from and parallel to the outside edge of pavement, and the second profile must be approximately 1.75 m (5.75') from the first profile, or as directed by the Project Engineer.

5.2   Measure profiles to the limits of the pavement areas, as specified. As per the Specifications, Publication 408, sampling areas must be designated as lots, and excluded areas must be defined and measured separately (Measure profiles of the excluded areas to their limits).

5.3   Only a single certified operator is to occupy the device during sampling. The weight of additional passengers, including Department personnel, may adversely affect results and is not permissible.

6.   CALIBRATION

6.1   The operational system software must allow the operator to perform a distance sensor calibration and use the calculated Distance Calibration Factor (DCF) to perform the operational distance measurements. The calibration software must also allow the operator to save the calculated DCF or change it to other than the calculated value. The operator must only enter the distance traveled in feet, kilometers, or miles and not make any calculations to determine the DCF. 1 m/km (5 ft. per mi.), or 0.2 m/0.2 km (1 ft. per 0.2 mi.), accuracy is required.

6.2   A distance sensor calibration must be performed each day that the LWP device is in use, prior to any measurements used to determine pavement ride quality for acceptance and payment.

6.3   The calibration software must also allow the operator to perform a profile system calibration. The values determined in calibration must be stored and recorded as above for use in the calculation.

6.4   No more than one single certified operator is to occupy the device during calibration, as per equipment specifications.

7.   PROCEDURE

7.1   Startup and initialization.

7.1.1   Clear the intended LWP path of all loose material and foreign objects.

7.1.2   Perform all necessary start up procedures.

7.1.3   Verify that distance measurement, sensors, and accelerometers are properly calibrated. Perform all necessary calibration procedures, as specified in Section 6, and as per equipment manufacturer procedures. Save all values.

7.1.4   Check that all sensor positions are displaying correctly, and verify that sensor collection rates are properly set.

7.1.5   Enter the location identification information (all data collected must have this information printed on all outputs), and define the direction of traffic for the pavement to be tested.

7.2   Data collection.

7.2.1   Position the LWP to a point where the testing speed can be reached before testing begins. When possible, it is recommended to collect at least 30 m (100 ft.) of data before the area to be tested, to eliminate all error through filtering in the program that processes the data. When this is not possible, provisions are necessary in the report program to eliminate some of the beginning and/or ending test data to minimize the error.

7.2.2   Verify that all software and hardware is ready to collect data. Start the data collection system.

7.2.3   The LWP shall remain stationary to wait for the system filters to stabilize (approximately 1 min).

7.2.4   Start the LWP moving and initiate testing when the LWP reaches testing speed.

7.2.5   If targeting is used, allow the target to reset the system at test start and finish.

7.2.6   Continue testing at a consistent speed until the test end point is passed.

7.2.7   Terminate the test after the test end point is passed, or allow targeting to terminate the test.

7.2.8   End data collection and save the file. It is recommended to save all data, and then delete unwanted data later, rather than abort the file save mode.

7.2.9   If applicable, mark where the total file may be broken into smaller files for analysis.

7.2.10 Upon completion of a sampling path, make ending notations and review the test for reasonableness. Repeat the procedure, driving the LWP in the same direction for successive sampling paths for a given section of pavement. Test each sampling path only once. Additional profiles may be taken to define the limits of an out-of-tolerance surface variation.

7.2.11 Measure IRI for excluded areas separately.

8.   SUBMITTALS

8.1   A file, on diskette, that contains the raw binary data collected for each wheel path must be provided. The data file must be in a format that allows for subsequent analysis by PENNDOT. Each diskette must be labeled to identify the County, State Route, Project Number, Lot Number, and Wheel path of each data file saved on the diskette. Also, a hard copy report must be provided for each wheel path. As a minimum, the following information must be printed for the interpreted output:

(1)   Date and time of day
(2)   Operator and equipment identification
(3)   Weather conditions: temperature, cloud cover, and wind
(4)   Surface description: type of pavement and condition
(5)   Location and description of section: Job ID, lot, lane, wheel path, beginning and ending stationing, and direction measured
(6)   Lot length
(7)   Software version: the version number or identification of the LWP device operational system
(8)   Data filter settings
(9)   High-pass filter setting = 30 m (100 ft.)
(10)   Lot IRI value: the average of the IRI values for the two wheel paths for each lot will be the IRI for the lot
(11)   IRI values for excluded areas

APPENDIX A

GENERIC SPECIFICATION FOR
LIGHT WEIGHT PROFILING SYSTEM

The purpose of this specification is to define the requirements for a Light Weight Profiling (LWP) System that can be used to collect roadway surface data for determining the roughness and profile of roads. The following items are required:

1.   The computer based system, with its profile sensing system described must be capable of the following:

(1)   interfacing with the operator
(2)   controlling the tests
(3)   measuring the necessary resultant test signal data
(4)   recording the resultant test data on IBM-PC compatible floppy diskettes
(5)   calculating and storing profile, roughness, and distance values
(6)   displaying the stored data
(7)   printing the stored data upon operator request

2.   The LWP operational system must be an all-terrain or golf-cart type vehicle equipped with various hardware and software that together allows the measurement and recording of the longitudinal profile of a traveled wheel track and the reference distance traveled along the traveled wheel track. The longitudinal profile must be measured using a concept where three transducers are used. These transducers include:

(1)   a height sensor which measures the distance between a vehicle reference point and the pavement while the vehicle is driven over the roadway.

(2)   an accelerometer which measures the vertical acceleration of the vehicle as it bounces in response to the road profile.

(3)   a distance sensor which provides a reference measurement of the vehicle as it traverses the pavement.

The data must be saved and recorded so that road profiles obtained with this system must be independent of the measuring speed and the type of vehicle used. After the post processing software is utilized the measured profiles must show variations in elevation and slope as they affect roughness. In addition, profile plots must be capable of being displayed on a computer screen or on hard copy after post processing. The system must be capable of obtaining and storing profile measurement data at selected longitudinal distance intervals down to a minimum of 1 reading per approximately 25 mm (1 in.).

3.   The roughness value must be calculated using the standardized International Roughness Index (IRI). In addition to the normal IRI unit value the system must also provide an "in./mi." (or "m/km") statistic. The IRI was developed as a reference measure by The World Bank, and is based on a quarter-car simulation as described in NCHRP Report 228. This value must conform to the requirements of ASTM E950-98. IRI measures obtained from this system must match those obtained from other valid profilometers, and also IRI measures obtained using rod and level survey equipment. A plot of roughness using any base length for averaging must also be reproducible. The above roughness results must be displayable on the system screen, printed on a printer or written into a disk file for processing.

4.   The profile system hardware and software for collecting and processing the data obtained in real time in conjunction with the post processing software must have as a minimum the following capabilities:

(1)   profile computation
(2)   RN/PI computation
(3)   IRI computation
(4)   high-pass filtering
(5)   low-pass filtering (smoothing)
(6)   height sensor error checking

5.   The system must be capable of calculating, displaying, and storing the average roughness value obtained from the stored data. Additionally, the system must be capable of putting the accumulated roughness test results through mathematical equations and printing results when enabled by the operator. These options must be done in real time or in post processing. The system must be capable of performing all required post processing operations. The post processing software must be capable of running on a IBM compatible PC with a SVGA monitor where graphics are used.

6.   The operational system through the Distance/Data Acquisition Subsystem (DAS) must provide all interfaces to collect data to derive distance, speed, and profile from the transducers mounted on the vehicle; activate the tests; derive distance and location information from the transmission mounted distance transducer; process operator inputs from the keyboard and Event Keyboard signaling that the test vehicle has encountered a significant feature; and pass information on about the feature and it's location to the processing unit for display and logging.

7.   An optical encoder must be mounted on the vehicle to produce a pulse for units of distance traveled by the vehicle on the roadway. The DAS must accept these pulses and, in combination with the DAS software, must determine the distance traveled and vehicle speed.

8.   The reference height of the vehicle above the pavement must be obtained through a laser or infrared module as required. The sensor must be totally enclosed in a case that may be sealed during bad weather or when not in use. The sensor must be formed in a manner so that it may be mounted on a vehicle approximately 0.3 m (1 ft.) above the pavement surface. The laser or infrared module shall be equivalent to a Selcom sensor, which has a resolution of 0.025 mm (0.001 in.). The sensor must provide continuous coverage of the roadway. The sensor module must send an infrared beam to the pavement and sample the height value at a rate of 16,000 times per second. The sample data must be averaged and stored referenced to time and/or distance so that the data may be processed into transverse profile data or aligned with the accelerometer data to provide a longitudinal profile.

9.   The displacement of the vehicle in the vertical direction used to calculate position shall be sensed using an accelerometer. The DAS must provide hardware and software to amplify and filter/integrate the signal as required to obtain the data required for storage and for further post processing into the required data.

10.   Upon delivery of the system, the equipment supplier must provide a complete description of the format of all files generated by the software, such that data files can be prepared on disks in a format necessary for the software to read and process all of the items defined in Item 4.

11.   Upon delivery of the system, the equipment supplier must also provide:

(1)   One copy of operating procedures for all operational software.
(2)   One copy of schematics, block diagrams and wiring diagrams covering electronic circuitry of the installed system.
(3)   One complete parts lists detailing the components of all equipment used.
(4)   A three day training session on the use of the new equipment, and a one day training session on data reduction.

12.   The equipment supplier must warrant all components of the operational system for a period of not less than one (1) year from the date of acceptance to be free from defects in material and workmanship.

The following item is optional:

13.   The vehicle will be equipped with infrared sensors to allow the operational system to perform system functions (start test, end test, reset DMI value, etc.) without operator intervention when using roadside targets.

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LABORATORY TESTING SECTION

Method of Test for

HIGH STRENGTH BOLT INSPECTION TESTING

1.   SCOPE

1.1   This method of test is in accordance with AASHTO M-164 (ASTM A 325), and AASHTO M-253 (ASTM A-490). Additional requirements of the 1996 supplement AASHTO Division II, Section 11.5.6.4.9, cover the procedures for final field inspection or shop testing of black or galvanized bolt, nut and washer assemblies.

1.2   Perform calibration at least once each inspection day (torque/tension relationship).

1.3   Washers or steel spacers are required behind nuts for all tests, even if not required on the plan (prevents face plate wear of the testing device).

1.4   Determine a job inspection torque for all representative combinations, (grade/size/condition) of Bolt/Nut/Washer assemblies as those under inspection. Do not reuse assemblies that have been tested in the installation process.

1.5   Assign an inspection lot number that coincides with each assembly in the section.

1.6   Test a minimum of three assemblies per inspection lot.

2.   EQUIPMENT REQUIRED

2.1   Use a Skidmore- Wilhelm Calibrator (Skidmore) or an acceptable equivalent device with proof of calibration within the last year. For bolts that cannot be assembled in the Skidmore test device, see Section 4 for the proper procedure.

2.2   Use a calibrated manual dial torque wrench with a 1355 N·m (1000 Ft.-lb.) capacity or a torque multiplication device with proof of calibration within the last year.

2.3   Use steel spacers and/or washers with a hole diameter a maximum 1.59 mm (1/16") greater than the diameter of bolt to be tested.

2.4   Use a rigid steel section upon which to mount the Skidmore test device. The flange of girders or cross frames, accessible from the ground, is satisfactory.

2.5   Use bolts, nuts, and washers (if used) having lubrication characteristics similar to the installed bolts.

3.   PROCEDURE FOR LONG BOLTS IN THE SKIDMORE

        3.1   Test three bolt, nut, and washer assemblies from each inspection lot. Install the nut on the bolt. Measure the length of bolt remaining when 3 to 5 full threads of the bolt are located between the bearing face of the nut and the bolt head. Measure the effective bolt length, (the distance from the end of the threaded shank to underside of the bolt head).

        3.2   Place the bolt in the Skidmore. Use steel shims or washers to take up any space, if necessary to produce the same length measured in Section 3.1 above. Tighten each bolt by any convenient means to the specified tension (see Table 2 for values).

        3.3   Apply an inspection wrench to the tightened bolt to determine the torque required to turn the nut head 5 degrees (approximately 25.4 mm (1") at a 304.8 mm (12") radius) in the tightening direction.

        3.4   The average of the torques required for all three bolts shall be taken as the job-inspection torque.

        3.5   Select ten percent (at least two per connection) of the tightened bolts on the structure represented by the test bolts in each connection.

        3.6   Apply job-inspection torque in the tightening direction to each of the selected bolts using the inspection wrench.

        3.7   If none of the selected bolt nuts or heads turn under the job-inspection torque, consider the bolts in the connection to be properly tightened.

        3.8   If the application of the job-inspection torque turns one or more bolt heads or nuts, apply the job-inspection torque to all bolts in the connection. Tighten and reinspect bolts whose head or nut turns under the job-inspection torque. The Contractor may, however, retighten all the bolts in the connection and resubmit it for inspection, under Sections 3.5 to 3.8, so long as bolts are not overtightened or damaged by this action.

        3.9   Record all test results on Attachment 1 of this procedure.

4.   PROCEDURE FOR BOLTS THAT CANNOT BE ASSEMBLED IN THE SKIDMORE

        Note 1 - Bolt assemblies that cannot be assembled in the Skidmore may be tested in a steel section with the hole diameter in the plate being a maximum 1.59 mm (1/16 in.) greater than the bolt diameter. The turn Test Tension requirement of Table 2 does not apply.

        4.1   Test three bolt, nut, and washer assemblies from each inspection lot. Install the nut on the bolt and measure the length of bolt when 3 to 5 full threads of bolt are located between the bearing face of the nut and the bolt head.

4.2   Choose a steel section with the proper size hole to install the bolt. Any available splice hole can be used with a plate thickness that will provide the required number of threads under the nut.

4.3   Install the bolt and use appropriate shims to produce the thread stick out measured in Section 4.1.

4.4   Install the nut and washer using a second wrench to prevent the bolt head from turning at all times.

4.5   Tighten the nut snug tight (approximately 75-100 ft-lb). Mark reference points on the socket, nut, bolt, and steel plate and turn the nut using a torque wrench to the minimum rotation required for turn of the nut installation in Table 1. Apply the inspection wrench in the tightening direction to the tightened bolt to determine the torque required to turn the nut head 5 degrees (approximately 25.4 mm (1") at a 304.8 mm (12") radius). Torque must be measured with the nut in motion. Record the torque.

Table 1

Bolt Length (measured in Section 4.1)	≤ 4 x Bolt Diameter	$>4 \leq 8$xBolt Diameter
Required Rotation	1/3	1/2

4.6   Continue inspection by following the procedures as described in Sections 3.4 through 3.8.

4.7   Record all test results on Attachment 1 of this procedure.

TABLE 2
REQUIRED FASTENER TENSION
MINIMUM BOLT TENSION IN KN (POUNDS)

Bolt Size mm (inches)	AASHTO M-164 ASTM A 325	AASHTO M-253 ASTM A 490
12.7 (½)	53.4 (12,000)	66.7 (15,000)
15.9 (⅝)	84.5 (19,000)	106.7 (24,000)
19.1 (¾)	124.5 (28,000)	155.7 (35,000)
22.2 (⅞)	173.5 (39,000)	218.0 (49,000)
25.4 (1)	226.8 (51,000)	284.7 (64,000)
28.6 (1⅛)	249.1 (56,000)	355.8 (80,000)
31.8 (1¼)	315.8 (71,000)	453.7 (102,000)
34.9 (1⅜)	378.1 (85,000)	538.2 (121,000)
38.1 (1½)	458.1 (103,000)	

ATTACHMENT 1

COUNTY _____ S.R._____ SECTION _____ DATE _____
Structure No. S-_____
==
Has the pre-installation process been verified?_____
What installation process was used?_____
Was it done correctly and documented?_____
==

High Strength Bolts Inspection Testing

1. Bolt: _____A 325 _____A 490   Length _____in.
   Inspection Lot # _____

   Galvanized: _____**Yes** _____**No**   Diameter _____in.
   Condition: _____

	Bolt	**Nut**	**Washer**
2. Manufacturer:	_____	_____	_____

3. **Specified Tension** (Table 2- Typical) _____ kips
   Note: Specified tension N/A for short bolts. Rotation in accordance with Table 1.

	Sample 1	**Sample 2**	**Sample 3**

4. **Measured Torque** _____ ft-lbs _____ ft-lbs _____ ft-lbs
   (Torque measured with a required nut turn of 5 degrees in the tightening direction.)_____**Yes**

5. **Average Torque** (Job Inspection Torque)   _____ ft-lbs
   Note: See Field Book # _____ Page _____
   Connection Description:

6.   Ten percent (at least two) bolts per connection verified with the inspection torque wrench? _____ **Yes** _____ **No**

7. Did any selected bolt or nut head assemblies turn in the connection under the job-inspection torque? _____**Yes** _____**No** (If no, consider the connection to be properly tightened. If yes go to question 8 or 9).

8. Was the job-inspection torque applied to all bolts or nuts in the affected connections?
                                                _____ **Yes** ____ **No** ____**N/A**
8A. Were all bolts that turned retightened?   _____ **Yes** ____ **No** ____**N/A**
8B. Were all bolts re-inspected and found not to turn?   _____ **Yes** ____ **No** ____**N/A**
    (If all of the questions in # 8 are answered yes, consider the connection to be properly tightened).

or

9. At the option of the Contractor were all of the bolt assemblies in the connection retightened that were found to turn.?   _____ **Yes** _____**No** _____**N/A**
9A. Were all bolts that turned retightened?   _____**Yes** _____**No** _____**N/A**
9B. Were all bolts re-inspected and found not to turn?   _____**Yes** _____**No** _____**N/A**
(If all of the questions in #9 are answered yes, consider the connection to be properly tightened).

Tested by:_____
Witnessed by:_____

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LABORATORY TESTING SECTION

Method of Test for

PLASTIC RE-BAR SUPPORTS

1.   SCOPE

    1.1   This method of test covers the sampling and testing procedures for plastic re-bar supports including chairs and bolsters.

2.   SAMPLING

    2.1   Samples for testing in accordance with this method will be taken for either Bulletin 15 approval, verification testing, or as otherwise deemed necessary by the Engineer.

    2.2   Obtain three bolster samples each at least 300 mm (12") in length for each size in use. Three chair samples will be obtained for each size in use.

3.   APPARATUS

    3.1   A LOCAP Testing Machine will be used to apply a minimum point load of 1.56 kN (350 pounds-force) to the center of the chair or bolster sample.

    3.2   Equip the test machine with a point load apparatus equal in size to a #19 metric (#6 English) reinforcing bar or a 19 mm (3/4") steel pin.

4.   REQUIREMENTS

    4.1   Both chairs and bolsters will accept a minimum point load of 1.56 kN (350 pounds-force) with no more than 6 mm (1/4") vertical deformation. In addition, chairs will not twist from the vertical axis prior to the application of the minimum load.

5.   PROCEDURE

    5.1   Bolsters - Center the point load apparatus between two leg supports on the bolster and secure the ends of the bolster in place without introducing a load or deforming the sample. Apply the load to the sample at a rate of 13 mm (1/2") per minute.

    5.2   Chairs - Center the chair under the testing apparatus and introduce the load. Apply the load at a rate of 13 mm (1/2") per minute.

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LABORATORY TESTING SECTION

Method of Test for

PAVEMENT MARKING SAMPLING OF LONGITUDINAL AND
TRANSVERSE LINES, LEGENDS, AND SYMBOLS FOR
RETROREFLECTOMETER TESTING

1.   PURPOSE

1.1   This method describes the procedure used to determine where pavement marking retroreflectometer measurements will be taken for longitudinal and transverse lines, legends, and symbols. The retroreflectometer test values for these materials at these locations are compared to the specification requirements to determine acceptable or unacceptable performance.

2.   EQUIPMENT

2.1   The instrument for measuring retroreflectivity of pavement markings shall be a portable hand-held 30-meter geometry retroreflectometer meeting all the requirements of the American Society for Testing and Materials' current designation E 1710. The entrance and observation angles of the retroreflectometer shall be 88.76° and 1.05°, respectively, as specified by the European Committee for Standardization (CEN).

2.2   A complete calibration, *zero calibration*, and *reference calibration* shall always be carried out before starting a new series of measurements.

3.   RETROREFLECTIVITY SAMPLING - LONGITUDINAL LINES

     3.1   The following chart describes the sampling criteria used when pavement marking retroreflectivity testing is performed on longitudinal lines. Three different zones of measurement, length of checkpoint area, number of checkpoint areas, number of test point measurements within the checkpoint area, and the acceptance criteria used when performing retroreflectivity testing on solid and broken longitudinal lines are described in the chart below.

Zone of Measurement (Project Length)	Length of Checkpoint Area	Number of Checkpoint Areas	Number of Test Point Measurements Within Checkpoint Area(s)		Acceptance Criteria
			Solid Lines	Broken Lines	
< 1 Mile (See Figure 1)	**400 ft.**	**One checkpoint area**	**20 Each line**	Two test point measurements on each of 10 skips; total of 20	If a random 20 sample size set average falls below the specified retroreflectivity requirements, the longitudinal line(s) within the entire zone of measurement (project) is unacceptable
1 Mile to 6 Miles (See Figure 2)	**400 ft.**	Minimum two checkpoint areas or one every mile; which ever is greater	**20 Each line**	Two test point measurements on each of 10 skips; total of 20	If a random 20 sample size set average falls below the specified retroreflectivity requirements, the longitudinal line(s) within the entire zone of measurement (project) is unacceptable
> 6 Miles (See Figure 3)	400 ft.	Minimum three checkpoint areas or one at the start and at the end of the zone and every 3 miles within the zone; which ever is greater	20 Each line	Two test point measurements on each of 10 skips; total of 20	If one or more longitudinal lines within one checkpoint are unacceptable, repaint the longitudinal line(s) within the checkpoint area. If one or more of the same longitudinal lines within two or more checkpoint areas are unacceptable, the longitudinal lines within the entire zone of measurement (project) are unacceptable.

3.2   This diagram (Figures 1, 2 & 3) describes typical retroreflectometer test point locations for different lengths of zones of measurement. Select sampling sites (Checkpoint Areas) that are mutually agreeable to both the Contractor and the Inspector-In-Charge. When the Contractor and the Inspector-In-Charge cannot agree on the sampling sites, then PTM #1 shall be used to select the locations for testing the retroreflectivity of the pavement markings.

PAVEMENT MARKING SAMPLING METHOD USING HANDHELD RETROREFLECTOMETER

FIGURE 1 - TYPICAL TEST POINT LOCATION FOR ZONE OF MEASUREMENT LESS THAN 1 MILE
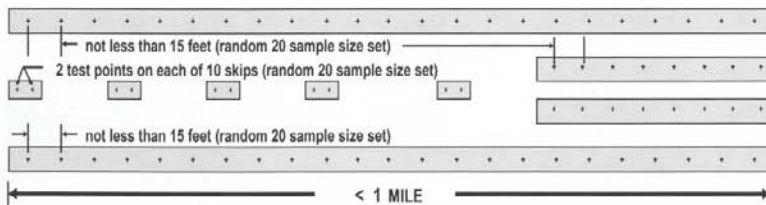
NOTES
  All measurements obtained in the sampling area are to be taken in the direction of traffic flow, except on the centerline of two-lane roads where the required number of measurements will be made in each direction. Both single and double lines are to be measured.

FIGURE 2 - TYPICAL TEST POINT LOCATIONS FOR ZONE OF MEASUREMENT 1 MILE TO 6 MILES
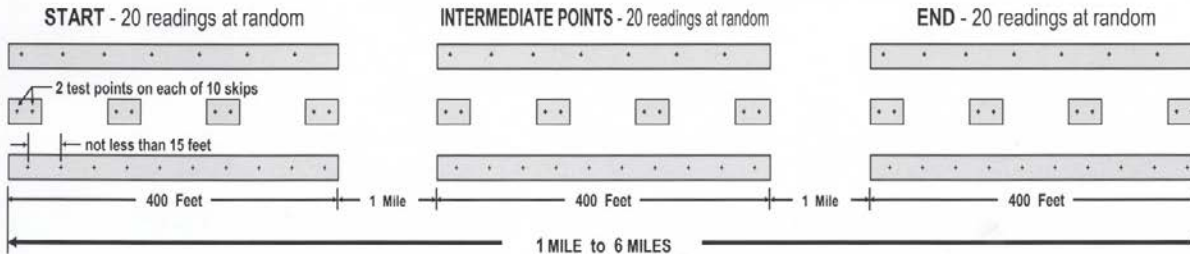
FIGURE 3 - TYPICAL TEST POINT LOCATIONS FOR ZONE OF MEASUREMENT GREATER THAN 6 MILES
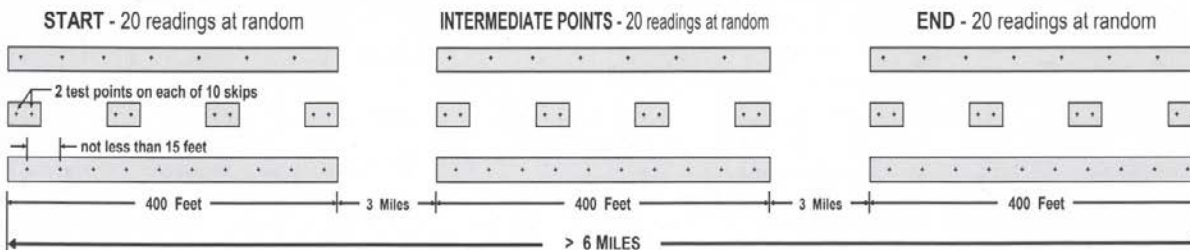
4.   RETROREFLECTIVITY SAMPLING - LEGENDS, SYMBOLS, AND
     TRANSVERSE LINES

   4.1   The following chart describes the sampling criteria used when retroreflectivity testing is
   performed on legends, symbols, and transverse lines. Zones of measurement, length of
   checkpoint area, number of test point measurements within the checkpoint area, and the
   acceptance criteria used when performing retroreflectivity testing on legends, symbols, and
   transverse lines are described in the chart below.

Zone of Measurement	Length of Checkpoint Area	Number of Test Point Measurements within Checkpoint Area	Acceptance Criteria
All Legends and Symbols	**Each letter and symbol is a checkpoint area**	**3 test point measurements on each letter and symbol, in the direction of travel**	Calculate the average of all test points from each legend, symbol or transverse line. If the average falls below the specified retroreflectivity requirements, the marking is unacceptable.
All Transverse Lines	Each transverse line is a checkpoint area	6 test point measurements on each transverse line, in the direction of travel	

PTM-431 Documentation

Contract Number: _____

Zone of Measurement

circle one: < 1 Mile   1 Mile to 6 Miles   > 6 Miles

District(s)	Counties	SR(s)	STA/Seg	STA/Off	STA/Seg	STA/Off

Type of Pavement Marking Material

circle one: Waterborne Paint   Epoxy   Cold/Thermo Plastic   Other: _____

Number of Checkpoint Areas

circle one: 1   2   3   Other: _____

District(s)	Counties	SR(s)	STA/Seg	STA/Off	STA/Seg	STA/Off

Number of Traffic Lanes on Roadway

circle one: 2   3   4   Other: _____

Initial Test Point Averages			
Direction of Travel	Line/color	Average Reading	*Minimum Required
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		

Final Test Point Averages			
Direction of Travel	Line/color	Average Reading	*Minimum Required
	/		
	/		
	/		
	/		
	/		
	/		
	/		
	/		
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	/		
	/		

North (N), South (S), West (W), East (E), Ascending (A), Descending (D)
Right Edge Line (REL), Left Edge Line (LEL), and Centerline (CL)
Right Edge Lines, Skips, Legends, and Transverse Markings are White (W)
Left Edge Lines and Center Lines are Yellow (Y)

Acceptance Signature: _____   Date: _____

*Minimum Retroreflectivity Readings as required by Publication 408

LABORATORY TESTING SECTION

Method of Test for

FINAL INSPECTION OF 100 YEAR DESIGN LIFE PIPE INSTALLATIONS

1.   SCOPE

        1.1   The purpose of this test method is to supply personnel in the field with a method of final inspection of all pipes and drainage structures with 100 year design life. All pipes 48-inch and smaller are to be inspected by means of remote inspection. All pipes larger than 48-inch are to be inspected by means of manual inspection. When defects and irregularities for pipes with diameters greater than 30-inch are observed but cannot be measured within acceptable tolerances using remote inspection procedures, utilize the man entry part of the manual inspection procedures. Both methods are described below. **The division of remote and manual inspection procedures at 48-inch is based on current equipment capabilities. Improvements of non-contact video micrometer and digital video cameras technologies are anticipated. This test method shall be monitored and updated as technology improvements become available. The National Association of Sewer Service Companies' Pipeline Assessment Certification Program (PACP) is in the process of adding a laser ring profile component. Operator certification requirements shall be considered as the laser ring components are implemented into the PACP.**

2.   REMOTE INSPECTION

        2.1   Equipment for Remote Inspection:

        2.1.1   Transport Device- A device that travels through the pipe in an unmanned fashion to transport associated inspection equipment such as cameras, lasers or other required devices. A letter of certification is required from the transport device manufacturer that the device has capabilities to do the following:

                (1) Traverse pipes ranging from a minimum diameter of 18-inch to a maximum diameter of 48-inch.

                (2) Is all-wheel drive or is track mounted.

                (3) Is able to maintain a constant speed not to exceed 30 feet per minute while the camera is recording. Provides a means to verify the speed while the camera is recording or operating the laser profiler.

                (4) Has a cable distance counter accurate to 1 foot per 100 feet or 1%.

(5) Maintain the camera and laser in the center of the pipe both vertically and horizontally.

(6) Will not obstruct or interfere with the camera view or movement, so that the camera view is unobstructed for 360° in the circumferential direction perpendicular to the axis of the pipe.

2.1.2   Video Camera and Recording Device- A color closed circuit television (CCTV) system capable of documenting the internal condition of the pipeline, with associated software allowing for annotation of defects and irregularities. A letter of certification from the camera manufacturer is required stating that the camera has the following capabilities:

(1) Is compatible with the transport device specified in Section 2.1.1.

(2) Inspects pipes ranging from a minimum diameter of 18-inch to a maximum diameter of at least 48-inch, and that the light source for the camera is adequate for this range of diameters.

(3) Has manual as well as automatic focus and iris control.

(4) Has a combination optical and digital zoom ratio of at least 40:1, with a minimum 10:1 optical zoom ratio.

(5) Pans or tilts 90° to the axis of the pipe and rotates 360° in the circumferential direction, or has a fish eye lens allowing for flat scanning.

(6) Records color digital video in MPEG2 or MPEG4 format with a minimum resolution of 720 x 480.

(7) Accurately measures crack widths and lengths, joint gaps, defects, debris, or other irregularities either directly or through a calibrated on-screen device or non-contact video micrometer. Measurements may be performed with a laser or other suitable measurement device. Where measurements are taken through a calibrated on-screen device or non-contact video micrometer, the measurement must be corrected for spherical lens distortion where this distortion may occur. The certification letter shall state the type of measurement device, indicate if it is necessary to perform a lens distortion correction, and shall certify the accuracy of the device to 1/32-inch or less for defects of 1-inch or smaller, and 1/8-inch or less for defects larger than 1-inch but less than 3-inch.

(8) Includes a lens distortion calibration chart, unless the measurement software specified in Section 2.1.3 can correct distortion for the specific camera model and manufacturer.

2.1.3 Laser Profiler System (includes Laser Profiler and Measurement Software)- Capable of providing pipe profile, diameter, and deflection data. The measurement software shall include lens distortion correction capability to ensure the measurement accuracy regardless of the survey camera used. Unless the measurement software can correct for the specific camera model and manufacturer, the software shall have the capability to reference and calibrate to the calibration chart specified in Section 2.1.2, ensuring accurate processing of the recorded survey. The device shall be prominently marked with a sticker indicating the class or grade of laser that also indicates the required personal protective equipment. Calibrate the laser profiling measuring equipment according to ASTM E691 and ASTM E177 annually and provide written certification by an independent testing laboratory that it meets these requirements. Recalibrate the equipment if the laser profiler or camera is modified, if there is any damage to and/or service on the profiler, or if inaccuracies are apparent or suspected. A letter of certification from laser profiler system manufacturer is required stating that the laser profiler system has the following capabilities:

(1) Is compatible with the crawler device specified in Section 2.1.1 and video camera and recording device specified in Section 2.1.2.

(2) Profiler is compatible with the associated measurement and analysis software.

(3) Provides a digital circumferential pipe profile along the longitudinal length of the pipe and a report of pipe deflection along the pipe when advanced through the pipe at a constant speed not to exceed 15 feet per minute.

(4) Provides profile data for pipes ranging from a minimum diameter of 18-inch to a maximum diameter of at least 48-inch.

(5) Provides measurements with an accuracy of 0.5% or better and repeatability of 0.12 percent or better. Accuracy must be certified on both 18-inch and 36-inch diameter concrete pipes, situated on grade (not buried).

(6) Includes a calibration target for the range of pipe sizes indicated in No.4 of this section.

(7) Utilizes either a projected laser ring or a rotating head measurement device. The certification letter shall state the type of laser measurement technology and the process through which the measurements are determined (measured directly, computed through software analysis of a projected ring shown in the video, or other means).

2.2   Procedure for Remote Inspection:

2.2.1 Unless the laser profiler has the ability to directly measure the pipe diameter and the reports generated from the laser inspection give direct measurements, determine the representative un-deformed diameter of a typical section of pipe. Determine the representative diameter by selecting a defect-free location near the center of a length of pipe, away from the joints, with less than 5% deflection, with no visible distortion from a circular/elliptical shape. Measure the internal diameter of the pipe, taking at least four measurements spaced at equal intervals around the circumference at the selected target location. Use a calibrated measurement device and method accurate to 1/16-inch or less. Take the mean of the four diameters and round to the nearest 0.01-inch to arrive at the representative diameter of that pipe run. For corrugated pipe, measure the internal diameter at the inside of the corrugation valley (smallest internal pipe diameter). Make one measurement of the representative diameter of the pipe per pipe run per diameter pipe in the run. If the pipe has helical corrugations that cause difficulties in measuring the actual diameter, use the nominal diameter plus a manufacturing tolerance of 1% or 1/2-inch undersize, whichever is greater. For a pipe arch, use the nominal rise and span dimensions with no allowance for manufacturing tolerances.

2.2.2 The transport device, video camera and laser profiler shall be placed in a dewatered, clean pipe. Continuously record the video camera feed during the visual and laser profile inspections, and provide a color digital video report as indicated in Section 2.3.

2.2.3 Center the camera and laser profiler in the pipe both vertically and horizontally. The laser head shall be positioned, in relationship to the camera, so that the laser ring fills a minimum of 75% of the monitor screen's height and the alphanumeric cable distance display does not interfere with the laser ring image. Where the camera measurement device requires lens distortion calibration, a lens distortion calibration chart shall be imaged by the survey camera and recorded in the survey DVD for 15 to 20 seconds.

2.2.4 If the laser profiler does not have the ability to directly measure the pipe diameter, take at least ten measurements of the average diameter using the laser profiler within ±3-inch of the longitudinal location where the representative diameter was measured (See Section 2.2.1). Between each reading, move the profiler at least 24-inch and return to the target location, or remove it from the pipe, and return it to the target location within the pipe for the next reading. All laser profiler diameter measurements must be within ± 0.5% of the accepted reference value. Data from the certification measurements must be provided with the certification. Report all individual data points and the mean and standard deviation of the data set. The mean must be within 0.25% of the reference value and the standard deviation less than 0.25% of the mean measured value. ASTM E177 is the reference for terminology.

2.2.5 The camera and laser profiler shall be moved through the pipe at a constant speed not to exceed 30 feet per minute, while continuously videoing the entire pipe run. At each joint, stop the crawler and position the camera perpendicular to the pipe axis so that it is directly facing the joint. Rotate the camera 360° around the joint to film the entire circumference at each joint. Measure the maximum joint separation at each joint, as well as any joint offset or

misalignment. Stop the camera and pan when necessary to document defects and other items identified in Table A through the use of notes and the camera's measurement device.

2.2.6 When defects or irregularities are observed with the camera but cannot be measured within acceptable tolerances on pipes greater than 30-inch, inspect and report in accordance with manual inspection, including man-entry procedures, as indicated in Section 3.

2.3   Report for Remote Inspection:

2.3.1 Provide a written summary report for Department review that indicates whether each pipe meets specified tolerances for the "items required for documentation" from Table A. Provide a summary report which includes the following:

(1) Full listing of specification tolerances used in order to determine defects or irregularities (example = maximum joint separation of 3/8 inch for 18-inch diameter pipe, straight-line placement)

(2) A listing of all defects or irregularities noted during the remote inspection. If no defects or irregularities are noted, include the statement "no defects or irregularities noted during remote inspection".

2.3.2   Provide a detailed color digital video report in MPEG2 or MPEG4 format with a minimum resolution of 720 x 480 that includes the following:

(1) Identification of the pipe run prior to filming (start and end structure numbers for the pipe run as shown on the project plans), project number, state route number, segment and offset, nominal diameter of pipe, and the date and time of inspection.

(2) Visual documentation of all defects and other items identified in Table A, including measurements of all defects and irregularities, as well as position along the length of the pipe.

(3) Notes that describe each irregularity with still frame images. Identify and record the maximum joint separation of each pipe joint. Identify and record any joint misalignment or offset.

2.3.3   The report generated from the laser profiler data shall include the following:

(1) Identification of the pipe run (start and end structure numbers for the pipe run as shown on the project plans), project number, state route number, segment and offset, nominal diameter of pipe, and the date and time of inspection.

(2) Actual representative diameter of the pipe run.

(3) A digital pipe profile along the longitudinal length of the pipe with a 3-D image and/or a color-coded flat display.

(4) Deflection measurements, computed based the actual representative diameter of the pipe, including a plot of deflection against longitudinal location in the pipe run. Deflection shall be calculated using the formula for Δ in X1.2.1 of ASTM F1216 (shown below) where the mean inside diameter is the un-deformed/unloaded diameter of thermoplastic pipe or the nominal diameter of metal pipes plus the manufacturing tolerance of 1% or 1/2-inch undersize, whichever is greater. For a pipe arch, use the nominal rise and span dimensions with no allowance for manufacturing tolerances.

Δ = percentage ovality of original pipe = 100 X $\dfrac{\textit{(Mean Inside Diameter - Minimum Inside Diameter)}}{\textit{Mean Inside Diameter}}$

3.   MANUAL INSPECTION

3.1   Equipment for Manual Inspection:

3.1.1   Tools – Provide tools meeting the follow requirements:

(1) Pipe gages, as specified in Publication 408, Section 601.2(a) 3.d.2.

(2) Metal tape measure, extension ruler, electronic deflectometer, or other calibrated gage accurate to 1/16-inch or less.

(3) Digital camera with a minimum resolution of 5 megapixels with a macro function.

3.2   Procedure for Manual Inspection:

3.2.1   Manual inspection will be comprised of a man-entry inspection to measure defects, irregularities, and deflections, where required.

3.2.2   The man-entry part of the manual inspection procedure shall be as follows:

(1) Manual inspection shall be performed in a dewatered, clean pipe.

(2) Starting at the upstream structure, document all defects and other irregularities including the required items in Table A, with location determined as pipe number, distance along the pipe from the upstream joint, and clock position looking in the downstream direction.

(3) At each joint, document the maximum joint separation and clock position for that separation, as well as any vertical or horizontal offset.

(4) Identify and measure the length and width of any cracks, gouges, or seam separations using a crack comparator or feeler gage capable of measuring a minimum crack width of 0.007-inch. Take photos of typical cracks, joint separations, and irregularities, as well as other irregularities using a digital camera with a minimum resolution of 5 megapixels with a macro function to document the overall condition of the pipe run.

(5) Determine the representative un-deformed diameter of a typical pipe by selecting a defect-free location near the center of a length of pipe, away from the joints, with less than 5% deflection, with no distortion from a circular/elliptical shape. Measure the internal diameter of the pipe, using a metal tape measure, a ruler, or other calibrated gage accurate to 1/16-inch or less. Take at least four measurements evenly spaced around the circumference at the selected location. Take the mean of the four diameters and round to the nearest 0.1-inch to arrive at the representative diameter of that pipe run. For corrugated pipe, measure the internal diameter at the inside of the corrugation valley (smallest internal pipe diameter). Make one measurement of the representative diameter of the pipe per pipe run per diameter pipe in the run. Measure and record the length of the pipe.

(6) Where deflection measurements are required by Table A, measure the smallest internal pipe diameter of each length of pipe in the run using a metal tape measure, a ruler, or other calibrated gage to the nearest 1/16-inch or less. At the location of the smallest internal diameter, note the clock position of the smallest diameter and distance from the upstream joint, and take three additional diameter measurements evenly spaced around the circumference, recording the clock position and diameter for each measurement. For corrugated pipe, measure the internal diameter at the inside of the corrugation valley (smallest internal pipe diameter).

3.3.   Report for Manual Inspection:

3.3.1   Provide a written report documenting joint separations and offsets, defects, and other abnormalities, including their location as pipe number (starting at the upstream structure), distance from the upstream joint, and clock position looking in the downstream direction. Augment the written report with photos of typical cracks and joint separations, as well as other irregularities as necessary to document the overall condition of the pipe run, including all items for each pipe type identified in Table A. If no defects or irregularities are noted, include the statement "no defects or irregularities noted during manual inspection".

3.3.2   The written report shall include identification of the pipe run (start and end structure numbers for the pipe run as shown on the project plans), project number, state route number, segment and offset, nominal diameter of pipe, and the date and time of inspection.

3.3.3 Where deflection measurements are required, report the minimum internal diameter of each section of pipe in the pipe run, as well as additional diameter measurements around the circumference at that longitudinal location. Identify the location of the minimum diameter by its distance from the upstream joint, and calculate the pipe deflection using the formula for Δ in Section 2.3.2(4) above.

TABLE A

REQUIREMENTS FOR PIPE CULVERT INSPECTION BY TYPE OF PIPE

Pipe Type	Measurement Equipment	Items Required for Documentation
Ductile Iron Pipe	Crawler- Mounted Camera with Laser Profiler*	Joint Separations, Crack Widths and Lengths, Deflection, Evidence of Leakage or Soil Intrusion, Vertical Alignment (i.e. ponded water)
Reinforced Concrete Pipe	Crawler- Mounted Camera with Laser Profiler*	Joint Separations, Crack Widths and Lengths, Spalls, Offset Joints, Bell/Spigot Shear Failure, Dimensional Tolerance, Evidence of Leakage or Soil Intrusion, Vertical Alignment (i.e. ponded water)
Corrugated Aluminized Steel Pipe	Crawler- Mounted Camera with Laser Profiler*	Joint Separations, Crack/Gouge Widths and Lengths, Dents, Buckling, Seam Separations, Deflection and Ovality, Evidence of Leakage or Soil Intrusion, Loss of Aluminized Coating, Oxidation, Vertical Alignment(i.e. ponded water)
Corrugated Aluminum Alloy Pipe	Crawler- Mounted Camera with Laser Profiler*	Joint Separations, Crack/Gouge Widths and Lengths, Dents, Buckling, Seam Separations, Deflection and Ovality, Evidence of Leakage or Soil Intrusion, Oxidation, Vertical Alignment (i.e. ponded water)
Thermoplastic Pipe	Crawler- Mounted Camera with Laser Profiler*	Joint Separations, Crack Widths and Lengths, Buckling, Deflection and Ovality, Evidence of Leakage or Soil Intrusion, Vertical Alignment (i.e. ponded water)

* Manual Tools as measurement equipment for pipes with manual inspection procedures

4.   REMEDIATION

        4.1   Develop a remediation plan as specified in Publication 408, Section 601.3(p) to address all joint gaps, cracks, deflections, and other irregularities exceeding specification limits as specified in Publication 408, Section 601.3(c) and Section 601.3(n)1, 2, or 3 or based upon the pipe manufacturer's tolerances for joint separations and other irregularities. Remediation plans should comply with Section C/6/11 of Publication 2, Project Office Manual.

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF FINENESS MODULUS OF FINE AGGREGATES

1.   SCOPE

1.1   This procedure is used for determining the Fineness Modulus of fine aggregates.

2.   APPARATUS

2.1   The apparatus shall be as specified in PTM 616.

3.   PROCEDURE

3.1   The sieve analysis of the given fine aggregate shall be conducted in accordance with PTM 616.

4.   CALCULATIONS

4.1   The calculations for the Fineness Modulus of a given sample of fine aggregate shall be made upon completion of the sieve analysis.

4.2   All of the sieves that are necessary for the determination of the Fineness Modulus are as follows: 150 μm, 300 μm, 600 μm, 1.8 mm, 2.36 mm and the 4.75 mm (No. 100, 50, 30, 16, 8 and 4) sieves.

4.3   Determine the percentage retained on each of the specified sieves by subtracting the percentage passing a given sieve from 100 percent. Percentages shall be rounded off to the nearest whole number (Note 1).

4.4   Obtain the Fineness Modulus by adding the total percentages of a sample of the aggregate retained on each of the specified series of sieves, and dividing the sum by 100.

5.   REFERENCES

5.1   PTM 616

Note 1. An example of a sieve analysis and the procedure used for calculating the Fineness Modulus is shown below.

(Column 1) Sieve Size	(Column 2) Mass Passing	(Column 3) Percent Passing	(Column 4) Percent Retained
150 μm (No.100)	12.7	2	98
300 μm (No. 50)	79.6	16	84
600 μm (No. 30)	223.9	44	56
1.18 mm (No. 16)	376.7	74	26
2.36 mm (No. 8)	458.7	90	10
4.75 mm (No. 4)	502.1	98	1
9.50 mm (No.3/8)	508.5	100	(Not included in calculations)

Fineness Modulus = $\dfrac{\text{Total of Column 4}}{100}$ = 2.75

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LABORATORY TESTING SECTION

Method of Test for

BULK SPECIFIC GRAVITY (SATURATED SURFACE-DRY BASIS),
ABSORPTION, AND SOLID VOLUME OF SLAG COARSE AGGREGATE

1.   SCOPE

    1.1   This method of test is intended for use in making, in the field, the determinations of bulk specific gravity (saturated surface-dry), absorption, and the solid volume of slag coarse aggregate (Note 1).

    NOTE 1 - The bulk specific gravity (S.S.D) is the value generally desired for calculating proportions of aggregates to be used in portland cement concrete (It should be recognized that the value obtained by this test is not a true determination because of the variation within the material, however it is a satisfactory method). After having obtained numerous values, it is possible to arrive at an average value which is referred to as the "Bulk Specific Gravity Factor for Slag."

2.   APPARATUS

    2.1   Balance - The balance or scale shall be readable to at least 45.4 grams (0.1 lbs).

    2.2   Tamping Rod - Refer to AASHTO T-19, Section 5

    2.3   Measure - Refer to AASHTO T-19 and use a 0.03 cubic meter (one cubic foot) measure meeting the requirements specified in Section 5.

3.   CALIBRATION OF MEASURE

    3.1   Refer to AASHTO T-19, Section 8

4.   SAMPLE

    4.1   Select a sample representative of the material to be tested, in the combination of sizes to be used in the concrete, and mix thoroughly. Exercise care to prevent segregation of the material and to prevent evaporation of moisture from the material during the test.

5.   DETERMINATION OF SURFACE MOISTURE

5.1   Refer to AASHTO T-85 and do the following:

5.1.1   Obtain a sample in accordance with Section 7.2 and discard the material passing the 4.75 mm (No 4) sieve. Immediately weigh the resultant sample to the nearest 1.0 g and record the mass. Make all subsequent weighing to the nearest 1.0 g.

5.1.2   Roll the material in a large absorbent towel until all visible films of water are removed, although the surfaces of the particles still appear to be damp. The larger fragments may be individually wiped. Exercise care to prevent evaporation during operation of surface drying. Weigh the saturated surface dry sample immediately and record the mass. After recording the mass, dry the sample to constant mass for use in Section 6.

5.1.3   Subtract the surface dry mass obtained in Section 5.1.2 from the sample mass recorded in Section 5.1.1 and calculate the percentage of surface moisture from the following formula:

$$\frac{100\,(A\text{ - }B)}{B} = C$$

Where:

A = Original wet mass of the sample (Section 5.1.1)

B = Surface-dry mass of the sample (Section 5.1.2)

C = Percent of surface moisture

6.   ABSORPTION

6.1   After drying the sample to constant mass, (Section 5.1.2) remove the sample from the source of heat and cool to room temperature.

NOTE 2 - Never place hot material on a scale or balance. If the sample is too hot to handle, it is too hot to weigh accurately.

6.2   Weigh the sample and calculate the percentage of absorption from the following formula:

$$\frac{100\,(B - F)}{F} = \text{Absorption, percent}$$

Where:

B = Mass of sample, S.S.D (Section 5.1.2)

F = Mass of sample after drying (Section 5.1.2)

7.   LOOSE UNIT WEIGHT DETERMINATION OF SURFACE-DRY AGGREGATE

7.1   Refer to AASHTO T-19 and, using the "Shoveling Procedure" outlined in Section 12. Determine the wet unit weight of the aggregate by multiplying the net mass of the aggregate in the measure by the factor found as described in Section 3.1. The product is the Wet Loose Unit Weight of the material (Note 2). Keep the material intact in the container where it shall remain undisturbed for use in later Solid Volume Determinations.

NOTE 3- Results with the same material shall check within 1.0 percent.

7.2   Calculate the Unit Weight of Surface-Dry Aggregate from the following formula:

$$\frac{H \times 100}{D} = E$$

Where:

H = Loose Unit Weight of Wet Aggregate

D = Percent of Surface Moisture + 100 percent

E = Loose Unit Weight of Surface-Dry Aggregate

8. DETERMINATION OF MASS PER SOLID VOLUME (kg/m^3)(lbs/ft^3)

8.1 Compact the material retained in the container (Section 6.1), preferably by jigging, so that all of the pieces of aggregate are below the top surface of the measure. Inundate the aggregate with water, agitating or tapping the measure (Note 3) as the water is being added, in order to remove all of the entrapped air. After all of the aggregate has been covered with water, place the container with aggregate and water on a level platform scale. Add water to the measure to the point of overflowing and carefully wipe dry any water that may have spilled onto the outer surface of the measure or the platform scale.

NOTE 4- A rubber mallet or a metal tamping rod may be used satisfactorily for tapping the measure in order to remove entrapped air while water is being added.

8.2 Calculate the Solid Volume by using the following formulas:

$$\frac{J-E}{K}=V \qquad\qquad 100-V=S \qquad\qquad \frac{E}{S}=T$$

Where:

J = Loose Unit Weight of wet aggregate plus the mass of water required to fill the container

E = Loose Unit Weight of the surface dry aggregate

K = Unit Weight of water per cubic meter - 1000 kg (per cubic foot - 62.4 lbs.)

S = Percent of Solids

V = % volume of voids

T = Mass per Solid Volume (kg/m^3)(lbs./cu. ft.)

9.   BULK SPECIFIC GRAVITY OF SLAG AGGREGATE (S.S.D.)

9.1   Calculate the Bulk Specific Gravity of Slag Aggregate, (Saturated Surface-Dry Basis) from the following formula:

$$\frac{T}{K} = R$$

Where:

T = Solid Volume (kg per cubic meter)(lbs. per cubic foot)

K = Mass of Water per cubic meter -1000 kg (per cubic foot - 62.4 lbs.)

R = Bulk Specific Gravity of Slag Aggregate, Saturated Surface Dry Basis

10.   REFERENCES

PTM 509
AASHTO T-85

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LABORATORY TESTING SECTION

Method of Test for

PREPARING HYDRAULIC CEMENT FOR TESTING

1.   SCOPE

1.1   This method covers the preparation of samples of hydraulic cement for laboratory testing. These samples may have been obtained from bulk storage at the place of manufacture, from bulk storage at the point of delivery, from bulk shipment by car or truck, or from packaged cement.

2.   SIZE AND NUMBER OF SAMPLES

2.1   The samples of cement shall be obtained, packaged, and shipped in accordance with PTM 509, Method of Sampling Hydraulic Cement.

2.2   Individual samples shall weigh not less than 2.5 kg (5 lb) when obtained for acceptance testing of a lot of cement and shall represent not more than 100 tonnes (100 tons) of cement (NOTE 1). Samples obtained for other purposes, including but not limited to project record samples and random quality assurance samples, shall weigh not less than 5 kg (10 lb) and each such sample shall be a test sample.

2.3   All samples submitted for testing shall be obtained by or under the supervision of a representative of the Department and shall be accompanied by complete identification as to manufacturer, location of plant, and bin number.

NOTE 1- A lot is a specific quantity of cement offered for inspection and acceptance at one time. Normally a lot will be the contents of a specific bin or silo at the place of manufacture.

3.   PREPARATION OF SAMPLES

3.1   Individual samples for acceptance testing and which are to be combined to constitute test samples shall be arranged in groups in the order in which the samples were taken. Each test sample shall be prepared from a group of consecutive, individual samples representing not more than 728 tonnes (800 tons) of cement, except that no lot of cement sampled for acceptance testing shall be represented by less than two test samples (NOTE 2).

NOTE 2- Generally, for large bins, each group will be composed of 8 individual samples, except for the last group which may contain a lesser number.

From each of the individual samples in a group take equal portions sufficient in amount to form a composite sample large enough to permit making the required physical and chemical determinations. Thoroughly mix the composite test samples thus prepared before using. A mechanical blender shall be used whenever available.

3.2   Tests may be conducted on individual samples from bulk storage or on composite samples representing less than 728 tonnes (800 tons) when deemed necessary because the quality history indicates lack of control, or when no samples from a given source have been tested within one year, or as otherwise required.

3.3   Before testing, pass each test sample through a 850 µm (No. 20) sieve in order to mix the sample, break up lumps, and remove foreign materials. Discard the foreign materials and hardened lumps that do not break up on sieving or brushing. Store the cement in airtight, moisture-proof containers to prevent aeration or absorption of moisture prior to testing.

4.   AMOUNT OF TESTING

4.1   Those chemical and physical tests required to show compliance with the requirements of AASHTO M-85 and M-240, shall be carried out on each test sample except as designated below:

4.1.1   The test for fineness may be carried out on a composite of all samples from a single lot offered for acceptance.

4.1.2   The test for fineness shall be carried out on samples obtained from a given lot subsequent to acceptance, only when deemed necessary.

4.1.3   The compressive strength test (AASHTO Designation T-106) on mortar cubes at age 28 days shall be carried out only when deemed necessary.

4.1.4   The compressive strength test shall be carried out in accordance with AASHTO Designation T-106 except that for composite test samples the strength at 3 days shall be the average of the compressive strengths of two specimens from the same test sample and the strength at 7 days shall be a single determination.

5.   REFERENCES

AASHTO T-127
ASTM C 183

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LABORATORY TESTING SECTION

Method of Test for

STANDARD METHODS FOR SAMPLING PORTLAND CEMENT

1.   SCOPE

        1.1   This method covers the taking of samples of hydraulic cement from the manufacturer's storage bins, from bulk transport units, from storage bins at concrete plants, and from bags of cement. The samples may be taken for acceptance testing, for quality assurance, or for investigational purposes.

2.   UNITS OF MEASUREMENT

        2.1   Cement in bulk storage or transport shall be measured in tonnes (tons). A tonne weighs 1000 kilograms and represents 0.615 cubic meters of cement. (A ton weighs 2000 pounds and represents 5.32 barrels of cement).

3.   SIZE, NUMBER, AND PROTECTION OF SAMPLES

        3.1   Each individual sample shall weigh not less than 2.5 kg (5 lb) and shall be placed in moisture-proof, airtight containers to prevent moisture absorption and aeration of the sample. When the samples are placed in 4-liter (1 gallon) plastic containers, fill the containers completely full and seal immediately. Moisture proof, multiple-wall paper bags may be used if they are strong enough to avoid breakage, and if they can be sealed immediately after filling in such a manner as to eliminate excess air in the sample and prevent moisture absorption and aeration of the sample.

        NOTE-   Cement should not be placed in direct contact with plastic containers unless the cement manufacturer has satisfied himself that the plastic will not have an adverse effect on the cement tests. Polyvinyl chloride containers have been found to affect the air-entraining potential of cement samples. The same problem might be experienced with containers made from other plastics.

        3.2   Number the containers consecutively in the order in which the samples were taken and show clearly on Form TR-447 (Sample identification), the manufacturer, plant location, bin number, and the size of the lot of cement represented by the set of samples. In addition, samples obtained from a concrete plant shall also show the concrete plant location, name of the concrete producer, and acceptance card or affidavit number.

4.   SAMPLING

4.1   From Bulk Storage at a Cement Plant or Shipping Terminal- Sample the cement as it flows from the discharge openings at such intervals that one 2.5 kg (5 lb) sample will be obtained for each 91 tonnes (100 tons) of cement. The procedure for determining the rate of sampling cement is explained in the Appendix to this PTM.

4.2   From Bulk Shipment of a Car or Truck- Take three samples weighing at least 2.5 kg (5 lb) each from three well-distributed points. Where a shipment consists of several cars or trucks loaded from the same storage bin on the same day, take 2.5 kg (5 lb) samples at the rate of at least one sample per 91 tonnes (100 tons).

4.3   From Bulk Storage at a Concrete Plant- Take three samples weighing at least 2.5 kg (5 lb) each from three well distributed points in the bin. When samples are taken from the discharge of the bin, they shall be taken to represent the cement flowing into three separate batches of concrete.

4.4   From Packaged Cement

4.4.1   For shipments of 25 bags or less, take one 5 kg (10 lb) sample from one bag.

4.4.2   For shipments of more than 25 bags, take one 2.5 kg (5 lb) sample from one bag for each 25 bags.

5.   SHIPMENT

5.1   When transportation is not provided by the Department, the individual samples shall be placed in a container that shall then be secured with a Department seal.

6.   REFERENCES

ASTM C 183
AASHTO T-127

APPENDIX

DETERMINATION OF THE SAMPLING RATE FOR CEMENT IN
BULK STORAGE AT A CEMENT PLANT OR SHIPPING TERMINAL

Withdraw cement from the discharge openings in a steady stream until sampling is completed by either of the following two methods: (1) Place markers on top of the cement in the bin or silo. Sampling at any discharge opening is completed when a marker passes through the opening. If a limited amount of cement (45.5 to 91 tonnes (50 to 100 tons)) is withdrawn before placing indicators in order to develop a conical depression in the top surface of the cement, the quantity so withdrawn shall be sampled and considered as part of a test sample. (2) The quantity of cement in tonnes to be withdrawn from one discharge opening may be estimated as $0.01025d^3(0.00032d^3)$, where d is the depth in meters (feet) of cement above the discharge opening. If a high circular silo is being sampled, all samples may be taken from one opening. If the quantity of the cement in the bin exceeds 1088 tonnes (1200 tons) when low rectangular bins are being sampled, the number of discharge openings employed in the sampling shall be such that for no opening shall the number of samples represent more than one- half the contents of the bin or more than 1814 tonnes (2000 tons).

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LABORATORY TESTING SECTION

Method of Test for

SOUNDNESS OF AGGREGATE BY USE OF SODIUM SULFATE

1.   SCOPE

1.1   This method of test, which is based on AASHTO T-104, covers the procedure to be followed in testing aggregates to determine their resistance to disintegration by saturated solutions of sodium sulfate. This is accomplished by repeated immersion in saturated solutions of sodium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the re-hydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions.

1.2   The values stated in SI units are to be regarded as the standard.

1.3   This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.   REFERENCED DOCUMENTS

2.1   AASHTO Standards:
- M-92, Wire-Cloth Sieves for Testing Purposes
- R-16, Regulatory Information for Chemicals Used in AASHTO Tests
- T-27, Sieve Analysis of Fine and Coarse Aggregate

2.2   ASTM Standards:
- C 670, Practice for Preparing Precision Statements for Test Methods for Construction Materials
- E 100, Specification for ASTM Hydrometers

3.   APPARATUS

3.1   Sieves- With square openings of the following sizes conforming to AASHTO M-92, for sieving the samples in accordance with Sections 5, 6, and 8:

4.75 mm	(No. 4)	63 mm	(2½")
4.00 mm	(No. 5)	50 mm	(2")
2.36 mm	(No. 8)	37.5 mm	(1½")
1.18 mm	(No. 16)	31.5 mm	(1¼")
600 μm	(No. 30)	25.0 mm	(1")
300 μm	(No. 50)	19.0 mm	(¾")
150 μm	(No. 100)	16.0 mm	(⅝")
		12.5 mm	(½")
		9.5 mm	(⅜")
		8.0 mm	(5/16")

3.2   Mechanical Sieving Device- A mechanical sieving device shall provide the motion specified in PTM 616, Sieve Analysis of Coarse and Fine Aggregate (Note 1).

NOTE 1- A mechanical sieving device is required for the testing of fine aggregate by this method. Its use is not permitted in the testing of coarse aggregate larger than 9.5 mm (3/8"), except for making a rough separation of material prior to washing the sample.

3.3   Containers- Containers for immersing the samples of aggregate in the sodium sulfate solution.

3.3.1   For Fine Aggregates- Stainless steel pots or pans, approximately 105 mm (4⅛") in diameter and not less than 76 mm (3") deep are satisfactory containers for the samples.

3.3.2   For Coarse Aggregates- Stainless steel or aluminum pans, approximately 203 mm (8") in diameter and not less than 76 mm (3") deep are satisfactory containers for the samples.

3.4   Temperature Regulation- Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate solution shall be provided.

3.5   Thermometer- A thermometer covering the recommended temperature range for solutions during the test and readable to 0.1°C (0.2°F).

3.6   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

3.7   Drying Oven- The oven shall be capable of being heated continuously at 110 ± 5°C (230 ± 9°F) and the rate of evaporation, at this range of temperature, shall be at least 25 g/h for 4 hours, during which period the doors of the oven shall be kept closed. This rate of evaporation shall be determined by the loss of water from 1-liter Griffin low-form beakers, each initially containing 500 g of water at a temperature of 21 ± 2°C (70 ± 3°F), placed at each corner and at the center of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

3.8   Specific Gravity Measurement- Hydrometers conforming to the requirements of ASTM E100, capable of measuring the solution specific gravity within ±0.001.

4.   SODIUM SULFATE SOLUTION

4.1   Prepare the sodium sulfate solution, for immersion of the test samples, in accordance with Section 4.1.1 (Note 2).

> NOTE 2-Some aggregates containing carbonates of calcium are attacked chemically by fresh sulfate solution, resulting in erroneously high measured losses. If this condition is encountered or is suspected, repeat the test using a filtered solution that has been used previously to test the same type of carbonate rock, provided that the solution meets the requirements of Sections 4.1.1 for specific gravity.

4.1.1   Sodium Sulfate Solution- Prepare a saturated solution of sodium sulfate by dissolving a reagent grade of the salt in water (Note 4) at a temperature of 25°C (77°F) minimum. Add sufficient salt (Note 3) of the anhydrous (NA_2SO_4) form to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 20.3 to 21.9°C (68.5 to 71.5°F). Again stir, and allow the solution to remain at the designated temperature for at least 48 hours before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly and determine the specific gravity of the solution. When used, the solution shall have a specific gravity of not less than 1.154 nor more than 1.171. The solution shall be reused until completion of the required 5 cycles of soaking and drying, after which it shall be discarded.

> NOTE 3- 215 g of anhydrous salt per liter of water is sufficient for saturation of the sodium sulfate solution at 22°C (71.6°F). However, since this salt is not completely stable and since it is desirable that an excess of crystals be present, the use of not less than 225 g of the anhydrous salt per liter of water is recommended.

> NOTE 4- Distilled water shall be used in referee or comparison testing.

4.2   Barium Chloride Solution- A 0.2 molar solution of barium chloride is used (41.6 g of BaCl$_2$ per liter of solution) to determine the presence of sodium sulfate in the wash water.

5.   SAMPLES

5.1   Fine Aggregate- Fine aggregate for the test shall be passed through a 9.5 mm (3/8") sieve. The sample shall be of such a size that it will yield not less than 100 g of each of the following sizes, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
9.5 mm (⅜")	4.75 mm (No. 4)
4.75 mm (No. 4)	2.36 mm (No. 8)
2.36 mm (No. 8)	1.18 mm (No. 16)
1.18 mm (No. 16)	600 μm (No. 30)
600 μm (No. 30)	300 μm (No. 50)

5.1.1   Should the sample contain less than 5 percent of any of the sizes specified in Section 5.1, that size shall not be tested.

5.2   Coarse Aggregate- Coarse aggregate for the test shall consist of material from which the sizes finer than the 4.75 mm (No. 4) sieve have been removed. The sample shall be of such a size that it will yield the amounts indicated in Table 1.

Table 1 - Coarse Aggregate Sample

Sieve Size	Mass, g
63 mm to 37.5 mm (2½" to 1½")	5000 ± 300
Consisting of:	
50 mm to 37.5 mm (2" to 1½") material	2000 ± 200
63 mm to 50 mm (2½" to 2") material	3000 ± 300
37.5 mm to 19.0 mm (1½" to ¾")	1500 ± 50
Consisting of:	
25.0 mm to 19.0 mm (1" to ¾") material	500 ± 30
37.5 mm to 25.0 mm (1½" to 1") material	1000 ± 50
19.0 mm to 9.5 mm (¾" to ⅜")	1000 ± 10
Consisting of:	
12.5 mm to 9.5 mm (½" to ⅜") material	330 ± 5
19.0 mm to 12.5 mm (¾" to ½") material	670 ± 10
9.5 mm to 4.75 mm (⅜" to No. 4)	300 ± 5

NOTE 5- The sample size for AASHTO No. 8's shall be 300 ± 5 g passing the 3/8" sieve retained on the No. 4 sieve only.

5.2.1   Should the sample contain less than 5 percent of any of the sizes specified in Section 5.2, that size shall not be tested. When a combination of sizes is specified for the test portion and one of the sizes specified is less than 5 percent of the sample, reduce the test portion by the applicable mass specified in Section 5.2 for the size not available.

5.2.2   When testing large rock (broken stone, ledge rock, cobbles, and boulders for use as riprap, channel lining, etc.), obtain the test portion by crushing, splitting, or sawing the larger sample pieces. Test only those pieces in the 37.5 to 19.0 mm (1½ to ¾") and 63 to 37.5 mm (2½ to 1½") size fractions when size reduction is by crushing or splitting.

5.2.3   When testing large rock (to evaluate a potential source) that will be subsequently crushed to produce aggregate, obtain the test portion by crushing the larger sample pieces. Test pieces only in those sizes that will be included in the produced aggregate, but ignoring any material finer than 4.75 mm (No. 4) sieve or coarser than 63 mm (2½") sieve.

5.2.4   When the finished aggregate material will contain particles coarser than 63 mm (2½"), such as aggregate for use in mass concrete, crush the material coarser than 63 mm (2½") and distribute the material among that in the range of 63 mm (2½") to 4.75 mm (No. 4) sieves. Discard material finer than 4.75 mm (No. 4) sieve.

6.   PREPARATION OF TEST SAMPLE

6.1   Fine Aggregate- Thoroughly wash the sample of fine aggregate on a 300 μm (No. 50) sieve, dry to constant mass at 110 ± 5°C (230 ± 9°F), and separate into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified in Section 5.1. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal (In general, a 110 g sample will be sufficient). Do not use fine aggregate sticking in the meshes of the sieves in preparing the samples. Weigh samples consisting of 100 ± 0.1 g out of each of the separated fractions after final sieving, record the masses of the test samples, and place in separate containers for the test.

6.2   Coarse Aggregate- Thoroughly wash and dry the sample of coarse aggregate to constant mass at 110 ± 5°C (230 ± 9°F) and separate it into the different sizes shown in Section 5.2 by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of Section 5.2 and combine them to the designated total mass (Note 6). Record the masses of the test samples and their fractional components. In the case of sizes larger than 19.0 mm (3/4"), record the number of particles in the test samples.

Note 6- The fractional components of each sample may be placed in separate containers if so desired but it is not required. If separate containers are used, the two sizes must be combined for the calculations under Section 8.1.2 (Table 2).

Table 2 - Suggested Form for Recording Test Data (with Illustrative Test Values)

Sieve Size			Grading of Original Sample, Percent Retained	Mass of Test Fractions Before Test, g	Percentage Passing Designated Sieve After Test	Weighted Percentage Loss
Soundness Test of Fine Aggregate						
Minus 150 μm			5			
300 μm to 150 μm			12			
600 μm to 300 μm			26	100	4.20	1.09
1.18 mm to 600 μm			25	100	4.80	1.20
2.36 mm to 1.18 mm			17	100	8.00	1.36
4.75 mm to 2.36 mm			11	100	11.20	1.23
9.5 mm to 4.75 mm			4		11.20[a]	0.45
Totals			100			5.33
Soundness Test of Coarse Aggregate						
63 mm to 50 mm 50 mm to 37.5 mm	2825 g 1958 g	63 to 37.5 mm	20	4783	4.80	0.96
37.5 mm to 25.0 mm 25.0 mm to 19.0 mm	1012 g 513 g	37.5 to 19.0 mm	45	1525	8.00	3.60
19.0 mm to 12.5 mm 12.5 mm to 9.5 mm	675 g 333 g	19.0 to 9.5 mm	23	1008	9.60	2.21
9.5 mm to 4.75 mm			12	298	11.20	1.34
Totals			100			8.11

[a] The percentage loss (11.20 percent) of the next smaller size is used as the percentage loss for this size, since this size contains less than 5 percent of the original sample as received. Section 10.1.3.2.

NOTE 7- Calculate the percentage loss and weighted percentage loss for each size fraction and the weighted average percentage loss to the nearest 0.01%. Record the soundness loss for the appropriate gradation to the nearest 0.01%.

6.3   For 2A, OGS, #57, #67, the standard grading is as follows:

Table 3 - AASHTO 2A OGS, #57, #67 Gradation

Sieve Size		Standard Grading %
Passing	Ret. On	
7.5 mm (1½")	19.0 mm (¾")	36.8
9.0 mm (¾")	9.5 mm (⅜")	36.9
9.5 mm (⅜")	4.75 mm (No. 4)	26.3

7.   PROCEDURE

7.1   Storage of Samples in Solution- Pour the prepared solution of sodium sulfate into the sample containers in such a manner that the solution covers them to a depth of at least 12.5 mm (1/2"), for not less than 16 nor more than 18 hours. Cover the containers to reduce evaporation and prevent the accidental addition of extraneous substances. Maintain the samples immersed in the solution at a temperature of 20.3 to 21.9°C (68.5 to 71.5°F) for the immersion period.

7.2   Drying Samples After Immersion- After the immersion period, carefully drain the solution from the sample container and return the solution to a common container for reuse. Then place the sample containers in a drying oven maintained at a temperature of 110 ± 5°C (230 ± 9°F). Dry the samples at the specified temperature until constant mass has been achieved. Establish the time required to attain constant mass as follows: with the oven containing the maximum sample load expected, check the mass losses of test samples by removing and weighing them without cooling, at intervals of 2 to 4 hours. Check to establish the required drying time for the least favorable oven location (Section 3.7) and sample condition (Note 8). Constant mass will be achieved when the mass loss is less than 0.1 percent of sample mass in 4 hours of drying. After constant mass has been achieved, allow the samples to cool to 20 to 25°C (68 to 77°F) (Note 9), when they shall again be placed in the prepared solution and tested as described in Section 7.1. Cooling may be aided by the use of an air conditioner or fan. The temperature of the material shall be checked by thermometer or other acceptable means before placing the material in the soaking solution.

> NOTE 8- Drying time required to reach constant mass may vary considerably for several reasons. Efficiency of drying will be reduced as cycles accumulate because of salt adhering to particles and in some cases, because of increase in the surface area due to breakdown. The different size fractions of aggregate will have differing drying rates. The smaller sizes will tend to dry more slowly because of their larger surface area and restricted interparticle voids, but this tendency may be altered by the effects of container size and shape.

NOTE 9- Experience has shown that sample temperatures significantly different than the solution temperature of 21.1°C (70.0°F) may change the temperature of the solution temporarily, thereby causing a change in salt saturation even though the solution returns to 21.1°C (70.0°F) for most of the soaking period. This may cause erroneous results.

7.3   Number of Cycles- Repeat the process of alternate immersion and drying until five cycles are completed.

8.   QUANTITATIVE EXAMINATION

8.1   Make the quantitative examination as follows:

8.1.1   After completion of the final cycle and after the sample has cooled, wash the sample free from the sodium sulfate. Wash by circulating water at 43 ± 6°C (110 ± 10°F) through the samples in their containers by introducing hot water near the bottom and allowing the water to pass through the samples and overflow out of the container. The thoroughness of washing shall be checked by obtaining a sample of rinse water after it has passed through the samples and checked with 0.2 molar barium chloride. Further washing is required if the sample becomes cloudy upon addition of the barium chloride solution. In areas where the water gives a reaction with barium chloride other analytical means shall be used to assure thoroughness of washing. In the washing operation, the samples shall not be subjected to impact or abrasion that may tend to break up particles.

8.1.2   After the sodium sulfate has been removed, dry each fraction of the sample to constant mass at 110 ± 5°C (230 ± 9°F). Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the sieve shown below for the appropriate size of particle. For fine aggregate, the method and duration of sieving shall be the same as were used in preparing the test samples. For coarse aggregate, sieving shall be by hand, with agitation sufficient only to assure that all undersize material passes the designated sieve. No extra manipulation shall be employed to break up particles or cause them to pass the sieves. Determine the mass of the material retained on each sieve and record each amount. The difference between each of these amounts and the initial mass of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial mass for use in Table 2.

Size of Aggregate	Sieve Used to Determine Loss
63 mm to 37.5 mm (2½ to 1½")	31.5 mm (1¼")
37.5 mm to 19.0 mm (1½ to ¾")	16.0 mm (⅝")
19.0 mm to 9.5 mm (¾ to ⅜")	8.0 mm (5/16")
9.5 mm to 4.75 mm (⅜" to No. 4)	4.0 mm (No. 5)

9.   QUALITATIVE EXAMINATION

9.1   Make a qualitative examination of test samples coarser than 19.0 mm (3/4") as follows (Note 10):

9.1.1   Separate the particles of each test sample into groups according to the action produced by the test (Note 10).

9.1.2   Record the number of particles showing each type of distress.

NOTE 10- Many types of action may be expected. In general, they may be classified as disintegration, splitting, crumbling, cracking, flaking, etc. While only particles larger than 19.0 mm (3/4") in size are required to be examined qualitatively, it is recommended that examination of the smaller sizes be made in order to determine whether there is any evidence of excessive splitting.

10.   REPORT

10.1   The report shall include the following data (Note 11):

10.1.1   Mass of each fraction of each sample before the test.

10.1.2   Material from each fraction of the sample finer than the sieve designated in Section 8.1.2 for sieving after the test, expressed as a percentage of the original mass of the fraction.

10.1.3   Weighted average calculated from the percentage of loss for each fraction, based on the grading of the sample as received for examination determined by using PTM 616 or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative except that:

10.1.3.1   For fine and coarse aggregates sizes finer than the 300 μm (No. 50) sieve they shall be assumed to have 0 percent loss.

10.1.3.2   For the purpose of calculating the weighted average, consider any size in Section 5.1 or 5.2 that contain less than 5 percent of the sample to have the same loss as the average of the next smaller and the next larger size, or if one of these sizes is absent, to have the same loss as the next larger or next smaller size, whichever is present.

10.1.3.3   For large rock tested according to Section 5.2.2 the weighted average (if more than one size fraction is tested) shall be the arithmetic mean of the loss on the fractions tested.

10.1.3.4   For large rock tested according to Sections 5.2.3 or 5.2.4, the weighted average shall be based on a sample grading conforming to the middle of the specification to which the aggregate will be produced, or the actual grading as produced. If the specification grading includes fractions larger than the 63 mm (2½") sieve, assume such sizes to have the same percentage loss as the 63 to 37.5 mm (2½ to 1½") fraction.

10.1.4   Report the weighted percentage loss to the nearest 0.01%.

10.1.5   In the case of particles coarser than the 19.0 mm (3/4") sieve before the test: (1) count the number of particles in each fraction before the test, and (2) count the number of particles affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc., as shown in Table 4.

Table 4 - Suggested Form for Qualitative Examination (with Illustrative Test Values)

Qualitative Examination of Coarse Sizes									Total No. of Particles Before Test
	Particles Exhibiting Distress								
	Splitting		Crumbling		Cracking		Flaking		
Sieve Size	No.	Percent	No.	Percent	No.	Percent	No.	Percent	
63 mm to 37.5 mm (2½ to 1½")	2	7			2	7			29
37.5 mm to 19.0 mm (1½ to ¾")	5	-	-	2	-	-	-	-	50

10.1.6   Type of solution (sodium sulfate)

10.1.7   Method of producing particles for test, when reduced from large pieces as described in Sections 5.2.2, 5.2.3, or 5.2.4

NOTE 11- Table 2, shown with test values inserted for purpose of illustration, is a suggested form for recording test data.

11.   PRECISION

11.1   For coarse aggregate with weighted average sulfate soundness losses in the ranges of 6 to 16 percent for sodium sulfate, the precision indexes are as indicated, in Table 5 (Note 12).

Table 5 - Precision Indexes

	Coefficient of Variation (1S%), Percent[a]	Difference Between Two Tests (D2S%), Percent of Average[a]
Multilaboratory:		
Sodium sulfate	41	116
Single-Operator:		
Sodium sulfate	24	68

[a] These numbers represent, respectively, the (1S%) and (D2S%) limits as described in ASTM C 670.

> NOTE 12- The values in the precision statement are based on testing according to this method prior to revision in 1991. The revisions in 1991 are believed to improve the precision of the method.

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LABORATORY TESTING SECTION

Method of Test for

PREPARATION OF ROCK CORES FOR
COMPRESSIVE STRENGTH TESTS

1.   SCOPE

1.1   This method covers the technique and specifications for preparing rock cores so that they can be subjected to certain standard strength tests.[*]

2.   APPARATUS

2.1   Rock Cut-Off Saw - A saw for cutting rock cores to the proper length and making the ends flat. This saw shall have a diamond blade, a clamping device for lateral adjustments, a cooling system for the blade, and an automatic feed device. This type of saw will make it possible to produce smooth cuts at right angles to the core axis.

2.2   Polishing Lap - Either an automated or manual lap to grind the ends of the cores flat (eliminate irregularities). The lap shall consist of a motor-powered rotating wheel, which either has an abrasive coating or has a smooth metal wheel on which one uses loose grinding compound. Specimens may be held against the wheel by hand or by the use of an automated device.

2.3   Dial Comparator - A device for determining the closeness of the rock core to an ideal right circular cylinder.

3.   TEST SPECIMENS

3.1   Test specimens shall be obtained from cores drilled from the rock under study. Cores shall be not less than NX core size, approximately 54 mm (2⅛"). The cores shall be carefully removed from the core barrel, clearly marked, placed in core boxes, and transported to the testing facility with a minimum of disturbance. Cores shall be wrapped in plastic if one wants to maintain the original moisture content until testing.

4.   PROCEDURE

4.1   Select the sections of the cores that are to be tested.

4.2   Using the cut-off saw, cut the section of interest out of the core maintaining a length-to-diameter ratio of 2.0 to 2.5.

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[*] Such tests include triaxial compression (any type) and unconfined compression.

4.3 Test specimens shall be right circular cylinders within the tolerances herein specified. The sides of the specimen shall be generally smooth and free of abrupt irregularities with all elements straight to within 0.50 mm (0.02") over the full length of the specimen. The ends of the specimen shall be cut parallel to each other and at right angles to the longitudinal axis. The ends shall be ground or lapped until flat to 0.254 mm (0.01") using the polishing lap. The ends shall not depart from perpendicularity to the axis by more than 1°. These requirements will be considered to have been met when five equally distributed measurements of the height of the specimen taken by means of a dial comparator agree within 0.762 mm (0.03"). If one adjusts the core carefully in the vice of the saw and uses an automatic feed device as specified, the resulting specimen should meet the tolerances specified in the preceding sentence.

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LABORATORY TESTING SECTION

Method of Test for

TOTAL MOISTURE IN ANTI-SKID MATERIALS

1.   SCOPE

1.1   This method of test covers the procedures for determining in the field the total amount of moisture in anti-skid materials.

2.   APPARATUS

2.1   Balances and Weights- Balances meeting the requirements of AASHTO M-231, Class G2. Weights used with the balance must meet the requirements of AASHTO M-231 also.

2.2   Hot Plate- Either gas or electric of a sufficient heating capacity.

2.3   Oven- The oven shall be capable of maintaining a uniform temperature of 110 ± 5 ºC (230 ± 9 ºF).

2.4   A small metal pan or dish, such as a pie pan or biscuit pan for use in drying the test sample.

3.   SAMPLES

3.1   Obtain all samples in accordance with AASHTO T-2.

3.2   Reduce the sample in accordance with AASHTO T-248 until the approximate minimum mass of the test portion is as follows:

Anti-Skid Material, Type	Approximate Minimum Mass in Grams (lbs.) (Note 1)
1*, 1A*	1500 (3.31)
AS2, AS3, AS4	1500 (3.31)
AS1	500 (1.10)
4*	1500 (3.31)

NOTE 1- In no case, however, should the selection of a sample of a pre-determined mass be attempted.

* These are for Municipal Services use in accordance with Publication 447.

4.   PROCEDURE

4.1   The sample selected for test shall be weighed, and the mass, to be used in later calculations, recorded to the nearest 0.1 gram (0.0035 ounces).

4.2   The pan containing the sample for test shall be placed in an oven or on a hot plate as specified in Section 2.

4.3   When a hot plate is used, the material shall be carefully stirred with a metal rod, spoon, or other suitable tool in such a way that none of the sample is lost. Particles of material adhering to the tool used for stirring shall be returned to the test sample.

4.4   As soon as the test sample has been dried, remove it from the source of heat and allow the sample to cool to a comfortable handling temperature (NOTE 2).

NOTE 2- A sample is dry when its mass loss is less than 0.1 percent of sample mass in four hours of drying.

4.5   After cooling, weigh the test sample and record the mass to the nearest 0.l gram (0.0035 ounces) (NOTE 3).

NOTE 3- Never place hot material on a scale or balance. If the sample is too hot to handle, it is too hot to weigh accurately.

5.   CALCULATIONS

$$\frac{(A-B)}{B} \times 100$$

5.1   Subtract the dry mass (B) of the test sample from the original mass or wet mass (A) of the test sample. Record to the nearest 0.1 gram (0.0035 ounces) the difference, which is the total amount of moisture contained in the test sample.

5.2   Divide the amount of moisture contained in the test sample, Section 5.1, by the dry mass (B), Section 4.1, and record the total percent of moisture contained in the test sample (NOTE 4).

NOTE 4-   An example of the calculations is as follows:

Wet mass of an original sample of
Anti-Skid Material, AS1 ....528.6 grams.

Mass of the same sample of Anti-Skid
Material, after drying ....485.3 grams.

Total Moisture contained in sample

$$\frac{528.6 - 485.3}{485.3} \times 100 = 8.92\%$$

Dry Tonnage Example:

Average Daily Moisture Reported…………..   8.92%

Convert the Percent Moisture to a Decimal Value= .0892 and
then add 1 to that value= 1.0892

Wet Tonnage Shipped to the Project………. 529.34 tons

Divide the Wet Tonnage by the converted daily Moisture Value

$$\frac{529.34}{1.0892} = 486 \text{ dry tons}$$

6.   REFERENCES

AASHTO T-2
AASHTO T-248

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF ACCELERATED POLISH OF COARSE
AGGREGATE USING THE BRITISH WHEEL

1.   SCOPE

        1.1   This test method describes a laboratory procedure by which an estimate may be made of the extent to which different coarse aggregates may polish under traffic.

2.   DEFINITIONS

        2.1   The "Polished Stone Value", (PSV) is defined as the state of polish reached by each sample when subjected to accelerated polish for ten hours in the presence of water and abrasive by means of a special machine.

                2.1.1   Samples of coarse aggregate are subjected to an accelerated polishing action in a special machine.

                2.1.2   The state of polish reached by each sample is measured by a British Pendulum Tester (ASTM E 303 and is expressed as the Polished Stone Value (PSV).

3.   APPARATUS

        3.1   Accelerated Polishing Machine[1]- A polishing device as shown in Figure l. An accelerated polishing machine shall be mounted on a firm, level, and non-resilient base of stone or concrete and shall include:

                3.1.1   A cylindrical wheel (referred to as the specimen wheel) having a flat surface periphery and such size and shape as to permit 14 specimens, as described later, to be clamped onto the periphery to form a continuous surface of aggregate particles, 44.45 mm (1¾") wide and 406.40 mm (16") in diameter.

                3.1.2   A means of rotating the specimen wheel about its own axis at a speed of 315 to 325 revolutions per minute.

                3.1.3   A means of bringing the surface of a smooth solid rubber tire of 203.20 mm (8") diameter and 40.00 mm (1 9/16") width to bear on the aggregate specimens mounted on the surface of the specimen wheel with a total load of 391.44 ± 4.45 N (88 ± 1 pound). The tire rubber hardness shall be 69 ± 3 IRHD measured according to ASTM D 1415. The tire shall be

_____

[1] Originally manufactured by Wessex, Engineering and Metal Craft Co., Ltd. Merchants Barton, Rome, Somerset England.

free to rotate about its own axis, which shall be parallel to the axis of the specimen wheel. The plane of rotation of the tire shall coincide with that of the specimen wheel.

      3.1.4   A means to feed the 125 µm (120) silicon carbide grit at the rate given in Section 6.5 of this PTM, in such a way that the silicon carbide grit is fed continuously with a uniform distribution directly onto the specimen wheel surface near the point of contact with the rubber-tired wheel. Alternately, the grit may be fed continuously onto the rubber-tired wheel at its highest point.

      3.1.5   A means to feed the water at the rate shown in Section 6.5 in such a way that the water is spread continuously and uniformly over the surface of the specimen wheel near the point of contact with the rubber-tired wheel.

      3.2   Metal Molds- A number of accurately machined metal molds for preparing specimens (these are usually supplied with the machine). The specimens formed from these molds are 88.90 mm long by 44.45 mm wide by 16.00 mm thick (3.50" long by 1.75" wide by 0.63" thick).

      3.2.1   Metal cradles- A number of sheets of metal approximately 114.30 mm long by 76.20 mm wide by 1.60 mm thick (4.5" long by 3" wide by 1/16" thick) shaped to fit the curvature of the mold. These cradles will be used to give the epoxy a curved surface.

      3.3   British Pendulum Tester- A friction measuring device. The British Pendulum Tester used shall conform to ASTM Designation E 303 with the following modifications:

      3.3.1   The slider contact path shall be 76.20 ± 1.59 mm (3 ± 1/16").

      3.3.2   The slider width shall be 31.75 mm (1¼").

      3.3.3   The rubber that is bonded to the slider shall meet the following dimensional requirements, 6.35 x 25.40 x 31.75 mm (1/4 x 1 x 1¼").

      3.3.4   The zero adjustment shall be checked before and after testing the specimens and as often as the operator deems necessary.

4. MATERIALS AND SUPPLIES

      4.1   Water- A supply of tap water for use where water is required for any purpose in this PTM.

      4.2   Fine Sand- A supply of fine sand for filling the spaces between the aggregate pieces prior to placing of the bonding material. Silica-rich sand of minus 150 µm (No. 100) mesh size works well.

4.3   Mold Release Agent- A supply of mold release agent used to prevent a bond between the mold and the bonding material. Number 10-30 SAE oil has been found to suitable for this purpose.

4.4   Silicon Carbide Grit- A supply of silicon carbide grit 125 µm (No. 120) grit size to be used as a polishing agent.

4.5   Bonding Agent- A supply of polyester resin and catalyst or other suitable bonding material, such as some epoxy resin, having a pot life of 20 to 30 minutes and curing time of 3 to 6 hours.

4.6   Coarse Aggregate- Approximately a 0.014 m^3 (one-half cubic foot) supply of coarse aggregate to be tested. The aggregate shall be from a normal plant run, but laboratory crushed material may be tested, if so identified.

4.7   Test Specimens and Test Control

4.7.1   Aggregate specimens shall be tested in sets of two or three for each aggregate to be evaluated. For control purposes, two positions of the specimen wheel shall be filled with two specimens made from a standard aggregate. The aggregate shall be of a uniform texture that will give consistent results for many years.

4.7.2   Adjustments to the polish value for a given run of the wheel shall be made by comparing the polish value of the standard sample to the polish value of the run. The following formula shall be used:

$$\text{Adjusted PSV} = \frac{\text{BPN}_\text{s} \text{ x } \text{BPN}_\text{ea}}{\text{BPN}_\text{es}}$$

Where:

PSV   = polished stone value

BPN$_\text{s}$ = British Pendulum Tester Number for the aggregate sample

BPN$_\text{ea}$ = Average British Pendulum Tester Number of the standard (established polish value)

BPN$_\text{es}$ = British Pendulum Tester Number of the standard for a given test.

5.   PREPARATION OF TEST SPECIMENS

5.1   The aggregate to be tested shall pass the 9.5 mm (3/8") sieve and shall be retained on the 6.3 mm (1/4") sieve.

5.2   The aggregate to be tested shall be thoroughly washed and dried at 60 ± 3 $^{\circ}$C (140 ± 5 $^{\circ}$F) to essentially constant mass.

5.3   The mold shall be coated with a mold release agent.

5.4   A thin layer (about 1.6 mm (1/16") thick) of fine sand described in Section 4.2 shall be placed in the bottom of the mold. This sand layer shall be moistened to produce a very viscous mud.

5.5   Each specimen shall contain a single layer of dry aggregate placed by hand as densely as possible with a flat surface down to cover the bottom surface of the mold. Each piece of aggregate should be pushed into the layer of wet sand so that its flat side is against the surface of the mold (NOTE 1).

> NOTE 1- Pieces selected should be representative of the material to be evaluated. Flat, elongated, or other non-equant shaped pieces shall be avoided because they can cause difficulty in placement and bonding. Misleading polish values can result from an inadequate surface area for polishing.

5.6   Prepare the bonding agent described in Section 4.5 according to the manufacturer's instructions. The consistency of the bonding material shall be such as to allow it to flow freely between the aggregate particles.

5.7   Fill the prepared mold just to overflowing with the bonding material. Place a metal cradle described in Section 3.2.1 on the plastic epoxy and work it back and forth to distribute the epoxy and force out the excess. Place some kind of mass (about 2 kg) (5 lbs. in weight) on the cradle to keep it in place until the epoxy hardens (NOTE 2).

> NOTE 2- If a thick epoxy-based mixture is used, (as described on supplementary notes at end of this test method), it is not necessary to use sand (Section 5.4) or a metal cradle (Section 5.7).

5.8   When the bonding material has cured properly (2 to 4 hours) remove the specimen from the mold.

5.9   Brush the sand from the face of the specimen. If necessary, use a pointed instrument to pick out any epoxy that has gotten on the surface of the aggregate pieces.

6.   ACCELERATED POLISH TEST PROCEDURE

        6.1   Determine the original friction number of the prepared test specimens and control specimens by following the procedure outlined in Sections 8.1 and 8.2 of AASHTO T-278, as modified by Section 3.3.4. Average the readings from the final four swings and record this average as the original friction number.

                6.1.1   An arrow shall be marked on the bottom of each specimen with a diamond pencil to indicate the direction of placement in the testing machine. This is done so that the sample can be run in the machine and tested on the British Pendulum Tester in the same direction each time.

        6.2   Fourteen specimens shall be clamped around the periphery of the specimen wheel, using an O-ring near the edge of the specimens, to form a continuous strip of particles on which the pneumatic-tired wheel shall ride freely without bumping or slipping. The O-ring provides a tight fit for the specimens when the retaining rim of the specimen wheel is clamped into place. If the specimens move during the test they may break in half (NOTE 3).

                NOTE 3- Sometimes there is a small gap between the last two specimens when all fourteen are in place. This gap can be closed by placing a properly cut section of an epoxy specimen into this gap.

                6.2.1   Samples must be positioned on the specimen wheel so that the arrows on them coincide with the direction of travel of the rubber-tired wheel.

        6.3   Maintain the temperature of the specimens, water, and apparatus at 24 ± 3 ^{o}C (75 ± 5 ^{o}F) during the entire time of the test.

        6.4   Feed No. 120 silicon carbide grit at a rate of 25 ± 5 grams (0.88 ± 0.18 ounces) per minute for ten hours. Feed water at the same rate as the silicon carbide grit.

        6.5   Bring the specimen wheel to a speed of 320 ± 5 rev./min., and bring the pneumatic-tired wheel to bear on the surface of the specimen with a total load of 391.44 ± 4.45 Newtons (88 ± 1 Pound).

        6.6   Remove the specimens from the specimen wheel and wash thoroughly to remove grit after the test is completed.

        6.7   After cleaning, test the specimens to determine the Polished Stone Value (PSV), using the British Pendulum Tester, and the same procedure used in Section 6.1 to determine the original friction number.

        6.8   Determine adjustments to the PSV by comparison of the PSV obtained for control specimens to the established value for the control specimen.

6.9   If the rate of polish is desired, repeat the procedure in Sections 6.2-6.7 at regular intervals of machine time such as 2, 4, 6, 8, and 10 hours.

>   6.9.1   If the rate of polish is determined by repeating the readings at intervals of time throughout the test then proceed as follows: Graph the results on graph paper or in a spreadsheet program with the time intervals plotted along the x-axis of the graph, and the beginning, intermediate, and final polished stone values along the y-axis of the graph. (See Figure 2.)

7.   REPORT

7.1   The report shall contain the following information as is appropriate to the needs of the users.

>   7.1.1   Identification of the coarse aggregate tested, including the gradation of the aggregate
>
>   7.1.2   Before-test friction values for the control specimens
>
>   7.1.3   After-test friction values for the control specimens
>
>   7.1.4   Before-test friction values for specimens containing aggregates to be evaluated
>
>   7.1.5   After-test friction values for specimens containing aggregates to be evaluated
>
>   7.1.6   Interim test time friction values for specimens containing aggregates to be evaluated and for control specimens when the rate of polishing is to be determined
>
>   7.1.7   Adjusted polish value for the aggregates evaluated
>
>   7.1.8   Temperature of the specimens during the determination of the British Pendulum Tester number
>
>   7.1.9   Dates of the testing period
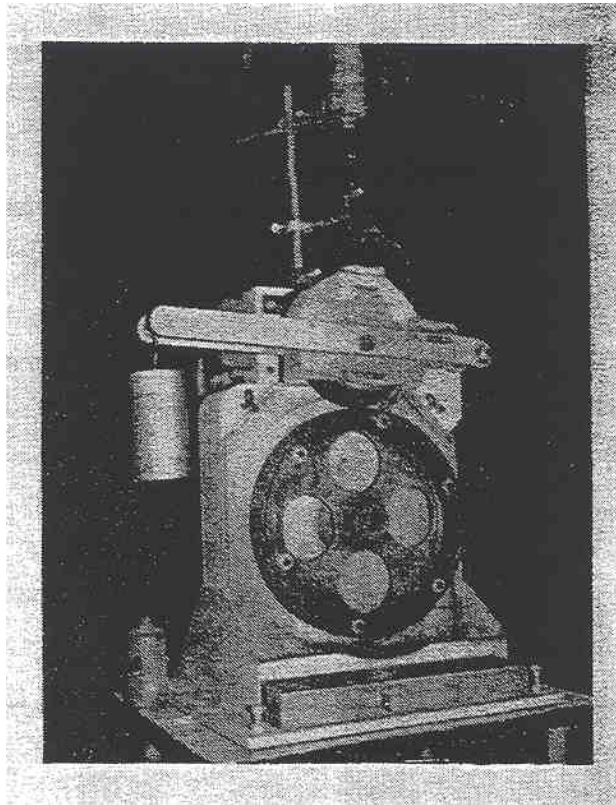
Figure 1: Accelerated Polishing Machine with a Specimen Wheel Cover Removed

APPENDIX

FORMULA FOR MAKING POLYESTER BINDER USED IN PREPARING COARSE
AGGREGATE SPECIMENS FOR THE ACCELERATED POLISH TEST

A.   Composition of the Resin Component

100 parts by mass - polyester resin

30 parts by mass - wollastonite P-4 extender pigment

4 to 5 parts by mass - collodial silica

0.5 parts by mass - 6% cobalt naphthanate solution (cobalt drier)

B.   Compounding of the Resin Component

Add the wollastonite to the polyester resin and mix the two together. Add silica that is extremely light (very low sp.gr.) and floats on top of the resin. Therefore, thorough mixing is needed to disperse the silica throughout the resin. After the silica is dispersed, the 6% cobalt solution is stirred in. This resin solution may be stored up to six months and used as required. When ready for use, simply add the correct amount of catalyst (hardener) and disperse it throughout the resin (All the mixing at the Pennsylvania Department of Transportation Testing Lab is done by hand using a rubber spatula in a plastic container).

C.   Molding the Specimen

After mixing all the previously mentioned ingredients together, the finished product has the consistency of thick putty. It holds its shape and does not run. After mixing in the hardener, fill the specimen molds with the resin mixture using a metal spatula. Make sure the resin is pushed down around the rocks that have previously been placed in the bottom of the mold. When the mold is filled, strike off the resin to the shape of the specimen mold. Because of its thick consistency, the resin mixture will hold this shape.

Run XXX - Limestone Standard
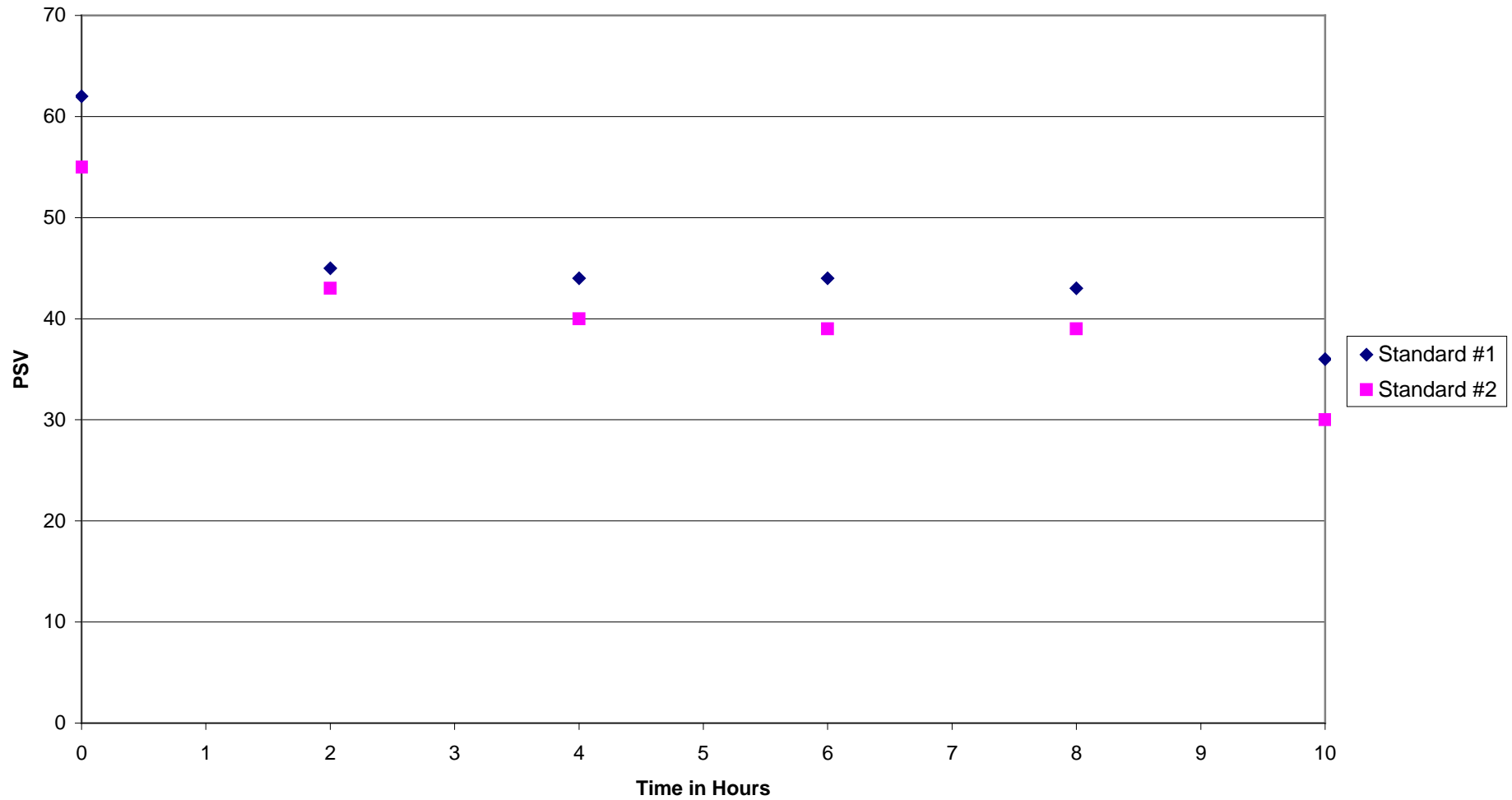
Figure 2. Graph of British Wheel results taken at set time intervals throughout the test

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LABORATORY TESTING SECTION

Method of Test for

HAND SPECIMEN PETROGRAPHIC EXAMINATION

1.   SCOPE

1.1   This procedure covers petrographic testing methods for coarse aggregate, rock lining, and fine aggregate.

2.   APPARATUS

2.1   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

2.2   Sieves- Sieves conforming to the requirements of AASHTO M-92.

2.3   Common Rock Hardness materials:

2.3.1   Penny or Copper rod

2.3.2   Steel knife or nail

2.3.3   Glass Plate

2.3.4   Scratch plates (white and black) for determining the color of powdered material

2.3.5   Munsel Rock Color Chart or Munsel Soil Color Chart

2.3.6   Ruler, marked to $1/16^{th}$ or $1/32^{nd}$ of an inch. Also marked to 1 mm.

2.3.7   Dilute Hydrochloric Acid (1:4 concentration)

2.3.8   Magnet

2.3.9   Tweezers

2.3.10   Illuminated Magnifier

2.3.11   Hand lens

2.3.12   Binocular Microscope (0.7X to 3X, with 10X objectives)

2.3.13 Hammer, anvil, and pans

3.   HAND SPECIMEN PETROGRAPHIC PROCEDURE

3.1 Coarse Aggregate (> 6.5 mm; 0.25 in)(Section 703.2 of Publication 408):

3.1.1   Sieve 800 to 2000 grams of washed and oven-dried aggregate. Remove material that is finer than the 6.5 mm (1/4 inch) screen.

3.1.2   Visually examine the aggregate retained on the 6.5 mm (1/4 inch) sieve.

3.1.3   Record the lithology, fresh and weathered colors, grain or crystal size, degree of weathering or alteration, mineralogy, nature of cement or matrix, presence of deleterious minerals, materials, or coatings, fossils, bioturbation, carbonaceous material, and presence of laminae, bedding, foliation, or fractures.

3.1.4   Determine the hardness of the individual clasts using a copper rod, glass plate, and knife blade.

3.1.5   Separate out the different lithologies.

3.1.6   Use dilute HCl to determine the presence of carbonate cements and types of carbonate (dolomite, calcite) and the presence of carbonaceous or argillaceous material.

3.1.7   Use the binocular microscope, magnifier, or hand lens to determine the mineralogy of small grains or crystals, degree of bedding, banding, and interlocking structure and degree of cementation or weathering on individual grains or between grains.

3.1.8 Classify *Carbonate Rocks* using ASTM C 294, Section 20 and Reference 5.6 in this PTM.

3.1.9   Classify *Conglomerates, Sandstones, and Quartzites* using ASTM C 294 Section 18, and Krynine's classification (Chart 1 in this PTM).

3.1.10   Classify *Claystone, Shales, Argillites, and Siltstones* using ASTM C 294 Section 19, and Table 1.

3.1.11   Classify *Igneous and Metamorphic Rocks* using ASTM C 294 Sections 15 and 23.

3.1.12   Classify *Blast Furnace and Steel Slags, Fly and Bottom Ash, and Recycled Concrete* based on training, experience, and using Chart 2 in this PTM.

3.1.13 Separate the potentially deleterious material (ferrous particles (use a magnet), coal, shale, shaley siltstone, shaley limestone, wood fragments, etc.).

3.1.14 If the potentially deleterious material exceeds the specifications for the aggregate in the current issue of PENNDOT Publication 408, submit the material for additional tests (wet/dry test using PTM 519, x-ray diffraction, etc.).

3.1.15 Determine the relative percentages of the lithologies by mass weighing the material to an accuracy of 0.1 gram:

> *3..1.15.1 Mass of Lithology/Total Mass of Sample = Relative Percentage of Lithology*

3.2   Rock Lining (Section 850 in PENNDOT Publication 408):

3.2.1 Wash and oven-dry the Rock Lining sample.

3.2.2 Measure the length, width, and thickness of the individual clasts. Note whether the ratio of length to either width or thickness exceeds 3:1 (Section 850.2(a) in PENNDOT Publication 408).

3.2.3 Visually examine the Rock Lining. Note the lithology, fresh and weathering colors, grain or crystal size, degree of weathering or alteration, presence of deleterious minerals, materials, or coatings, presence of laminae, bedding, fractures, and/or grain shape.

3.2.4 Determine the hardness of individual clasts using a copper rod, glass plate, and knife blade.

3.2.5 Separate out the different lithologies.

3.2.6 Use dilute HCl to determine the presence of carbonate cements and types of carbonate (exp. dolomite, calcite).

3.2.7 Classify *Carbonate Rocks* using ASTM C 294, Section 20 and Reference 5.6. in this PTM.

3.2.8 Classify *Conglomerates, Sandstones, and Quartzites* using ASTM C 294, Section 18, and Krynine's classification (Chart 1 in this PTM).

3.2.9 Classify *Claystone, Shales, Argillites, and Siltstones* using ASTM C 294, Section 19, and Table 1.

3.2.10 Classify *Igneous and Metamorphic Rocks* using ASTM C 294, Sections 15 and 23.

3.2.11 Classify *Blast Furnace and Steel Slags, Fly and Bottom Ash, and Recycled Concrete* based on training and experience and using Chart 2 in this PTM.

3.2.12 Separate the potentially deleterious material (ferrous particles (use a magnet), coal, shale, shaley siltstone, shaley limestone, woody fragments, etc.).

3.2.13 If the potentially deleterious material exceeds the specifications for the aggregate in the current version of PENNDOT Publication 408 submit the material for additional testing.

3.2.14 Determine the relative percentages of the lithologies by mass weighing the material to an accuracy of 1.0 gram:

> *3.2.14.1 Mass of Lithology/Total Mass of Sample = Relative Percentage of Lithology.*

3.3   Fine Aggregate (<6.5 mm; 0.25 in.) (Section 703.1 in Publication 408):

3.3.1 Sieve 250 to 500 grams of washed aggregate; examine material that passes the 6.5mm (1/4 inch) screen.

3.3.2 Count a minimum of 160 grains (where possible) from each of the Nos. 4, 8, and 16 screens (add the material retained on the #20 screen if insufficient material is present on the larger screens):

3.3.3 Visually examine the aggregate. Note the lithology, fresh and weathering colors, grain or crystal size, composition of cement or matrix, degree of weathering or alteration, presence of deleterious minerals, materials, or coatings, and presence of laminae, bedding, or fractures.

3.3.4 Determine the hardness of the individual clasts using a copper rod, glass plate, and knife blade.

3.3.5 Separate out the different lithologies.

3.3.6 Use a magnet to separate out ferrous particles.

3.3.7 Use dilute HCl to determine the presence of carbonate cements and types of carbonate (exp. dolomite, calcite).

3.3.8 Use the binocular microscope or a hand lense to determine the mineralogy of the small grains or crystals, degree of bedding or interlocking structure, and the degree of weathering on individual grains or between grains.

3.3.9 Classify *Carbonate Rocks* using ASTM C 294, Section 20 and Reference 5.6 in this PTM).

3.3.10 Classify *Conglomerates, Sandstones, and Quartzites* using ASTM C 294 Section 18, and Krynine's classification (Chart 1 in this PTM).

3.3.11 Classify *Claystone, Shales, Argillites, and Siltstones* using ASTM C 294 Section 19, and Table 1.

3.3.12 Classify *Igneous and Metamorphic Rocks* using ASTM C 294, Sections 15 and 23.

3.3.13 Classify *Blast Furnace and Steel Slags, Fly and Bottom Ash, and Recycled Concrete* based on training and experience and using Chart 2 in this PTM.

3.3.14 Separate the potentially deleterious material (coal, shale, shaley siltstone, shaley limestone, ferrous material etc.).

3.3.15 Weigh the deleterious particles and compare their weights to the weight of material retained on the 6.5 mm (1/4 inch) sieve.

3.3.16 Determine the relative percentages of the lithologies using point counts:

   3.3.16.1 Point Count of Individual Lithology/Total Point Count of Sample = Relative Percentage of Lithology.

4. REQUIRED RECORDS

4.1 TR- 447 Sample Identification

4.2 TR- 4127 Petrographic Description Lab Report

4.3   Petrographic Data Tables/Spread Sheet

5. REFERENCE DOCUMENTS

5.1 ASTM C 294, Standard Descriptive Nomenclature for Constituents of Natural Mineral Aggregates

5.2 ASTM C 1005, Standard Specification for Reference Masses and Devices for Determining Mass and Volume for use in the Physical Testing of Hydraulic Cements

5.3 AASHTO M-92, Specification for Wire-Cloth Sieves for Testing Purposes

5.4   PENNDOT Specifications: Publication 408

5.5   PENNDOT PTM 519, Method of Test for Wet/Dry Durability Test

5.6   Folk, R.L., 1968. <u>Petrology of Sedimentary Rocks</u>: The University of Texas, Hemphill's, Austin, TX (pp. 152-168).

6. TRAINING

6.1 The Petrographer shall have a Bachelor's Degree in Geology, or its equivalent.

7. ATTACHMENTS

3.1 Chart 1- Rock Classification Chart Used by the Petrographic Unit

3.2 Chart 2 - Slag Classification Chart Used by the Petrographic Unit

CHART 1: ROCK CLASSIFICATION USED BY THE PETROGRAPHIC UNIT

Igneous and Metamorphic Rocks: Classification based on ASTM C 294, Sections 15 and 23
Sedimentary Rocks:

      Carbonate Rocks: classification based on ASTM C 294, Section 20 with additional descriptions from Folk, R.L., 1968. Petrology of Sedimentary Rocks: The University of Texas, Hemphill's, Austin, TX (pp. 152-168).

      Conglomerates, Sandstones, and Quartzites: classification based on ASTM C 294, Section 18 with further elaboration from Krynine's classification (below).

          Conglomerate- quartz, graywacke, or arkosic with descriptive adjective relating to the size of particles (pebble, granule, etc.). Conglomerate includes any rock with particles over 2 mm (0.08 in.) in diameter.

          Sandstone and Quartzite- grains ranging in diameter from 0.0625 mm (0.003 in.) to 2 mm (0.08 in.).

          Quartzite- Quartz grains plus over 75% silica in the cement

          Impure Quartzite- Quartz grains plus 51% to 75% silica in the cement

          Quartzitic Sandstone- Quartz grains plus 25% to 50% silica in the cement

          Quartzose Sandstone- Quartz grains plus less than 25% silica in the cement

          Graywacke- Gray, greenish gray, to reddish gray sandstone, containing quartz, feldspar, and rock fragments in a matrix resembling claystone or shale

          Claystone, Shales, Argillite, Siltstone- based on ASTM C 294, Section 19 with the following additions:

Shale and Siltstone Classification

TEST	LAMINATED (FISSILE)	NON-LAMINATED
Fingernail scratches rock	*Clay Shale*	*Claystone*
Penny barely scratches rock	*Shale* with thin laminae (less than 5 mm; 0.2 in.), possibly silty or calcareous	*Argillite*
Rock scratches glass with effort	*Shaley Siltstone* with thick laminae (5 mm; 0.2 in)	*Silty Argillite*
Rock scratches glass easily	*Laminated Siltstone*	*Siltstone*

CHART 2: SLAG CLASSIFICATION USED BY THE PETROGRAPHIC UNIT

BLAST FURNACE	OPEN HEARTH
Finely to Coarsely Crystalline	Finely Crystalline to Microcrystalline
Low Density	High Density
Highly Vesicular	Few Vesicles
Rotten Egg Smell	
Colors: olives, browns, blues, greens	Darker Colors: dark grays, brownish black

LOOK FOR:
- Fire Brick
- Flux (LS, SS, SH)
- Coal, Coke, glassy particles
- Friable Particles and Aggregates
- Iron Particles (highly magnetic) Removed from the matrix.
- Slightly Magnetic Aggregates
- Lime Particles (resembles *caliche*) and Lime Crystals

Use Section 703.2.a Table B in the PENNDOT Publication 408:

	Type A	Type B	Type C
Friable Particles	1 %*	1%	------
Coal or Coke	1%	1%	5%
Iron	3%	3%	3%
Glassy Particles	4%** or 0%***	4%** or 0%***	------

* Percent by Weight
** for cement or concrete
***for bituminous

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LABORATORY TESTING SECTION

Method of Test for

WET-DRY DURABILITY TEST

1.   SCOPE

        1.1   This test is used to determine the resistance of shaley material to splitting and cracking under conditions of successive and alternating exposure to wetting and then drying. The test is generally performed on processed coarse aggregate samples (except for AASHTO #10's) which have been found to contain, through petrographic analysis of a hand sample specimen, total amounts of shaley material exceeding the allowed specification limits for deleterious shale as stated in Table B, Section 703.2 of Publication 408. This test can also be performed on unprocessed coarse aggregate samples, such as material intended for use in embankments and backfill, in order to give the potential user an indication of how the material may perform through time. This test is also applicable to coarse aggregate extracted from a bituminous overlay, in order to evaluate the current durability and quality of the aggregate present in the overlay, and to help evaluate whether or not the overlay will perform as expected during the remainder of its anticipated life span.

        1.2   This test is not applicable to processed fine aggregates and AASHTO # 10's.

        1.3   For the purposes of this test only, the term "shaley material" includes the following categories of rock types:

        1.3.1   shale - a very fine-grained detrital sedimentary rock composed of silt-sized and clay-sized particles, that are thinly bedded and which tend to part along the bedding planes.

        1.3.2   shaley limestone - limestone, which is composed mainly of $CaCO_3$, that is thinly bedded and has thin beds of shale intercalated between the thin layers of limestone, and which tends to part along the bedding planes.

        1.3.3   shaley laminated siltstone- a fine-grained to very fine-grained detrital sedimentary rock, thinly bedded, which consists of intercalated beds of predominantly silt-sized material and shale, and which tends to part along the bedding planes.

                Note 1- It is assumed that the person who performs the petrographic analysis or identifies the presence of shaley material in the sample is qualified by education and experience to describe and classify the individual constituents of an aggregate sample.

        1.4   This test is not applicable to fine-grained detrital sedimentary rocks that are massive and show absolutely no signs of bedding on a fine scale, such as massive argillites, mudstones, and claystones.

2.   APPARATUS

2.1   Pans - Pans shall be composed of metal or a plastic, durable at the required oven temperature (see Section 2.3), and shall be deep enough to allow the sample to be completely covered by at least 6.4 mm (1/4") of water.

2.2   Syringe or aspirator - A syringe consisting of a rubber squeeze bulb and nozzle with a capacity of at least 80 cc has been found to be satisfactory.

Note 2- A satisfactory style of syringe may be found in automotive supply stores which supply batteries and battery accessories. Such stores usually stock a syringe or bulb aspirator for adjusting the level of acid in unsealed batteries that can be used in this test without any alterations.

2.3   Ovens

2.3.1   Oven - An oven which shall be capable of maintaining a temperature of 60 ± 3 °C (140 ± 5 °F), and shall be large enough to hold as many samples as are likely to be tested at the same time.

2.3.2   Oven - An oven which shall be capable of maintaining a temperature of 110 ± 5 °C (230 ± 9 °F), and shall be large enough to hold as many samples as are likely to be washed at the same time.

2.4   Sieves - A 4.75 mm (#4), 6.3 mm (1/4"), 25.0 mm (1"), and 50.0 mm (2") sieves, conforming to AASHTO M-92.

2.5   Balance - The balance shall conform to Class G2 of AASHTO M-231 for samples less than 2000 g (4.4 lbs.); or Class G5, AASHTO M-231, for samples 2000 g (4.4 lbs.) or more, but less than 5000 g (11 lbs).

2.6   Brush - A brush of sufficient size and with sufficiently heavy bristles to loosen dried, fine particles from the bottom of the pan at the end of the test.

3.   SAMPLE

   3.1   Processed coarse aggregate samples

   3.1.1   Processed coarse aggregate samples on which this test may be performed shall be obtained in accordance with AASHTO T-2. Any processed coarse aggregate samples coarser in gradation than an AASHTO #467 shall be treated as an unprocessed coarse aggregate sample (Section 3.2).

   3.1.2   The sample shall be reduced in size by AASHTO T-248 to a weight slightly higher than the minimum desired weight (Section 3.1.5).

   3.1.3   Wash the reduced sample in order to remove all fines and adhering dust, and dry in an oven capable of maintaining 110 ± 5 °C (230 ± 9 °F). This is the standard temperature range used in preparing aggregate samples for various tests.

   3.1.4   Grade the sample from Section 3.1.3 over a 6.3 mm (1/4") sieve and discard the material that passes this sieve.

   Note 3- Sections 3.1.3 and 3.1.4 may be performed in reverse order, if desired.

   3.1.5   The final test sample of processed coarse aggregate shall meet the minimum weight requirement given below:

Original Gradation	Minimum Weight
AASHTO #8 and #7	800 g
AASHTO #467, #5, #57, & #67	1000 g
PA 2A or OGS	1200 g

   Record the weight (W_o) of the final test sample to the nearest tenth of a gram (ounce).

   3.1.6   After obtaining the final test sample, it may be prepared for the wet-dry test in one of two ways:

   3.1.6.1 If the final test sample contains a fraction identified as shaley material (Note 1), check each piece of shaley material for cracks. Set any cracked pieces of shaley material aside, after noting their total weight (C_s) to the nearest tenth of a gram. The bulk of the sample is now ready for the wet-dry test.

   3.1.6.2 Instead of performing the wet-dry test on the entire final test sample of processed coarse aggregate; the following procedure may be followed:

3.1.6.2.1 Perform a petrographic analysis on the final test sample (Note 1), and record the weights of each of the rock types present in the sample to the nearest tenth of a gram.

3.1.6.2.2 Calculate the percentage, by total sample weight, of the portion of the final test sample comprised of shaley material. For example:

Weight of the final test sample (W_o)   1010.0 g
Weight of shaley material in the test sample (S_o)   100.0 g

% shaley material in the test sample

$$\frac{S_o}{W_o} x100 = \frac{100g}{1010g} x100 = 9.9\%$$

3.1.6.2.3 The wet-dry test will be performed if the percentage of shaley material present in the final test sample exceeds the allowed limit of deleterious shale for the designated quality level of the aggregate (see Table B, Section 703.2, Publication 408 (Specifications), Deleterious Shale, Max. %, for Types A, B, and C coarse aggregates). Otherwise, discard the entire test sample, and do not proceed with the remainder of the test procedure.

3.1.6.2.4 Prepare the shaley material for the wet-dry test by checking each piece of shaley material for cracks. Set aside the cracked pieces after noting their total weight (C_s) to the nearest tenth of a gram. The shaley material fraction of the final test sample is now ready for the wet-dry test.

3.2   Unprocessed coarse aggregate samples (and processed coarse aggregate samples coarser than AASHTO #467's)

3.2.1   Samples shall be obtained in the field in accordance with AASHTO T-2.

3.2.2   Pieces of the sample larger than 50.8 mm (2") (maximum dimension) shall be broken down to less than 50.8 mm (2"). The whole sample shall be passed over a 50.0 mm (2") and a 25.0 mm (1") sieve. Only the material passing the 50.0 mm (2") and retained on the 25.0 mm (1") sieve shall be utilized in the wet-dry test. If necessary, reduce the amount of sized material by AASHTO T-248 to obtain a workable test sample, and set the remainder of the minus 50.0 mm (2") plus 25.0 mm (1") material to one side.

3.2.3   Wash the test sample to remove fines and adhering dust, and dry in an oven capable of maintaining 110 $\pm$ 5 °C (230 $\pm$ 9 °F). If during the process of washing the sample of unprocessed rock, pieces of the sample begin to disintegrate, immediately stop the

washing process, discard the sample, and split out a new sample from the remaining minus 50.0 mm (2") plus 25.0 mm (1") material from Section 3.2.2. For the new sample, immediately go from Section 3.2.2 to Section 3.2.4, and do not attempt to wash the new sample.

3.2.4   The sample from Section 3.2.3 or Section 3.2.2 (if unwashed) shall not weigh less than 800 g (1.75 lbs).

3.2.5   After obtaining the final test sample, prepare it for the wet-dry test as follows (Note 1):

3.2.5.1 If the final test sample contains a fraction identified as shaley material, check each piece of shaley material for cracks. If it does not contain shaley material, do not proceed with this test.

3.2.5.2 Discard any cracked pieces of shaley material, and check the weight of the remaining sample, which shall not be less than 800 g (1.75 lbs).

3.2.5.3 If the sample now weighs less than 800 g (1.75 lbs.), combine this material with the remaining minus 50.0 mm (2") plus 25.0 mm (1") fraction from Section 3.2.2, and resplit the sample to produce a test sample of sufficient size that will weigh at least 800 g (1.75 lbs.) when any cracked pieces of shaley material are removed.

3.2.5.4 Note the weight of the final test sample (W_o) to the nearest tenth of a gram.

3.2.5.5 The sample is now ready for the wet-dry test, if you wish to perform the test on the bulk sample.

3.2.6   If you wish to subject only the shaley material portion of the prepared, unprocessed rock sample to the wet-dry test, remove the shaley material from the prepared sample (Note 1), and record the weight of the shaley material fraction (S_o) from the prepared sample to the nearest tenth of a gram.

3.3   Coarse aggregate samples extracted from bituminous overlays

3.3.1   Take the extracted aggregate sample, which usually includes the coarse and the fine aggregate fractions, and sieve it over a 6.3 mm (1/4") sieve, saving the material finer than the 6.3 mm (1/4") sieve. Weigh the plus 6.3 mm (1/4") aggregate. If this material weighs more than 400 g (14 ounces), proceed to Section 3.3.2. If the plus 6.3 mm (1/4") material weighs less than 400 g (14 ounces), recombine it with the minus 6.3 mm (1/4") material, and resieve the entire sample over the 4.75 mm (#4) sieve. If the sample of plus 4.75 mm (#4) material weighs 400 g (14 ounces) or more, proceed with the test. If the plus 4.75 mm (#4) material weighs less than 400 g (14 ounces), do not proceed with the remainder of the test.

3.3.2   Wash the aggregate sample in acetone to remove as much of the remaining asphalt binder as possible, and dry the sample to a constant weight in an oven capable of maintaining 60 ± 3 °C (140 ± 5 °F).

3.3.3   Resieve the aggregate sample over the 4.75 mm (#4) sieve to remove any fines released from the coarse aggregate particles by the acetone bath. Reweigh the plus 4.75 mm (#4) aggregate. If the plus 4.75 mm (#4) aggregate sample weighs less than 400 g (14 ounces), do not proceed with the remainder of the test. If the plus 4.75 mm (#4) aggregate sample weighs 400 g (14 ounces) or more, record the sample weight (W_o) to the nearest tenth of a gram, and proceed with the test.

3.3.4   Perform a petrographic analysis of the sample. Note the different types of rocks present, record the weight of each individual rock type present to the nearest tenth of a gram (S_o, for the shaley material fraction), and calculate the percentages, by total sample weight (W_o), of each type of rock present in the sample (Note 1). Since the color of the rock types present will have been distorted somewhat by the use of an asphalt binder, only the general color ranges of the rock types present should be noted.

3.3.5   The wet-dry test shall be performed on the shaley material from the extracted aggregate sample if the total percentage of shaley material present in the extracted coarse aggregate sample exceeds the allowed limit of deleterious shale for the designated quality level of the coarse aggregate (see Table B, Section 703.2, Publication 408 (Specifications), Deleterious Shale, Max. %, for Types A, B, and C coarse aggregates). Otherwise, there is no point in continuing with the remainder of the test procedure.

3.3.6   Prepare the shaley material for the wet-dry test by checking each piece of these materials for cracks. Set aside any cracked pieces, after noting their total weight (C_s) to the nearest tenth of a gram. The shaley material fraction of the extracted aggregate sample is now ready for the wet-dry test.

4.   PROCEDURE

4.1   Place the test sample in a pan and cover the sample with at least 6.4 mm (1/4") of water. If necessary, split a sample between 2 or more pans in order to achieve the necessary amount of water coverage. Soak the sample for 17 ± 2 hours. After this period is over, remove the water by first pouring the water off, and then by suction using the syringe or aspirator. While removing the water from the pans, be very careful not to lose any material, large or small, from the pan(s).

4.2   After removing the water from the sample(s), place the sample(s) in an oven at 60 ± 3 °C (140 ± 5 °F) and dry the sample(s) for 7 ± 1 hours.

4.3   Repeat the cycle of wetting and drying three (3) more times. After removing the samples from the oven, allow them to cool to room temperature before they are covered with water again.

4.4   After the end of the fourth cycle, remove the sample(s) from the oven, and allow the pan(s) to cool to room temperature.

4.5   Remove any pieces of shaley material from the sample that show the following characteristics:

4.5.1   Splitting or cracking apart, which is apparent through simple visual inspection, or which occurs through application of moderate manual pressure to the piece of aggregate.

NOTE 4- Sometimes an aggregate particle may split apart during the test, and the resulting smaller pieces will become separated from each other. Such pieces of aggregate are considered to be part of the "deleterious" fraction, and can be detected by looking for pieces of aggregate with freshly exposed surfaces that can be matched so that the smaller pieces fit together to form one larger piece of aggregate.

4.5.2   Complete or partial disintegration to minus 4.75 mm (#4) sieve-sized material.

NOTE 5- Pieces of shaley material which undergo partial disintegration typically lose their sharper edges in the process, and end up with rounded areas that have fresher, darker colors, that are interspersed with more weathered areas that represent the centers of the original fractured faces. The disintegrated material frequently ends up as minus 4.75 mm (#4) sieve-sized material, and may have to be brushed out of the pan into the container of "deleterious" shale with a stiff-bristled brush.

Where a piece of shaley material has completely disintegrated during the test, the disintegrated material will have to be brushed out of the pan into the container of "deleterious" shale with a stiff-bristled brush.

The shaley material that shows these characteristics is considered as being the "deleterious" shale fraction. Weigh the shale, and record the weight (D_s) to the nearest tenth of a gram. Weigh the remaining "non-deleterious" fraction, and record its weight to the nearest tenth of a gram.

NOTE 6- Depending on how the sample was processed, this "non-deleterious" fraction may consist only of "non-deleterious shaley material" (N_s), or it may consist of "non-deleterious shaley material and other rock types" (N_{sr}) (Section 3).

5.   CALCULATIONS

5.1   Check for excessive loss of material during the pour-off of water

5.1.1   Bulk processed aggregate samples (Section 3.1.6.1)

W_o = weight of the final test sample
C_s = weight of cracked pieces of shaley material removed before the
start of the test
D_s = weight of deleterious shale after the end of the test
N_{sr} = weight of non-deleterious shaley material and other rock types after the
end of the test

Add together the following weights: C_s, D_s, and N_{sr}. These three weights, when added together, normally do not differ from W_o, the final test sample weight, by more than 2 g. If the total of these three weights is more than 3 g less than W_o, then material has been lost during the pour-off of water at the end of the soaking periods. The sample shall be discarded and the test repeated using a fresh sample.

5.1.2   Bulk unprocessed aggregate samples (Section 3.2)

W_o = weight of the final test sample
D_s = weight of deleterious shale after the end of the test
N_{sr} = weight of non-deleterious shaley material and other rock types after
the end of the test

Add together the following weights: D_s and N_{sr}. These two weights, when added together, normally do not differ from W_o, the final test sample weight, by more than 2 g. If the total of these two weights is more than 3 g less than W_o, then material has been lost during the pour-off of water at the end of the soaking periods. The sample shall be discarded, and the test repeated using a fresh sample.

If the sample was not washed, the total of D_s and N_{sr} shall be no more than 4 g less than W_o. Otherwise, the test shall be repeated using a fresh sample.

5.1.3   Shaley material fraction from processed aggregate samples (Section 3.2), and shaley material fraction from asphalt-extracted aggregate samples (Section 3.3).

S_o = weight of the shaley material fraction of the sample
C_s = weight of the cracked pieces of shaley material removed before the start
of the test
D_s = weight of deleterious shale after the end of the test
N_s =weight of non-deleterious shaley material after the end of the test

Add together the following weights: C_s, D_s, and N_s. These three weights, when added together, normally do not differ from S_o, the original weight of the shaley material fraction, by more than 1 g. If the total of these three weights is more than 2 g less than S_o, then material has been lost during the pour-off of water at the end of the soaking periods. The sample shall be discarded, and the test repeated using a fresh sample.

5.1.4   Shaley material fraction from unprocessed aggregate samples (Section 3.2).

S_o = weight of the shaley material fraction of the sample
D_s = weight of deleterious shale after the end of the test
N_s = weight of non-deleterious shaley material after the end of the test

Add together the following weights: D_s and N_s. These two weights, when added together, normally do not differ from S_o, the original weight of the shaley material fraction, by more than 1 g. If the total of these two weights is more than 2 g less than S_o, then material has been lost during the pour-off of water at the end of the soaking periods. The sample shall be discarded, and the test repeated using a fresh sample.

If the sample was not washed, the total of D_s and N_s shall be no more than 4 g less than S_o. Otherwise, the test shall be repeated using a fresh sample.

5.2   Percent deleterious shale calculation

W_o = original total weight of the entire sample
D_s = weight of deleterious shale found in the sample after the test
P_{ds} = percent deleterious shale in the sample

Calculate the percent of deleterious shale in the sample, using the following formula:

$$P_{ds} = \frac{D_s}{W_o} x100$$

6.   REPORT

6.1   Report the percent of deleterious shale found in the sample to the nearest tenth of a percent. Specify the type of sample on which the test was performed (Section 3), and state how the sample was prepared for the test. If a specification limit for deleterious shale applies to the sample, state whether the sample meets or fails to meet the applicable specification limit. Finally, state in a clear and concise manner the qualifications of the person who performed the petrographic analysis or identified the presence of shaley material in the sample.

7.   REFERENCES

Publication 408 (Specifications)
AASHTO M-92
AASHTO M-231
AASHTO T-2
AASHTO T-248

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF SHAPE INDEX

1.   SCOPE

1.1   This method of test describes the procedure for determining the shape index of a sample of coarse aggregate.

1.2   The shape index of an aggregate is the percentage by mass of particles whose least dimension (thickness) is less than three fifths of their mean dimension. This test is not applicable to material passing a 6.35 mm (1/4") sieve.

2.   APPARATUS

2.1   Gauge - A metal thickness gauge made to the specifications shown in Figure 1.

2.2   Balance - The balance shall conform to the requirements described in Table 2 of AASHTO M-231.

2.3   Container - Pans of a size sufficient to contain the appropriate size fractions.

3.   TEST SAMPLES

3.1   Obtain a sample in accordance to Note 1 below. Select a test portion in accordance with AASHTO T-248. The test portion shall not be less than the mass specified in the following table.

	Approx. Min. Mass	
Gradation	kg.	lb.
No. 8	0.25	(0.5)
No. 57, No. 67	1.5	(3.0)
2A, No.3	2.5	(5.0)

NOTE 1- It is recommended to perform this test on material first tested by PTM 100.

4.   SIEVING

4.1   The test portion shall be separated into the appropriate size fractions from Table 1 by sieving in accordance with PTM 616.

4.2   Discard all material passing the 6.3 mm (1/4") sieve.

Table 1
Size of Material

Passing	Retained
63 mm (2½")	50 mm (2")
50 mm (2")	37.5 mm (1½")
37.5 mm (1½")	25.0 mm (1")
25.0 mm (1")	19.0 mm (3/4")
19.0 mm (3/4")	12.5 mm (1/2")
12.5 mm (1/2")	9.5 mm (3/8")
9.5 mm (3/8")	6.3 mm (1/4")

5.   SEPARATION OF FLAT MATERIAL

5.1   Each size fraction shall be tested piece by piece for its ability to pass through the appropriate slotted gauge.

5.2   Determine to the nearest gram the mass of flat material in the test portion obtained in Section 5.1, then add the retained portion and record the mass of the flat material and the total mass of the test portion.

6.   CALCULATIONS

6.1   The percentage of flat material shall be determined as follows:

$$Shape\ Index = \frac{A}{B} x100$$

Where:

A = Mass of the flat material

B = Total mass of the test portion

7.   REPORT

      7.1   Report the Shape Index to the nearest percent

8.   REFERENCES

      BS 812
      PTM 100
      PTM 616
      AASHTO M-231
      AASHTO T-2
      AASHTO T-248

These sizes
marked on gauge

4 in.

$2\frac{1}{2}$ to 2

2 to $1\frac{1}{2}$

$3\frac{1}{2}$" in.

$1\frac{1}{2}$ to 1

3 in

1 to $\frac{3}{4}$

$2\frac{1}{2}$ in.

$\frac{3}{4}$ to $\frac{1}{2}$

2 in

$\frac{1}{2}$ to $\frac{3}{8}$

1.5 in

$\frac{3}{8}$ to $\frac{1}{4}$

1 in

0.188 in

0.263 in

0.375 in

0.525 in

0.750 in

1.350 in.

1.050 in.

$1\frac{1}{4}$ to 1

$2\frac{3}{4}$ in

0.575 in
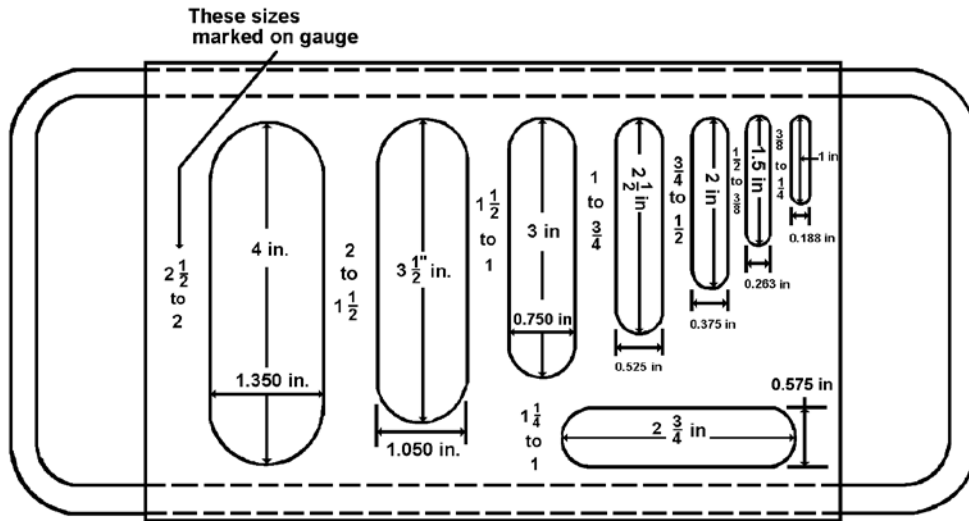
0.598 (16 MSG) steel sheet
rolled over 5/16 dia. bar

Metric conversion table

METRIC mm	101.60	88.900	76.200	69.850	63.500	50.800	38.100	34.290	31.750	26.670
ENGLISH in.	4.000	3.500	3.000	2.750	2.500	2.000	1.500	1.350	1.250	1.050
METRIC mm	25.400	19.050	14.605	13.335	12.700	9.525	6.680	6.350	4.775	
ENGLISH in.	1.000	0.750	0.575	0.525	0.500	0.375	0.263	0.250	0.188	

Figure 1. Thickner Gauge

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LABORATORY TESTING SECTION

Method of Test for

MOLDING OF CYLINDERS FOR TESTING COMPRESSIVE STRENGTH OF
NON-SHRINK GROUTS

1.   SCOPE

        1.1   This method covers the molding and curing procedure for making cylinders for
testing the compressive strength of non-shrink grout mixes in the field.

2.   APPARATUS

        2.1   Specimen Molds - The molds shall be in conformance with PTM 611, except that
their size shall be 75 x 150 mm (3 x 6 in.) or larger.

        2.2   Tamping Rod - The rod shall be a round, straight, steel rod 16 mm (5/8 in.) in
diameter and 300 mm (12 in.) long with at least the tamping end rounded to a hemispherical tip
of the same diameter.

        2.3   Small Tools - Tools and items that may be required such as shovels, pails,
trowels, and scoops.

3.   SAMPLING GROUT

        3.1   The elapsed time between obtaining the first and final portions of the composite
samples shall be as short as possible, but in no instance shall it exceed 10 minutes.

        3.2   Obtain a sufficient amount of grout to make six test cylinders. Place this sample
of grout in a pail or other container in preparation for molding the specimens.

        3.3   Sampling from mixing machines -All sampling shall be done in accordance with
PTM 601, except where pumped grout is used.

                3.3.1 Sampling from the Grout Pump Discharge - Sample the grout at two or
more regularly spaced intervals during discharge from the middle portion of the batch. To insure
that the middle portion of the batch is being sampled, coordinate timing with the pump and mixer
operators.

4.   MOLDING SPECIMENS

        4.1   Place of Molding - Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and disturbances, at a place as near as practicable to the location where the specimens are to be stored until the grout sets.

        4.2   Placing the Grout

                4.2.1   Place the grout in the cylinder in two equal layers using a scoop or trowel.

                4.2.2   Rod each layer with the rounded end of the rod using 25 strokes per layer. Distribute the strokes uniformly over the cross section of the mold and for the upper layer of the specimen allow the rod to penetrate about 13 mm (1/2") into the underlying layer. If the tamping rod leaves voids, tap the sides of the mold lightly to close the voids.

                4.2.3   After consolidation, bring the excess grout to the center, leaving excess grout piled slightly high. Finish the grout to a level surface flush with the top of the mold using the straight edge of a trowel or a strike-off bar. Then, immediately place the tight fitting caps over the tops of the cylinders.

5.   CURING

        5.1   Curing - Do not disturb or move the specimens between 15 minutes and 22 hours after molding. Store the molds containing the test specimens under conditions that maintain the temperature immediately adjacent to the molds in the range of 16 to 27º C (60 to 80º F). Keep the molds sealed until just prior to testing. Test the cylinders in accordance with PTM 604.

                NOTE 2 - If cylinders are to be capped, remove them from the molds at least an hour before testing. After capping keep the cores moist. Capping, if required, shall be carried out according to Section 8, PTM 611.

6.   REFERENCES
        PTM 604
        PTM 611
        ASTM C 31

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LABORATORY TESTING SECTION

Method of Test for

DETERMINING DURABILITY OF AGGREGATE USING THE MODIFIED WASHINGTON
DEGRADATION TEST

1.   SCOPE

        1.1   This method of test covers a procedure for determining the durability of aggregate
for use in construction, using the Modified Washington Degradation Test.

2.   APPARATUS

        2.1   Sieves- Standard 203 mm (8") sieves, meeting the requirements of
AASHTO M-92 (2.00 mm (No. 10), 75 µm (No. 200), 12.5 mm (1/2"), and 6.3 mm (1/4")).

        2.2   Sieve shaker- Standard Tyler sieve shaker or equivalent

        2.3   Plastic canister- About 175 mm (7") in diameter and 100 mm (4") high with a lid.
The sides shall be perpendicular or have a slope of no more than 5 degrees (the top being wider
than the base).

        2.4   Graduated cylinder- A graduated cylinder of 500 mL capacity

        2.5   Funnel- A metal funnel with a top large enough to hold a 203 mm (8") sieve. The
bottom must be able to fit into a 500 mL graduated cylinder.

        2.6   Sand Equivalent cylinder- A 432 mL cylinder, graduated in 2.54 mm (1/8")
increments from 0 to 381 mm (0 to 15")

        2.7   Oven- Capable of maintaining a uniform temperature of 60 ± 3 ℃ (140 F ± 5°F).

        2.8   Balance- Conforming to the requirements of AASHTO M-231, Class G2

3.   SAMPLE

    3.1   Samples of each aggregate are graded over nested 12.5 mm (1/2"), 6.3 mm (1/4"), and 2.00 mm (No. 10) sieves. 250 grams of the material passing the 12.5 mm (1/2") sieve, retained on the 6.3 mm (1/4") sieve are added to 250 grams of material passing the 6.3 mm (1/4") sieve, retained on the 2.00 mm (No. 10) sieve.

4.   PROCEDURE

    4.1   The 500 gram sample is placed in a plastic canister with 100 mL of water. The canister is then tightly covered and placed on a sieve shaker and shaken. Following this shaking, the canister is emptied into nested 2.00 mm (No. 10) and 75 µm (No. 200) sieves that have been placed in a funnel over a 500 mL graduate. The canister is washed out and the aggregate in the sieves is washed until the graduate is filled to 500 ml mark. The material in the graduate is brought into suspension by turning the cylinder upside down approximately l0 times; the liquid is poured into a sand equivalent cylinder into which 3.5 mL of sand equivalent solution has been previously placed. Fill the cylinder to the 381 mm (15 inch) mark. The sand equivalent cylinder is inverted twenty times in about thirty-five seconds, and then allowed to sit for twenty minutes at which time the height of the sediment is measured. The aggregate retained on the 2.00 mm (No. 10) and 75 µm (No. 200) sieves is oven-dried, re-sieved, and the mass of material retained on these sieves determined. Loss through each sieve is determined as follows:

$L_{2.00}$ = 500 - mass of material retained on the 2.00 mm (No.10) sieve after re-sieving.

L_{75} = $L_{2.00}$ - mass of material retained on the 75 µm (No.200) sieve after re-sieving.

5. CALCULATIONS

5.1 After the test results are obtained, the degradation factor (D) is computed using the following formula:

$$D = \left[0.3 \left(100\, \frac{L_{75}}{L_{2.00}} \right) + 0.7 \left(\frac{6 - 0.4H}{6 + 0.6H} \right) \times 100 \right]$$

Where:

L_{75} = Mass of material lost through the 75 mm (No. 200) mesh sieve

$L_{2.00}$ = Mass of material lost through the 2.00 mm (No. 10) mesh sieve

H = Height of sediment in the sand equivalent cylinder.

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LABORATORY TESTING SECTION

Method of Test for

DETERMINING THE FREEZE-THAW RESISTANCE OF LIGHTWEIGHT AGGREGATE

1.   SCOPE

        1.1   This method of test covers a procedure for determining the resistance of lightweight coarse aggregate to repeated cycles of rapid freezing and thawing.

2.   EQUIPMENT

        2.1   Container - A wire mesh container capable of holding at least 1000 grams of aggregate. The mesh of this container shall have approximately 2.36 mm (No. 8) square openings.

        2.2   Freezing and Thawing Apparatus

        2.2.1   The freezing and thawing apparatus shall consist of a suitable chamber or chambers in which the specimens may be subjected to the specified freezing and thawing cycle, together with the necessary refrigerating and heating equipment and controls to produce continuously, and automatically, reproducible cycles within the specified temperature requirements. In the event that the equipment does not operate automatically, provisions shall be made for either its continuous manual operation on a 24 hour a day basis or for the storage of all specimens, in a frozen condition, when the equipment is not in operation.

        2.2.2   The apparatus shall be so arranged that each specimen is completely surrounded by air during the freezing phase of the cycle and by water during the thawing phase.

        2.3   Sieves – Standard 203 mm (8") sieves, meeting the requirements of AASHTO M-92 (12.5 mm (1/2 inch), 4.75 mm (No. 4), and 2.36 mm (No. 8)).

        2.4   Oven - An oven capable of maintaining a uniform temperature of 60 ± 3 ºC (140 ± 5 ºF).

3.   FREEZING AND THAWING CYCLE

3.1   The nominal freezing and thawing cycle for this test method shall consist of alternately lowering the temperature of the specimens from 4.4 to -17.8 ℃ (40 to 0 ℉) and raising it from -17.8 to 4.4℃ (0 to 40℉) in not less than 2 nor more than 5 hours. Not less than 20% of the time shall be used for thawing.

3.2   At the end of the cooling period, the temperature at the centers of the specimens shall be -17.8 ± 1.7℃ (0 ± 3℉). At the end of the heating period the temperature shall be 4.4 ± 1.7℃ (40 ± 3℉).

4.   SAMPLE

4.1   Grade a sample of the lightweight aggregate over the 12.5 mm (1/2 inch) and 4.75 mm (No. 4) sieves for 25 mm (1") and 19.0 mm (3/4") size aggregate; use 12.5 mm (1/2 inch) and 2.36 mm (No. 8) sieves for 12.5 mm (1/2") and 9.5 mm (3/8") size aggregate. Select approximately 800 grams of aggregate that passes the 12.5 mm (1/2 inch) and is retained on the 4.75 mm (No. 4) or 2.36 mm (No. 8) sieves for testing.

5.   PROCEDURES

5.1   Oven dry the sample at a temperature of 60℃ (140^{o}F) for 24 hours. Allow the sample to cool to room temperature and determine the mass to the nearest 0.1 gram.

5.2   Place the sample under water for 24 hours. The water shall be maintained at a temperature of 22 ± 3 ℃ (72 ± 5℉).

5.3   At the end of the 24-hour-soaking period, pour the sample into the wire mesh basket, being careful not to lose any pieces.

5.4   Place the basket and aggregate into the freezing and thawing apparatus and allow the sample and basket to remain there for 300 cycles.

5.5   At the end of 300 cycles remove the basket and sample from the freezing and thawing apparatus and place them in the oven. Oven dry the sample at 60 ℃ (140℉) for 24 hours. Sieve the oven-dry aggregate over a 4.75 mm (No. 4) or 2.36 mm (No. 8) sieve (depending or the size of course aggregate being tested) and weigh the amount retained.

6.   CALCULATIONS

6.1   Calculate the percent loss as follows:

$$L = \frac{W_i - W_f}{W_i} \times 100$$

Where:

L = % of aggregate loss through the 4.75 mm (No. 4) or 2.36 mm (No. 8) at the end of 300 cycles

W_i = initial mass of the sample at the start of the test

W_f = mass of aggregate retained on the 4.75 mm (No. 4) or 2.36 mm (No. 8) at the end of 300 cycles.

7.   REPORT

7.1   The percent loss after 300 cycles of freezing and thawing shall be reported to the nearest tenth of a percent.

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LABORATORY TESTING SECTION

Method of Test for

DETERMINING THE RATE OF ABSORPTION OF LIGHTWEIGHT AGGREGATE

l.   SCOPE

l.1   This method of test covers the determination of the rate of absorption of coarse lightweight aggregate. The speed at which lightweight aggregate absorbs water is related to its durability. This test provides a test value called an aggregate absorption factor (AAF).

2.   APPARATUS

2.l   Balance - Conforming to the requirements of AASHTO M-231, Class G2.

2.2   Container - A glass Mason jar fitted with a conical brass cap with a hole 6.4 mm (1/4") in diameter in the top of the cap.

2.3   Oven - An oven capable of maintaining a uniform temperature of 60 ± 3 °C (140 F ± 5°F)

3.   SAMPLE

3.l   Approximately 400 grams of the aggregate shall be selected by quartering the sample to be tested.

4.   PROCEDURE

4.l   The sample shall be dried in an oven at a temperature of 60 °C (140 °F) for 24 hours. The sample shall then be allowed to cool to room temperature and the mass determined to the nearest 0.l gram.

4.2   After weighing, the sample shall be placed in the Mason jar and the jar filled with distilled water. The cap shall be placed on the jar and water added to fill the jar completely. The jar with sample and water shall then be weighed to the nearest 0.l gram. With a little practice, this first weighing can be accomplished within two minutes after the water is first introduced into the container. Weighing's shall be made at intervals of 2, 4, 6, 8, 10, 20, 30, 60 and 90 minutes and 2, 4, 6, and 24 hours from the beginning of the test, taking care to agitate the sample by rolling and shaking the jar to remove any air trapped between the particles and refilling the jar so that a constant volume is maintained before each weighing is made.

5.   CALCULATIONS

5.1   Calculate the percent absorption at each time interval using the following formula:

$$A = \frac{(W_x - W_i)}{W_s} \times 100$$

Where:

A = % absorption

W_x = mass of the jar, water, and sample at each time interval

W_i = initial mass of the jar, water and sample

W_S = mass of the oven dried sample

5.2   Plot a graph with the percent absorption values on the vertical axis and time in minutes on the horizontal axis. Draw a smooth line through the points.

5.3   Determine the percent absorption at 100 minutes (A_{100}) and 1000 minutes (A_{1000}) from the graph. Calculate the aggregate absorption factor (AAF} as follows:

$$AAF = A_{1000} - A_{100}$$

6.   REPORT

6.1   The report shall include the following:

6.1.1   The graph of the percent absorption versus time with A_{100} and A_{1000} marked on the line.

6.1.2   The aggregate absorption factor reported to the nearest tenth of a percent.

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING FRESH CONCRETE

This PTM is a modification of AASHTO R-60. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications of AASHTO R-60 are as follows:

5.   PROCEDURE

      5.2.4   Sampling from Revolving Drum Truck Mixers or Agitators- The sample shall be taken from the first one-third of the batch and the subsequent portions if required, except that samples shall not be taken at the beginning or end of discharge. Sampling shall be done by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream completely so that it discharges into a container. The rate of the discharge of the batch shall be regulated by the rate of revolution of the drum, and not by the size of the gate opening. The slump and air content of the concrete shall be determined before one-third of the batch has been placed.

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LABORATORY TESTING SECTION

Method of Test for

COMPRESSIVE STRENGTH OF MOLDED CONCRETE CYLINDERS

This PTM is a modification of AASHTO T-22. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 2001 (www.transportation.org).

The modifications to AASHTO T-22 are as follows:

1.   SCOPE

1.5   A compressive strength test of concrete shall consist of two or more specimens of the same age prepared from the same sample of concrete. Specimen results that deviate from each other by approximately 6.9 Mpa (1000 psi or more) shall be considered invalid.

7.   PROCEDURE

7.1.1   Independent Assurance (IA) samples shall be cured and tested under the same conditions in which the structure the samples came from experienced.

7.3.1   Due to the time needed for shipment of samples to the Laboratory Testing Section, a permissible tolerance of +10 days is allowed for testing compressive strength samples at 28 days for field samples obtained by the Innovation and Support Services Division, Construction QA Section.

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MATERIALS AND TESTING DIVISION

Method of Test for

EVALUATING PORTLAND CEMENT CONCRETE PAVEMENT THICKNESS

1.   SCOPE

1.1   This method covers the procedure for measuring pavement thickness of Portland Cement Concrete (PCC) pavement.

2.   EQUIPMENT

2.1   An electromagnetic pulse induction device that generates a variant magnetic field that creates an eddy current in a reflector capable of measuring pavement thickness

2.2   Steel targets, 11.8 inches in diameter, 24 gauge, meeting ASTM A 653, Type II commercial steel with a G90 coating (about 0.45 oz/SF per side)

2.3   Verification platform(s)

3.   VERIFICATION OF EQUIPMENT

3.1   A platform(s) shall be constructed similar to those shown in Figure 1 to verify the accuracy of the gauge readings. The platform heights shall be approximately 6, 9 and 12 inches. An adjustable platform may also be used.

3.2   A steel target shall be placed in the platform.

3.3   The device shall be operated to locate the center of the target. The distance to the target shall be determined. Record the reading.

3.4   Repeat Step 3.3 until five (5) readings have been recorded for each of the designated platform heights.

3.5   The average height shall be determined in accordance with Section 5.1.4 for each designated height.

3.6   Verification of the device shall be considered acceptable if the average height is within 0.125 inch of each of the designated heights. If verification of the device is not obtained, determine and address the cause, then repeat the verification process. A new calibration function may need determined for the targets being used (see Appendix A).

Figure 1, Verification Platforms

4.   SELECTION OF TARGET LOCATIONS

4.1   Acceptance of the PCC pavement thickness shall be on the basis of consecutive probability test measurement results for each Lot. Each Lot will be comprised of Sublots of approximately 600 SY of pavement. One test location shall be established for each Sublot. Test locations are to be selected by means of a random testing plan as outlined herein.

4.2   Steel dowel bars and tie bars interfere with the accuracy of the results, therefore, test locations shall be excluded from within 5 feet of a doweled joint and from within 4 feet of a tied joint. The "X" value of PTM No. 1 shall be multiplied by the Sublot length to determine the pavement slab to be tested for each Sublot.

4.3   For pavements with tied longitudinal joints greater than 10 feet in width, two (2) steel targets shall be transversely placed 4 feet from each longitudinal joint near the approximate longitudinal center of the pavement slab determined in Section 4.2. The L/R indicator of the corresponding "Y" value of PTM No. 1 shall be used to determine which target will be tested. The decimal fraction contained in the "Y" value shall not be used.

For all other pavements, one (1) steel target shall be placed near the approximate center of the pavement slab determined in Section 4.2.

The targets shall be secured to the base course with nail(s) to prevent movement during paving operations at the determined random locations. If the target location is within 5 feet of a doweled joint and/or within 4 feet of a tied joint, adjust the location to the closest testable area.

5.   PROCEDURE

5.1   The manufacturer's instructions for operating the thickness gauge shall be followed. It is important to avoid testing close to any steel including vehicles, equipment, steel-toed shoes as well as tie bars, dowel bars, and manhole covers. Keep steel-toed shoes and other metal objects at least 2 feet from the gauge during the test. Testing may be conducted as soon as the concrete has reached sufficient strength to prevent damage to the surface.

5.1.1   The selected target shall be located with the gauge. The gauge shall be moved over the target at a steady speed. The calculated thickness shall be displayed on the gauge immediately after the scan and recorded.

5.1.2   Three readings shall be taken at each target location. The readings should all be within 0.125 inch of each other. If the difference between any of the readings is more than 0.125 inch, 2 additional readings shall be obtained. If the two additional readings are within 0.125 inch of any of the first 3 readings, the measurement is valid for that location. If not, it shall be noted that the readings for the location are not valid and select the next target location for testing.

5.1.3   US manufactured targets may produce a slight bias on the unit and therefore, a correction factor may need to be established and applied to each reading. All calculated readings shall be recorded.

5.1.4   The Sublot thickness shall be the average of the calculated readings obtained in Section 5.1.3 and recorded using the following calculation:

$$\overline{X} = \frac{\sum x}{n}$$

Where: $\overline{X}$ =   average Sublot thickness
$\sum x$ =   sum of the calculated thickness readings
n =   number of thickness readings

APPENDIX A

TARGET PLATE CALIBRATION PROCEDURE
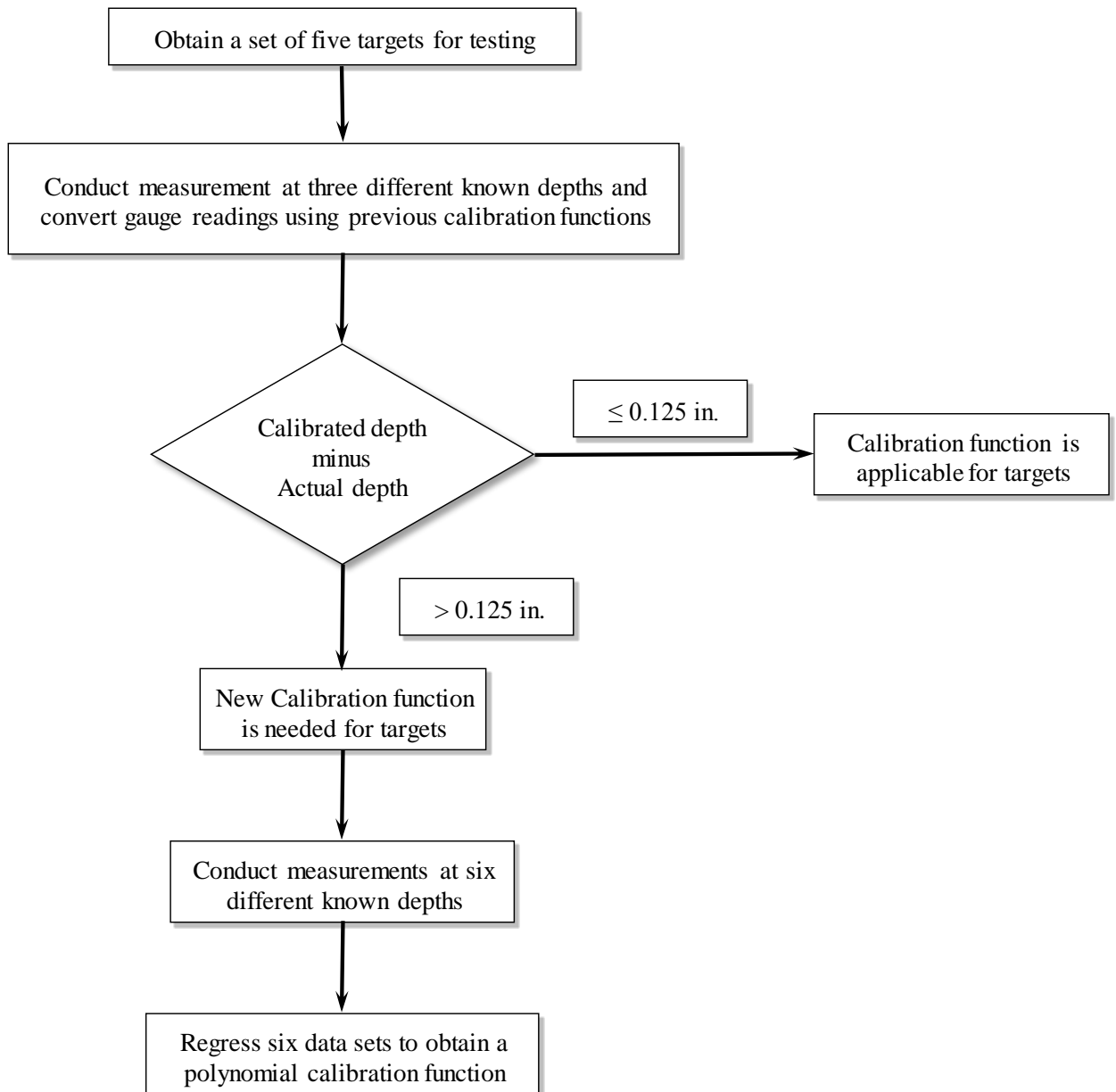
```
┌─────────────────────────────────────────┐
│  Obtain a set of five targets for testing │
└─────────────────────────────────────────┘
                    │
                    ▼
┌──────────────────────────────────────────────────────┐
│  Conduct measurement at three different known depths and │
│  convert gauge readings using previous calibration functions │
└──────────────────────────────────────────────────────┘
                    │
                    ▼
              ◇ Calibrated depth ◇        ≤ 0.125 in.    ┌──────────────────────┐
              ◇    minus         ◇ ─────────────────────▶│ Calibration function is │
              ◇ Actual depth     ◇                       │ applicable for targets  │
                    │                                     └──────────────────────┘
                    │  > 0.125 in.
                    ▼
        ┌──────────────────────┐
        │  New Calibration function │
        │  is needed for targets    │
        └──────────────────────┘
                    │
                    ▼
        ┌──────────────────────┐
        │  Conduct measurements at six │
        │  different known depths      │
        └──────────────────────┘
                    │
                    ▼
        ┌──────────────────────────┐
        │  Regress six data sets to obtain a │
        │  polynomial calibration function   │
        └──────────────────────────┘
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Laboratory Testing Section

Method of Test for

OBTAINING AND TESTING DRILLED CORES OF CONCRETE

1. Scope

    1.1   This method covers the procedures for obtaining, preparing, and testing cores drilled from concrete for length or for compressive strength determinations. This method replaces previously referenced AASHTO T 24 regarding obtaining and drilling cores of concrete

2. Apparatus

    2.1   Core drill, for obtaining cylindrical core specimens diamond drill shall be used.

3. Sampling

    3.1   General. Do not take samples of hardened concrete for use in the preparation of strength test specimens until the concrete has reached sufficient compressive strength to permit sample removal without disturbing the bond between the mortar and the coarse aggregate. In general, the concrete shall be 14 days old before the specimens are removed. Cores submitted for evaluation of compressive strength must be at least 28 days old. When preparing strength-test specimens from samples of hardened concrete, do not submit samples that show abnormal defects or samples that have been visibly damaged in the process of removal (Note 1).

NOTE 1 - Utilize a pachometer to locate reinforcement. Cores for determining compressive strength that contain embedded reinforcement can yield either higher or lower values than cores without embedded steel and will not be tested with reinforcement present. Cores containing reinforcement can be submitted for testing, provided they are sufficient in length to obtain a L/D of 1.00 after removal of the reinforcement.

    3.2   Core Drilling. A core specimen taken perpendicular to a horizontal surface shall be located, when possible, so that its axis is perpendicular to the bed of the concrete as originally placed. A specimen taken perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a unit of deposit when possible, and not near formed joints or obvious edges of a unit of deposit.

4. Length of Drilled Core Specimens

    4.1   Length of Specimens. A core specimen for the determination of length shall have a diameter of at least 2 in.

    4.2   Procedure for Length Determination. Measure the lengths of cores in accordance with the provisions of the Method of Measuring Length of Drilled Concrete Cores (PTM 614).

5.   Compressive Strength

    5.1   Test Specimens. The diameters of core specimens for the determination of compressive strength should be at least 3 times the maximum nominal size of the coarse aggregate used in the concrete, and must be at least twice the maximum nominal size of the coarse aggregate. Obtain the largest practical sized diameter core as possible while avoiding interference and damage or cutting of any structural reinforcement.

        The length of the specimen, when capped, shall be as nearly as practicable twice its diameter. A core having a maximum height of less than 95% of its diameter before capping or a height less than its diameter after capping shall not be tested. Cores submitted for compressive strength testing shall be not less than 2" nor greater than 6" in diameter. Obtain permission from the District Materials Engineer/Manager or Chief Structural Materials Engineer (for precast or prestressed concrete members) if cores less than 4" in diameter shall be submitted for compressive strength testing.

    5.2   End Preparation. The ends of the specimens to be tested in compression shall be essentially smooth, perpendicular to the longitudinal axis, and of the same diameter as the body of the specimen. If necessary, saw or tool the ends of the specimens until the following requirements are met:

        5.2.1 Projections, if any, shall not extend more than 0.2 in. above the normal plate.

        5.2.2 The planes of the ends shall not depart from perpendicularity to the Longitudinal axis by more than 5 degrees.

        5.2.3   The diameters of the ends shall not depart more than 0.1 in. from the mean diameter of the specimen.

    5.3   Moisture Conditioning. Completely submerge the test specimens in lime-saturated water at 73.4 ± 3.0 °F for 48 +/- 2 hours prior to performing the compression test. Test the specimens promptly after removal from water storage. During the period between removal from water storage and testing, keep the specimens moist by covering with a wet blanket or burlap or other suitable absorbent fabric.

    5.4   Capping. Before making the compression test, cap the ends of the specimens in conformance with procedure prescribed in AASHTO T-231. The capped surfaces of the specimens shall conform to the planeness requirements of PTM 611.

5.5   Measurement. Prior to testing, measure the lengths of the capped specimens to the nearest 0.1 in.. Determine the average diameters by averaging two measurements taken at right angles to each other about the mid-height of the specimens. Measure core diameters to the nearest 0.01 in. whenever possible, but at least to the nearest 0.1 in.

5.6   Testing. Test the specimens in accordance with the applicable provisions of the Method of Test for Compressive Strength of Molded Concrete Cylinders (PTM 604).

5.7   Calculations. Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen and any other applicable factors from Table 1 below. If the ratio of length to diameter of the specimen exceeds 2.00, it shall be reduced to as close to 2.00 as practical without exceeding 2.00. LTS will analyze the results for extreme values using PTM 4 at the 5% significance level and compute the average compressive strength, F' cores, after discarding any individual extreme values.

The in-place strength of the concrete is computed using equation 5-7:
Equation 5-7: F'c = F' core x F ld x F dia x F mc
Equation 5-8: F'cores = $\sum$ F'core/n

where:

F'c: factored in-place concrete strength of each core as computed by Equation 5-7

F' core: unfactored compressive strength of individual core

F ld: standard correction factor as indicated in Table 1.0

F dia: variable correction factor based on core diameter as indicated in Table 1.0

F mc: standard correction factor as indicated in Table 1.0

n: total number of cores to be averaged to determine in place concrete strength,
    averaged to nearest whole psi

F' cores: average computed in-place concrete strength

Table 1.0 Magnitude and accuracy of strength correction factors for
        converting core strengths into equivalent in-place strengths.

Primary Factor	Secondary Factor, if applicable [3]	Correction Factor [1]
F ld: L/D ratio	N/A	$1 - \{0.117 - \alpha F'core\}(2 - L/D)^2$
Fdia: Core Diameter	2 in. [2]	1.06
	4 in. [2]	1.00
	6 in.	0.98
F mc: core moisture content	Soaked 48 (+/- 2 hrs) in water	1.09

[1] α: Constant (α) equals 3 x 10 ^ - 6
[2] See section 5.1
[3] Utilize the correction factors for the actual core size received:

Core dia., in.	Correction factor, Fmc
2	1.06
2 1/8	1.06
2 1/4	1.05
2 3/8	1.05
2 1/2	1.04
2 5/8	1.04
2 3/4	1.03
2 7/8	1.03
3	1.03
3 1/8	1.02
3 1/4	1.02
3 3/8	1.01
3 1/2	1.01
3 5/8	1.01
3 3/4	1.01
3 7/8	1.00
4	1.00
4 1/8	1.00
4 1/4	1.00
4 3/8	0.99
4 1/2	0.99
4 5/8	0.99
4 3/4	0.99
4 7/8	0.99
5	0.99
5 1/8	0.98
5 1/4	0.98
5 3/8	0.98
5 1/2	0.98
5 5/8	0.98
5 3/4	0.98
5 7/8	0.98
6	0.98

5.8   Report. Report the results as required by PTM 604 with the following information:

> 5.8.1   Length of test specimen before and after capping, individual core diameter, in-place concrete strength (F'core) as computed using equation 5-7 and average in-place concrete strength (F'core avg)

> 5.8.2   Compressive strength to the nearest 10 psi when the diameter is measured To the nearest 0.01 in. and to the nearest 50 psi when the diameter is nearest 0.1 in., after correction for length-diameter ratio when required,

> 5.8.3   Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed, and

> 5.8.4   The moisture condition at the time of testing.

6.   References

AASHTO: T-24
AASHTO: T-231
ASTMC42
ACI 214.4R-10

End of PTM 606

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING STONE, SLAG, GRAVEL, SAND AND
STONE BLOCK FOR USE AS HIGHWAY MATERIALS

This PTM is a modification of AASHTO T-2. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to AASHTO T-2 are as follows:

4.   Securing Samples

         4.4   Delete Table 1.

                 Table 1 of AASHTO T-2 will be replaced with all standard acceptance and control tests covered by Methods of the Pennsylvania Department of Transportation and specify the quantity of sample required for each specific test as shown in PTM 616, Section 7.4.

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LABORATORY TESTING SECTION

Method of Test for

CALIBRATION OF MECHANICAL SIEVE SHAKER

1.   SCOPE

   1.1   This method of calibration describes a procedure to be used in determining the shaking efficiency of a mechanical sieve shaker.

2.   APPARATUS

   2.1   Balance- The balance or scale shall conform to the following criteria:

Class	Readability and Sensitivity	Accuracy [a]
G2	0.1 g	0.2 g or 0.1%
G5	1	2 g or 0.1%
G20	5 g	5 g or 0.1%
G100	20 g	20 g or 0.1%

   [a]Accuracy equal to the mass stated or 0.1% of the test load, whichever is greater, throughout the range of use.

   NOTE 1- The balance shall have sufficient capacity to handle the greatest weighing made in conducting the test.

   2.2   Sieves- The sieves shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieves shall conform to the requirements of AASHTO M-92.

   2.3   Mechanical Sieve Shaker- A mechanical sieve shaker shall impart a vertical, or lateral and vertical motion to the sieve, causing the particles to bounce and turn so as to present different orientations to the sieving surface.

   2.4   Timers- Electric or mechanical timers shall be accurate and variable in 1 minute increments. The timers shall have a capacity of at least 15 minutes.

   2.5   Oven- The oven shall be capable of maintaining a uniform temperature of 110 ± 5ºC (230 ± 9 ºF).

NOTE 2- Hot plates may be used when test results must be obtained quickly. Confirmation samples shall be tested using ovens as described above.

3.   SAMPLES

3.1   A representative sample sufficient to yield not less than the appropriate mass of dry material, as shown below, shall be selected in accordance with AASHTO T-248. The selection of samples of an exact pre-determined mass shall not be attempted.

3.2   After drying, sample fractions of fine aggregate shall have an approximate mass as follows:

Material with a minimum of 95 percent passing the 2.36 mm (No. 8) sieve…………………………………………...100 g

Material with a minimum of 85 percent passing the 4.75 mm (No. 4) sieve, and more than 5 percent retained on a 2.36 (No. 8) sieve………500 g

NOTE 3- In no case, however, shall the fraction retained on any sieve at the completion of the sieving operation weigh more than 200 g for the usual 203.2 mm (8") diameter sieve. The amount of material retained on the critical sieve may be regulated by the introduction of a larger sieve immediately above the critical sieve or by the selection of a sample of a proper size.

3.3   After drying, samples of coarse aggregate shall have a minimum mass as follows:

AASHTO Number	Minimum Mass of Sample kg	lb.
#3	20	(44)
#5	10	(22)
#57	10	(22)
#67	10	(22)
#7	10	(22)
#8	5	(11)
PA No. 2A	15	(33)

NOTE 4- Samples failing to meet the mass requirements of Sections 3.2 and 3.3 shall be deemed to be insufficient to produce reliable results and shall not be tested. However, the intent of this method will be satisfied for samples of aggregate larger than 50 mm (2") nominal maximum size if a smaller mass of a sample is used, provided the criterion for acceptance or rejection of the material is based on the average of the results of at least three samples. The sample size used times the number of samples averaged shall equal the minimum mass of the

sample shown in Section 3.3. The differences in individual sample sizes shall not vary by mass by more than 20 percent from each other.

4.   PROCEDURE

    4.1   Coarse Aggregate

        4.1.1   This procedure is to be used for each aggregate size produced. After obtaining a representative sample, shake the particular material at least one minute less than the time currently being used on the mechanical sieve shaker for a given aggregate size.

        4.1.2   Weigh and record the amount retained on each individual sieve. Return the amount retained onto each one of the individual sieves where there is a significant amount of material retained. Typically, these are the middle sieves of the gradation.

        4.1.3   Place the first sieve that has a significant amount of material retained on the sieve mesh into the shaking device. Shake for an additional minute. Weigh and record the amount retained on this sieve after one minute of additional mechanical shaking. Follow the same procedure for the remaining individual sieves that have been determined to have a significant amount of material retained.

        4.1.4   Calculation to Determine Shaking Efficiency:

$$P = \frac{W_o - W_a}{W_t} \times 100$$

        Where:

                P = Percentage difference of weight retained on the individual sieve

                W_o = Original weight retained on the individual sieve

                W_a = Weight retained on the individual sieve after additional sieving

                W_t = Total sample weight, dry

4.1.5   When the difference between the weights retained on each individual sieve after additional mechanical sieving and the original sieving is 0.5 %, or less, of the total oven dry sample weight, **FOR ALL SIEVE SIZES**, the shaking time used in Section 4.1.1 is sufficient. If any of the differences calculated are greater than 0.5 % of the total oven dry sample weight, repeat this process outlined above with a new representative sample. Increase the mechanical shaking time by one minute. Repeat the process as many times as necessary, but do not exceed 12 minutes of shaking time for any aggregate on any shaking device. If the shaking device cannot meet this requirement, replace or repair the shaking device.

4.1.6   Example of a Shaking Efficiency Determination:

No. 57 Coarse Aggregate
Total Dry Sample Weight   = 30.00 lbs

	Weight Retained After 7 Minutes of Mechanical Shaking, lbs.	Weight Retained After 1 Minute of Additional Mechanical Shaking, lbs.
Sieve		
5/8 in	6.20	6.10
1/2 in.	12.10	12.00
3/8 in.	4.10	4.00

Calculation to Determine Shaking Efficiency

5/8 in.   6.20 lbs – 6.10 lbs = 0.10 lbs ÷ 30.00 lbs x 100 = 0.3 % difference
1/2 in.   12.10 lbs – 12.00 lbs = 0.10 lbs ÷ 30.00 lbs x 100 = 0.3 % difference
3/8 in.   4.10 lbs – 4.00 lbs = 0.10 lbs ÷ 30.00 lbs x 100 = 0.3 % difference

The results of this calculation to determine shaking efficiency for each of the three sieves indicate that all three sieves meet the 0.5% requirement stated in Section 4.1.5. In this example, therefore, a mechanical shaking time of 7 minutes is sufficient for this #57 coarse aggregate material on this shaking device.

4.2   Fine Aggregate

    4.2.1   This procedure is to be used for each aggregate size produced. Retain the fine aggregate after the wash test and mechanically shake for at least 1 minute less than the time currently being used on the mechanical sieve shaker for a given aggregate size.

    NOTE 5- Washing the sample before performing the shaking efficiency determination is not necessary for bituminous sands and Type 1, 1A, 2, 3, 3A, and 4 anti-skids.

    4.2.2   Weigh and record the amount retained on each individual sieve. Return the amount retained onto each one of the individual sieves where there is a significant amount of material retained. Typically, these are the middle sieves of the gradation.

    4.2.3   Hand sieve each individual sieve size in accordance with AASHTO T-27, Section 8.4 stated as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at a rate of about 150 times per minute, turning the sieve about one-sixth of a revolution at intervals of about 25 strokes. Weigh and record the amount retained on each individual sieve after one minute of additional hand shaking.

    4.2.4   Calculation to Determine Shaking Efficiency:

$$P = \frac{W_o - W_a}{W_t} \times 100$$

Where:

    $P =$ Percentage difference of weight retained on the individual sieve

    $W_o =$ Original weight retained on the individual sieve

    $W_a =$ Weight retained on the individual sieve after additional sieving

    $W_t =$ Total sample weight, dry

4.2.5   When the difference between the weight retained on each individual sieve after additional hand sieving and the original sieving is 0.5 %, or less, of the total oven dry sample weight, **FOR ALL SIEVE SIZES**, the shaking time used in Section 4.2.1 is sufficient. If any of the sieves have differences calculated that are greater than 0.5 % of the total oven dry sample weight, repeat this process outlined above with a new representative sample. Increase the mechanical shaking time by one minute. Repeat the process as many times as necessary, but do not exceed 12 minutes of shaking time for any aggregate on any shaking device. If the shaking device cannot meet this requirement, replace or repair the shaking device.

4.2.6   Example of a Shaking Efficiency Determination:

Type A Concrete Sand
Total dry sample weight   =   490.0 grams

Sieve	Weight Retained After 7 Minutes of Mechanical Shaking, lbs.	Weight Retained After 1 Minute of Additional Mechanical Shaking, lbs.
No. 8	120.0	115.0
No. 16	140.0	138.0
No. 30	100.0	98.0

Calculation to Determine Shaking Efficiency

No. 8   120.0 g – 115.0 g = 5.0 g ÷ 490 g x 100 = 1.0 % difference
No. 16   140.0 g – 138.0 g = 2.0 g ÷ 490 g x 100 = 0.4 % difference
No. 30   100.0 g – 98.0 g = 2.0 g ÷ 490 g x 100 = 0.4 % difference

Although the No. 16 and the No. 30 sieves met the requirement of 0.5 % for this material, the No. 8 sieve did not. Therefore, increase the shaking time for this material to 8 minutes and repeat the process with another new representative sample.

5.   REFERENCES

PTM 616
AASHTO T- 27

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LABORATORY TESTING SECTION

Method of Test for

EVALUATION OF BOND STRENGTH OF CEMENT MORTAR OVERLAYS
BY USE OF THE SHEAR/BOND TEST

1.   SCOPE

        1.1   This method covers a procedure for testing the bond strength of a mortar overlay to cement concrete using a shear/bond test.

2.   APPARATUS

        2.1   Compression-Tension Machine -The testing machine may be of any type of sufficient capacity, and shall be capable of providing the rate of loading prescribed in Section 6.5. The machine must be power operated and must apply this load continuously rather than intermittently and without shock.

              2.1.1   The Compression-Tension Machine shall conform to the requirements of Sections 16, 17, and 18, of ASTM Method E 4, Verification of Testing Machines.

              2.1.2   The testing machine shall be equipped with a steel bearing block (table) on which the specimen holder will rest. This block shall contain T-slots to accommodate a clamping device to clamp the specimen holder securely in place. The ram of the compression machine shall be equipped with a vice-type clamp to hold the shearing collar in place above the specimen holder (see Figure 1 for the position of the specimen holder and shearing collar on the testing machine).

        2.2   Specimen Holder and Shearing Collar -The specimen holder is essentially a metal sleeve welded to a flat metal base. The sleeve is split down its length and is fitted with clamps so that a cylindrical test specimen can be clamped within the sleeve. It is recommended that the diameter of the sleeve be 152 mm (six inches) (NOTE 1). The specimen holder and shearing collar shall be constructed as shown in Figures 2 and 3, respectively.

              NOTE 1 - Any diameter sleeve may be used as long as it conforms to the diameter of the specimens being tested. However, since 152 mm (six-inch) diameter cylinders and cores are the ones in common use, this size is recommended.

2.3 Overlay Mold - A cylindrical piece of plastic or metal about 125 mm (five inches) high which is clamped around the top of a concrete core or cylinder to produce a form for making a 25 mm (one-inch) thick mortar overlay. This mold can easily be made from a plastic cylinder mold. Cut off the upper 125 mm (five inches) of the mold, and then cut one side apart vertically to produce a split sleeve. This sleeve can then be placed around the top of a core or cylinder and clamped into place with a large adjustable hose clamp. Any gap that exists in the sleeve mold can be filled with modeling clay.

3. TEST SPECIMENS

3.1 Cores can be obtained from in-place concrete by drilling, or cylinders can be made in the laboratory. The diameter of the core or cylinders used depends on the size of the specimen holder.

3.2 Drilled Cores - Cores drilled from pavement that has a mortar overlay need no further specimen preparation. These cores shall be immersed in water and soaked for 48 hours prior to testing.

3.3 Laboratory Specimens - Preparing specimens in the laboratory consist of placing a 25 mm (one-inch) thick mortar cap on a core or cylinder of hardened concrete.

3.3.1 Either a previously drilled core or a cylinder of concrete may be used as a base for the overlay cap. The core or cylinder shall be at least 150 mm (six inches) long so that it can be adequately clamped in the specimen holder.

3.3.2 The core or cylinder shall have a flat top with the coarse aggregate exposed; this can best be achieved by sawing a short piece off of one end. The face of the flat end shall then be lightly scarified using sand blasting or acid etching.

3.3.3 After the top face is prepared, the cylinder or core shall be immersed in water and soaked for one hour. This action will saturate the upper part of the core or cylinder and insure that water will not be drawn out of the mortar mix into the concrete.

3.3.4 Place the overlay mold around the top of the prepared cylinder or core and clamp it in position so that it stands 25 mm (one inch) above the face.

4.   MIXING MORTAR AND MOLDING SPECIMENS

        4.1   Mix the mortar in a suitable mechanical mixer, such as that described in ASTM C305. The mixing sequence and proportions shall be in accordance with the manufacturer's instructions if a commercial grout or overlay material is used. If a standard mortar mix is used, it shall be mixed in accordance with the applicable provisions of ASTM Method C 305.

        4.2   Using a medium size brush, brush a slurry of the mix into the top surface of the core or cylinder. Then, pour the mortar into the mold until it is filled. If necessary, the mortar may be tamped into place using the tamper described in ASTM C 109. Strike off the excess mortar using a brass or steel bar and then smooth the surface with the same bar.

5.   CURING SPECIMENS

        5.1   Curing shall be carried out in accordance with the manufacturer's directions except as follows :

                5.1.1   Latex modified mortars - These mortars shall be wet-cured for one day, then dry-cured at $50 \pm 10\%$ RH and 23 ± 3 ℃ (73 ± 5 °F) for 27 days, and then immersed in water at 23 ± 3 ℃ (73 ± 5 °F) for seven days.

                5.1.2   Standard Mortar- This mortar shall be cured in accordance with ASTM C 109.

6.   TEST PROCEDURE

        6.1   Specimens are to be tested in a saturated condition. Therefore, they shall be tested as soon as possible after they are removed from the soaking or curing bath.

        6.2   After taking the specimen out of the bath, insert the specimen into the sleeve of the specimen holder so that the mortar cap plus about 3 mm (1/8 inch) of concrete extend beyond the end of the sleeve.

        6.3   Place the specimen holder on the bottom plate of the compression/tension testing machine.

        6.4   Place the shearing collar in the clamp in the ram (upper platen) of the testing machine. Adjust the position of the specimen holder and the shearing collar until the collar is lined up over the mortar cap (Figure 1). None of the collar shall extend over the concrete. Securely fasten the specimen holder to the plate of the testing machine and the shearing collar to the ram.

6.5   Rate of Loading - Bring the shearing collar down to, but not touching the mortar cap. Begin applying the load continuously and without shock. The load shall be applied at a rate of 1.3 mm/min (0.05 in./min).

6.6   Apply the load until the mortar cap breaks loose from the concrete and record the maximum load carried by the specimen during the test. Note the type of failure; that is, describe whether the shear plane is at the mortar/concrete interface, partly in the mortar, partly in the concrete, etc.

7.   CALCULATION

7.1   Calculate the shear bond strength by using the following formula:

English

$$f_s = \frac{F}{A}$$

Where:

f_s = shear bond strength (psi)

F = load (lbs.)

A = cross-sectional area of the test specimen (sq. in.)

Metric

$$f_s = \frac{F}{A \times 1000}$$

Where:

f_s = shear bond strength kPa

F = load N

A = cross-sectional area of the test specimen m^2

8.   REPORT

    8.1   The report shall include the following:

        8.1.1   Identification number

        8.1.2   Diameter of the specimen

        8.1.3   Cross-sectional area of the specimen

        8.1.4   Maximum load in newtons (pounds)

        8.1.5   Shear bond strength

        8.1.6   Brief description of the shear plane

        8.1.7   Source and age of the specimen

COMPRESSION—TENSION MACHINE MUST HAVE VICE GRIPS TO HOLD SHEARING COLLAR

BASE OF SPECIMEN HOLDER MAY BE HELD ON BASE OF COMPRESSION—TENSION MACHINE WITH "C" CLAMPS, OR BY USING T-SLOT NUTS, CLAMPNG STUDS AND STRAP CLAMPS

FIG 1 POSITION OF SPECIMAN HOLDER AND SHEARING COLLAR ON COMPRESSION MACHINE
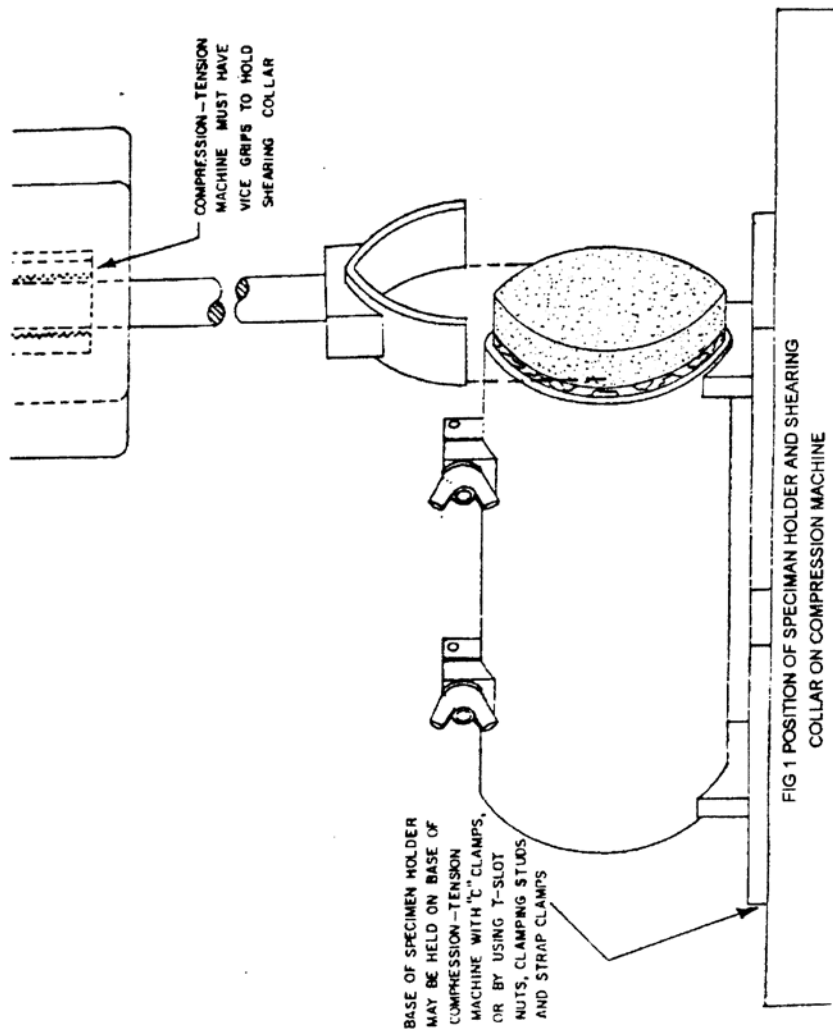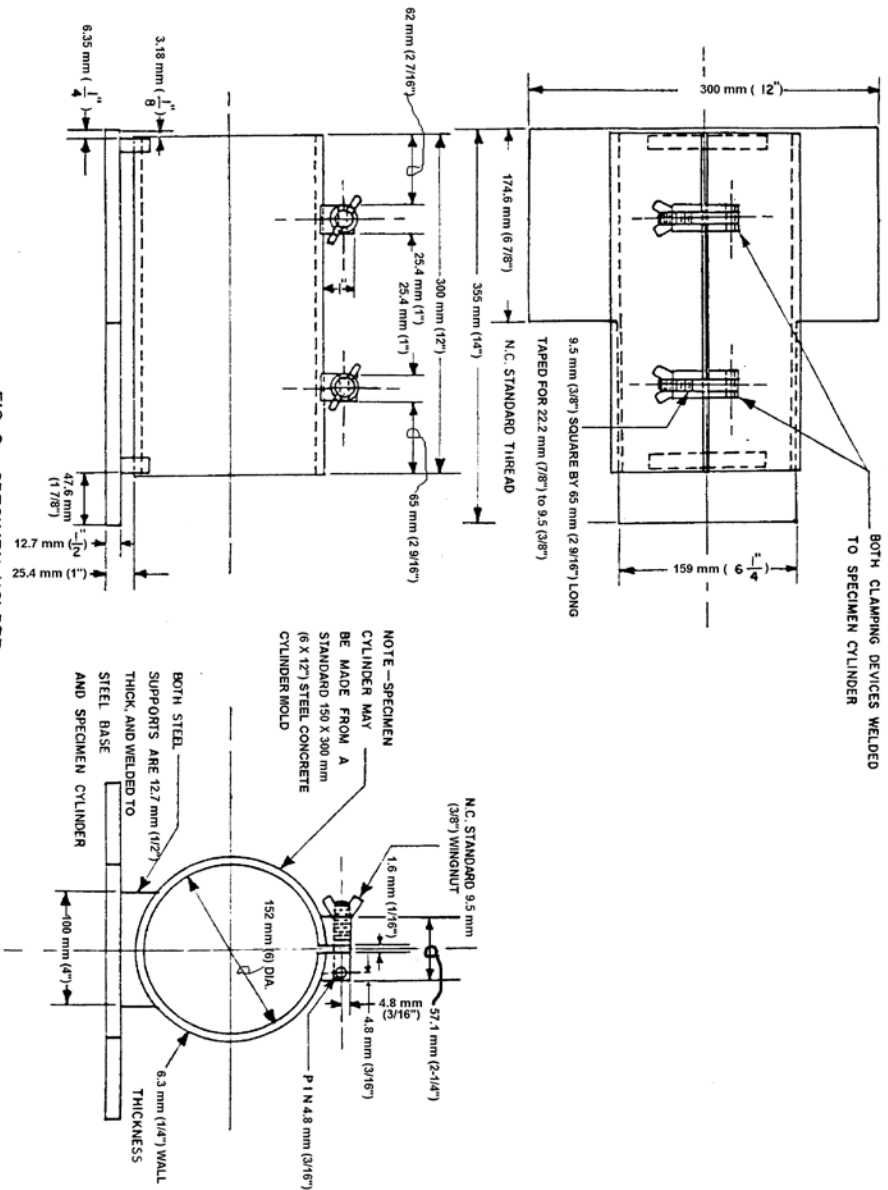
FIG. 2   SPECIMEN HOLDER

FIG. 3 SHEARING COLLAR

482 mm (19")

95 mm (3 3/4")

76 mm (3")

6.4 mm ($\frac{1}{4}$")

7.6 mm (3")
radius

102 mm (4")

31.8 mm (1$\frac{1}{4}$")DIA. STEEL SHAFT

WELD

SHEARING COLLAR MAY
BE CUT FROM STANDARD
150 x 300 mm (6 x 12")
STEEL CONCRETE MOLD

41.3 mm (1 5/8")

25 mm (1")

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LABORATORY TESTING SECTION

Method of Test for

MAKING AND CURING CONCRETE COMPRESSION AND
FLEXURAL TEST SPECIMENS IN THE FIELD

1.   SCOPE

1.1   This method covers the procedures for making and curing specimens of concrete sampled from concrete being used in construction in accordance with AASHTO T-23 and T-231.

2.   APPARATUS

2.1   Molds for Compression Test Specimens- The molds shall be cylindrical, have non-absorbent surfaces and shall be substantial enoug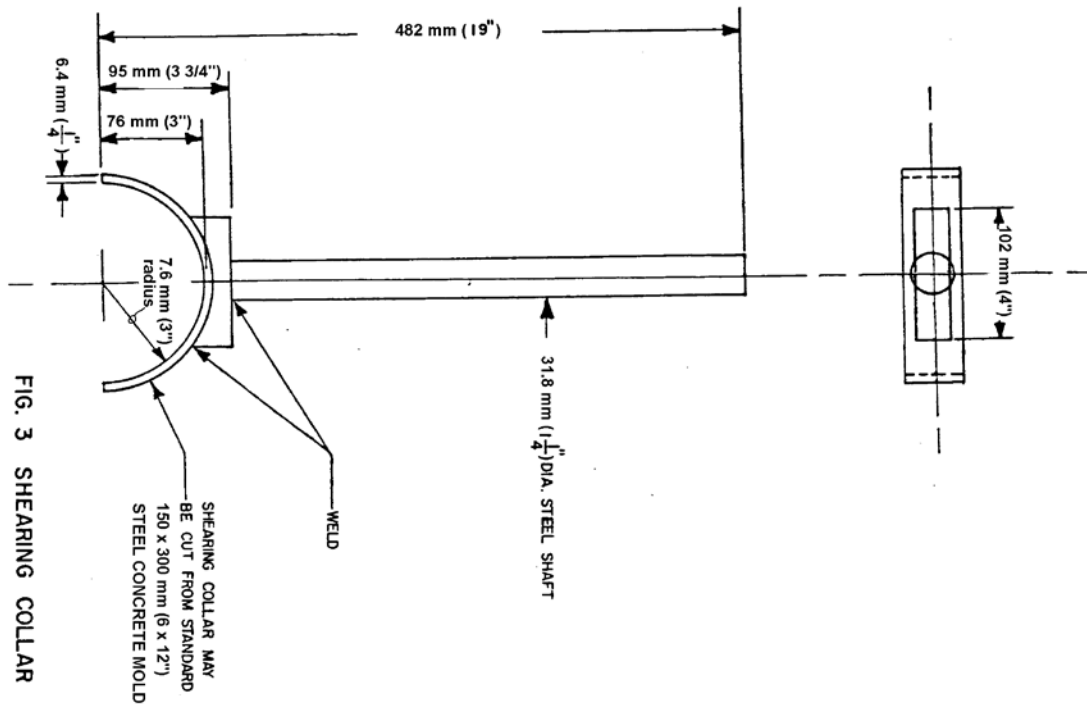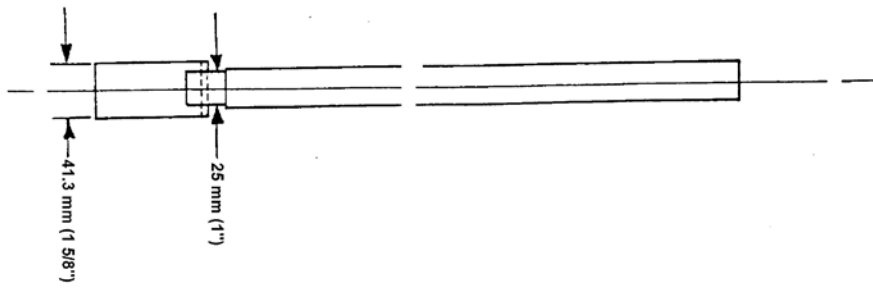h to hold their shape during the molding of test specimens (NOTE 1). All molds shall be provided with tight-fitting caps. The plane of the rim of the mold shall be normal to its axis. The molds shall not vary from the prescribed diameter (Section 6) by more than 1.6 mm (1/16") nor from the prescribed length (Section 6) by more than 6.4 mm (1/4"). No two diameters shall differ more than 3.2 mm (1/8") from each other. Reusable metal molds shall be provided with a machined metal base plate. Molds made of material other than metal shall be provided with a base plate or bottom, with a means for securing the base plate or bottom to the mold at a right angle to the axis of the cylinder. The mold shall stand upright on its base plate or bottom and the top end shall be open to receive the concrete. The assembled mold and base plate or bottom shall be oiled with a light coat of mineral oil before use. The assembly shall be watertight, and a suitable sealant used where necessary to prevent leakage through the joints. Paraffin cardboard molds, and sheet metal molds shall comply with the requirements of the Specification for Single-Use Molds for Forming 152 x 305 mm (6" x 12") or 102 x 203 mm (4" x 8") Concrete Compression Test Cylinders.

NOTE 1- Satisfactory molds may be made from cold-drawn, seamless steel tubing or from steel pipe. These tabular sections shall be cut to the proper length, split at one side parallel to the axis, and fitted with a circumferential metal band and bolt for closing. Split molds shall be machined inside to ensure a perfectly round shape after splitting and clamping. Satisfactory molds may also be made from iron or steel castings. Molds made from formed sheet metal must be used with care to ensure that they are not deformed more than the stipulated tolerances. Paraffin cardboard molds shall be used only under expert supervision. The use of a tube of heavy gage metal around sheet steel or cardboard molds, when the specimen is being molded, will preserve the dimensional integrity of the form. The use of plastic molds is also acceptable.

2.2   Molds for Flexure Test Specimens- Molds for flexure test specimens shall be rectangular and of the dimensions specified in Section 9. The mold shall be at least 50.8 mm (2") longer than the length of the span. Molds shall be watertight and made of rigid, non-absorbent

material. Means shall be provided for securing the base plate firmly to the mold. The inside surfaces of the mold shall be smooth and free from holes, indentations, or ridges. The sides, bottom, and ends shall be at right angles and shall be straight and true so that the specimen will not be warped. Maximum variation from the nominal cross-section shall not exceed 3.2 mm (1/8"). The assembled mold and base plate shall be lightly coated with mineral oil before use.

2.3   Tamping Rod- The tamping rod shall be a round, straight steel rod, 16.0 mm (5/8") in diameter and approximately 610 mm (24") in length, having one end rounded to a hemispherical tip, the diameter of which is 16.0 mm (5/8").

2.4   Vibrators- Internal vibrators may have rigid shafts or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7000 rpm or greater. The outside diameter of the vibrating element shall be not smaller than 19 mm (3/4") nor greater than 38 mm (1½"). The length of the shaft shall be at least 610 mm (24"). External vibrators may be of two types, either table or plant (NOTE 2). The frequency for external vibrators shall be 3600 rpm or higher (preferably higher). For both table and plant vibrators a provision shall be made for clamping the mold securely to the apparatus. A tachometer shall be used to check the frequency of vibration.

> NOTE 2- Vibratory impulses are frequently imparted to table or plank vibrators through electro-magnetic means, or by use of an eccentric weight on the shaft of an electric motor or on a separate shaft driven by a motor.

2.5   Small Tools- Tools and items such as shovels, pails, rubber mallets, trowels, wood floats, blunted trowels, straight-edges, feeler gages, scoops, and rulers shall be provided.

2.6   Slump Apparatus- The apparatus for measurement of slump shall conform to the requirements of the Method of Test for Slump of Portland Cement Concrete (AASHTO T-119).

2.7   Sampling and Mixing Receptacle- A suitable pan, wheelbarrow, or a flat, clean non-absorbent mixing board of sufficient capacity to allow easy mixing by shovel or trowel of the entire sample.

2.8   Air Content Apparatus- The apparatus for measuring air content shall conform to the requirements of the Method of Test for Air Content and Voids of Freshly Mixed Concrete by the Volumetric Method (AASHTO T-196), or by the Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method (AASHTO T-152).

3.   SAMPLING CONCRETE

3.1   Samples of concrete for test specimens shall be taken in accordance with the Method of Sampling Fresh Concrete (PTM 601). The place of depositing the load of concrete that was sampled shall be noted in the job records.

4.   SLUMP AND AIR CONTENT

    4.1   Slump- The slump of each load of concrete sampled for test specimens shall be measured, immediately after sampling, in accordance with AASHTO T-119. Concrete used for the slump test shall be discarded.

    4.2   Air Content- The air content of each load sampled for test specimens shall be determined in accordance with either AASHTO T-152 or AASHTO T-196. Concrete used for determination of air content shall be discarded.

5.   MOLDING SPECIMENS

    5.1   Place of Molding- Specimens shall be molded on a level, rigid, horizontal surface free from vibration and other disturbances, at a place as near as practical to the place where they are to be stored during the first 24 hr. If it is not practical to mold the specimens where they will be stored, they may be moved to the place of storage within 15 minutes after being struck off (NOTE 3). All jarring, striking, tilting, or scarring of the surface of the specimens shall be avoided when moving specimens to a safe place.

        NOTE 3- A trowel slipped under the bottom of a cardboard mold will aid in preventing distortion of the bottom during moving.

    5.2   Method of Consolidation- Concrete at different slump levels require different methods of consolidation to prepare satisfactory test specimens. The selection of the method of consolidation shall be based on the slump, unless the method of consolidation of test specimens is stated in the specifications under which the work is being performed. The two methods of consolidation are rodding and internal or external vibration. Concrete with a slump greater than 76 mm (3") shall be rodded. Concrete with a slump of less than 25 mm (l") shall be consolidated by vibration. Concrete with a slump of 25 - 75 mm (1-3") may be consolidated by either vibration or rodding (NOTE 4).

        NOTE 4- Concrete with a zero slump and relatively dry mixtures used in pipe and block plants may require the use of special means for consolidation. This concrete is not covered by this method.

    5.3   Placing the Concrete- The concrete shall be placed in the molds in two or three layers using a scoop or blunted trowel. In placing each portion of concrete, the scoop or trowel shall be moved around the top edge of the mold as the concrete is discharged in order to ensure a symmetrical distribution of the concrete and minimize segregation of the coarse aggregate within the mold. The concrete may be further distributed by use of a tamping rod prior to the start of consolidation. After consolidation by any of the methods described above, the surface of the concrete shall be struck off without undue manipulation using a straightedge or trowel, the beams are finished with a wood float, and all specimens are covered immediately with glass or metal plates, polyethylene film, or other covering to prevent evaporation.

5.4   Relation between Specimen Size and Aggregate Size- The diameter of the cylindrical specimen or the minimum cross-section dimension of a concrete beam shall be at least three times the maximum nominal size of the coarse aggregate in the concrete. Occasional oversize aggregate particles may be removed by hand picking during the molding of the specimens.

COMPRESSION TEST SPECIMENS

6.   SPECIMENS

6.1   Size of Specimens- Compression test specimens shall be cylindrical, with a length equal to twice the diameter. The standard specimen shall be a 152 mm by 305 mm (6" x 12") cylinder when the nominal maximum size of the aggregate does not exceed 50 mm (2"). When the nominal maximum size of the coarse aggregate does not exceed 25 mm (1"), the specimen may be 102 mm by 203 mm (4" x 8") cylinders, for mix design purposes only. Cylinders 102 mm by 203 mm (4" x 8") are permitted in pre-cast plants as stated in PTM 631. Specimens smaller than 152 mm (6") diameter shall not be made from concrete sampled in the field.

6.2   Molding Specimens- Specimens shall be molded as prescribed in Section 5. An inverted slump cone or suitable funnel may be used to direct concrete into the mold.

6.3   Identification of Specimens- Compression Test Specimens shall be identified as prescribed in Section 12.

7.   METHOD OF CONSOLIDATION

7.1   Rodding- The concrete shall be placed in the mold in three layers of approximately equal volume. Using the tamping rod with the hemispherical tip in contact with the concrete, each of the layers shall be rodded 25 strokes. The bottom layer shall be rodded throughout its depth. The strokes shall be distributed uniformly over the cross-section of the mold, and for each layer the strokes shall penetrate about 25 mm (1") into the underlying layer. If voids are left by the tamping rod, the sides of the mold shall be tapped lightly to close the voids.

7.2   Vibration- A standard duration of vibration shall be observed for the particular kind of concrete, vibrator, and specimen mold involved. Vibration shall be continued only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation. The mold shall be filled and vibrated in two approximately equal layers. All of the concrete for each layer shall be placed in the mold before starting vibration of that layer. The second layer shall be added so as to avoid overfilling by more than 6.4 mm (1/4"). After vibrating the second layer, enough concrete shall be added and worked into the surface concrete with a trowel to overfill the mold about 3.2 mm (1/8") and then struck off. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth in appearance.

7.2.1   Internal Vibration- Three insertions of the vibrator at different points shall be used for each layer. In compacting the bottom layer, the vibrator shall not be allowed to rest on the bottom or touch the sides of the mold. The vibrator shall penetrate through the second layer and into the bottom layer by approximately 25 mm (1"). Care shall be taken that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen.

7.2.2   External Vibration- When external vibration is used, care shall be taken to ensure that the mold is rigidly attached to or securely held against the vibrating element or surface.

8.   CAPPING SPECIMENS

8.1   General Provisions- The ends of all compression test specimens that are plane within 0.05 mm (0.002") shall be capped or ground plane. Capped surfaces shall not depart from a plane by more than 0.05 mm (0.002"). The plane of the caps of every tenth specimen shall be checked by means of a straightedge and feeler gage, making a minimum of three measurements on different diameters. The capped surface of the specimen in contact with the lower bearing block of the testing machine shall not depart from perpendicularity to the axis of the cylinder by more than 0.5 degree (approximately equivalent to 3 mm in 305 mm (1/8" in 12") and the combined departure of the two capped surfaces from perpendicularity to the axis shall not exceed 3 degrees. Caps shall be made as thin as practical. Any capping material when tested as 50.8 mm (2") cubes of the same age and composition as the caps of the concrete cylinder shall develop a compressive strength greater than the anticipated strength of the concrete cylinder (NOTE 5). Caps made from mixtures of sulfur type materials shall be formed against metal plates. Metal plates shall be at least 25 mm (1") greater in diameter than the specimen, and shall not depart from a plane by more than 0.05 mm (0.002"). In no case shall the recess formed by the plates(s) be greater than 13 mm (1/2"). Adhesion of the capping material to the capping plate may be avoided by coating the plate with light machine oil or mineral oil. Suitable alignment devices shall be used in conjunction with the plates to ensure that the specified perpendicularity of the caps and the axis of the specimen is attained. Surface roughness of newly finished metal plates shall not exceed 3.2 micrometers (125 micro-in.) as set forth in Table 4 of ASA B46.1 on Physical Specimens of Surface Roughness and Lay for any type of surface and direction of lay. The surface when new shall be free from gouges, grooves, or indentations beyond those caused by the finishing operations.

> NOTE 5- The compressive strength of mixtures of sulfur and granular materials may be determined in accordance with Section 7 of the Specifications for Sulfur Mortar (ASTM Designation: C 287).

8.2   Sulfur and Granular Materials- Proprietary or laboratory prepared mixtures of sulfur and granular materials may be used and caps shall be allowed to harden at least 1/2 hr. before the specimens are tested. A melting pot equipped with automatic temperature controls shall be used for heating these mixtures.

NOTE 6- Caution. Melting pots equipped with peripheral heating will protect against accidents happening when reheating cooled sulfur mixtures that have a crusted-over surface. When using melting pots that are not so equipped, care should be exercised to avoid the build-up of pressure under the hardened surface crust by means of a metal rod which contacts the bottom of the pot and projects above the surface of the fluid sulfur mix as it cools. The rod shall be of sufficient size to conduct enough heat to the top, on reheating, to melt a ring around the rod first and thus avoid the development of pressure. Sulfur melting pots shall be used under a hood to exhaust the fumes to the outdoors. The proper range of pouring temperature is from 129 to 143°C (265 to 290°F). Since the flash point of sulfur is approximately 227°C (440°F), the mixture may ignite due to overheating. Heating over an open flame is dangerous. Should the mixture start to burn, covering it will snuff out the flame. If the flame is extinguished immediately, the sulfur mixture may be used for capping.

8.3   Neoprene Caps- Use of neoprene caps shall be considered as a suitable alternate for use in compressive strength testing. The material and procedure shall be in accordance with AASHTO T-22. When 102 mm x 203 mm (4" x 8") cylinders are used, neoprene caps are required 105 mm (4 1/8") in diameter and 12.7 mm (1/2") thick. The material and procedure shall be in accordance with the Annex listed in PTM No. 631.

FLEXURE TEST SPECIMENS

9.   SIZE OF SPECIMENS

9.1   The size of flexure test specimens shall be rectangular beams 152 mm x 203 mm x 559 mm (6" x 8" x 22"). Maximum variation from the nominal cross-section shall not exceed 3.2 mm (1/8").

10   PLACING AND CONSOLIDATION

10.1   Placing and Concrete- The concrete shall be placed in the molds using a scoop or shovel. Molds 203 mm (8") or less in depth shall be filled in two approximately equal layers. An effort shall be made to minimize segregation while filling the molds. Concrete shall be symmetrically distributed within the mold. The concrete may be distributed by means of the tamping rod prior to the start of consolidation.

10.2   Rodding- Each layer shall be rodded evenly over its area 50 times. The bottom layer shall be rodded throughout its depth. The upper layers shall be rodded so that the strokes penetrate approximately 12 mm (1/2") into the immediately underlying layer. The top layer shall slightly overfill the mold. After each layer is rodded, the concrete shall be spaded along the sided and ends of the mold with a trowel or other suitable tool. The sides of the mold shall be tapped with a rubber mallet to close the voids.

10.3   Vibration- Vibration shall be continued only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied when the surface of the concrete becomes relatively smooth in appearance.

10.3.1 Internal Vibration- The vibrator shall be inserted at intervals not exceeding 150 mm (6") along the center line of the long dimension of the specimen. For specimens wider than 150 mm (6"), alternating insertions along two lanes shall be used. The vibrator shall not be allowed to rest on the bottom or strike the sides of the mold. The vibrator shall penetrate into the bottom layer approximately 25 mm (1"). Care shall be taken that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen.

10.3.2 External Vibration- When external vibration is used, care shall be taken to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

CURING COMPRESSION AND FLEXURAL TEST SPECIMENS

11.   SPECIMENS

11.1   Specimens for Checking the Strength of Concrete for Trial Mix Designs- Molds shall be placed on a rigid horizontal surface free from vibration and other disturbances. During the first 24 ± 2 hrs. all test specimens shall be stored under conditions that maintain the air temperature immediately adjacent to the specimens in the range of 16 to 27 ^{o}C (60 to 80 ^{o}F) and prevent loss of moisture from the specimens. Storage temperatures may be regulated by means of ventilation or by evaporation of water from sand or burlap (NOTE 7), or by using heating devices such as stoves, electric light bulbs, or thermostatically controlled heating cables. A temperature record of the specimens shall be maintained by means of high-low thermometers or other appropriate temperature recording devices. Specimens may be stored in tightly constructed, firmly-braced wooden boxes, damp sand pits, or temporary buildings at construction sites, under wet burlap in favorable weather, or by other suitable methods, provided the foregoing requirements limiting specimen temperature and moisture loss are met. Specimens formed in cardboard molds shall not be stored for the first 24 ± 2 hr. in contact with wet sand or wet burlap or under any other conditions that will allow the mold to absorb water. Cardboard molds can be covered with a layer of polyethylene sheeting and wet burlap can be placed over the molds. After 24 ± 2 hr. of curing under the above conditions, the specimens shall be removed from the molds and stored in a saturated lime solution (curing tank). Specimens shall be protected from dripping or running water. At the end of the curing period, between the times the specimen is removed from curing until testing is completed, drying of the surfaces of the specimens shall be prevented (NOTE 9). Specimens shipped from the field to the laboratory for testing shall be packed in a sturdy wooden box or other suitable container surrounded by wet sawdust or wet sand and protected from freezing during shipment. Upon receipt by the laboratory, the specimens shall be placed immediately in moist curing at 23 ± 2 ^{o}C (73 $\pm$ 3 °F) (NOTE 10). In all cases,

the demolded specimens shall be kept in a moist condition (NOTE 8) in the temperature range of $23 \pm 2\,^{\circ}\text{C}$ ($73 \pm 3\,°\text{F}$).

> NOTE 7- The temperature within damp sand and under wet burlap or similar materials will always be lower than the temperature in the surrounding atmosphere if evaporation takes place.

> NOTE 8- A moist condition is that in which free water is maintained on the surface of the specimens at all times.

> NOTE 9- Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

> NOTE 10- Under no conditions shall the specimens be disturbed or moved between 15 min. and 24 ± 2 hr. after molding. Any disturbances of the specimen may cause a reduction in final test results.

11.2   Specimens for Field Control- Specimens shall be placed on a rigid horizontal surface free from vibration and other disturbances. During the first 24 ± 2 hr. all test specimens shall be stored under conditions that maintain the air temperature immediately adjacent to the specimens in the range of 16 to $27\,^{\circ}\text{C}$ (60 to $80\,^{\circ}\text{F}$) and prevent loss of moisture from the specimens. Storage temperatures may be regulated by means of ventilation or by evaporation of the water from sand or burlap (NOTE 7), or by using heating devices such as stoves, electric light bulbs, or thermostatically controlled heating cables. A temperature record of the specimens shall be maintained by means of high-low thermometers or other appropriate temperature recording devices. Specimens may be stored in tightly constructed, firmly-braced wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap in favorable weather, or by other suitable methods, provided the foregoing requirements limiting specimen temperature and moisture loss are met. Specimens formed in cardboard molds shall not be stored for the first 24 ± 2 hr. in contact with wet sand or wet burlap or under any other conditions that will allow the mold to absorb water. Cardboard molds can be covered with a layer of polyethylene sheeting with wet burlap placed over them. After 24 ± 2 hr. of curing under the above conditions, the specimens shall be stored in or on the structure as near to the point of use as possible, and shall receive, insofar as practical, the same protection from the elements on all surfaces as is given to the portions of the structure which they represent. Specimens shall be tested in the moisture condition resulting from the specified curing treatment (NOTE 9). To meet these conditions, the specimens shall be removed from the molds at the time of removing form work (NOTE 10).

12.   IDENTIFICATION AND SECURITY OF COMPRESSION TEST SPECIMEN MOLDS AND COMPRESSION TEST SPECIMENS MOLDED ON CONSTRUCTION PROJECTS

12.1   Identification of Specimen Molds- All compression test specimen molds shall be identified prior to molding of compression test specimens. A PENNDOT Representative shall identify each individual compression test specimen mold using a permanent marker. At a minimum, identification of the compression test specimen molds shall include the following information: date molded, construction area, specimen type, series number, and class of concrete (NOTE 11). In addition, the contractor's PENNDOT certified concrete field technician and the Representative of the Department shall affix their signatures to each compression test specimen mold. The contractor's PENNDOT certified concrete field technician will also legibly include their PENNDOT Concrete Field Technician certification number on each compression test specimen mold (NOTE 12).

NOTE 11- The construction area will be defined as Structure (S), Pavement (P), Pavement Patching (PP), Miscellaneous (M), or RPS Concrete Pavement (RPS). The specimen type will be defined as Acceptance Testing (AT), Quality Control (QC), Verification Testing (VT), Independent Assurance (IA), or Quality Assurance (QA). The series number of the first set of specimens molded in each construction area, molded on a specific project will be the number 1(one). Numbering of subsequent specimen series in each construction area will increase incrementally by 1(one) and will continue for the duration of the project.

12.2   Identification of Specimens- Immediately after the compression test specimen molds are removed from the compression test specimens but prior to curing the compression test specimens, a PENNDOT Representative shall identify each individual compression test specimen using a permanent marker. The PENNDOT Representative will transfer the exact identifying information from the compression test specimen molds to the compression test specimens. In addition, the contractor's PENNDOT certified concrete field technician and the Representative of the Department shall affix their signatures to each specimen. The contractor's PENNDOT certified concrete field technician will also legibly include their PENNDOT Concrete Field Technician certification number (NOTE 12).

NOTE 12- The signatures of the contractor's PENNDOT certified concrete field technician and the PENNDOT Representative are a security measure to ensure that the specimens are not tampered with prior to testing and/or at any time during the curing period.

13.   REFERENCES

AASHTO T-23
AASHTO M-205
ASTM C 31
PTM 604

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LABORATORY TESTING SECTION

Method of Test for

MEASURING THE LENGTH OF DRILLED CONCRETE CORES

1.   SCOPE

        1.1   This method covers the procedure for determining the length of a core drilled from a concrete structure or pavement.

2.   APPARATUS

        2.1   The apparatus shall be a caliper device that will measure the length of axial elements of the core. While the details of the mechanical design are not prescribed, the apparatus shall conform to the requirements of Sections 2.2 to 2.6 of this test method.

        2.2   The apparatus shall be so designed that the specimen will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end of the core. These supports shall be short posts or studs of hardened steel. The support ends that bear against the surface of the specimen shall be rounded to a radius of not less than 6.4 mm (1/4 in.) and not more than 12.7 mm (1/2 in).

        2.3   The apparatus shall provide for the accommodation of specimens of different nominal lengths over a range of at least 100 to 280 mm (4 to 11 in).

        2.4   The caliper device shall be so designed that it will be possible to make a length measurement at the center of the upper end of the specimen and at eight additional points spaced at equal intervals along the circumference of a circle whose center point coincides with the end area of the specimen and whose radius is three-fourths the radius of the specimen.

        2.5   The measuring rod or other device that makes contact with the end surface of the specimen for measurement shall be rounded to a radius of 3.2 mm (1/8 inch). The scale on which the length readings are made shall be marked with clear, definite, accurately spaced graduations. Major graduations shall be 2.5 mm (0.10 inch) with minor graduations at each 0.5 mm (0.02 inch).

2.6   The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.25 mm (0.01 inch) during all normal measuring operations.

3.   TEST SPECIMENS

3.1   Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used. The core specimens for pavement purposes shall be nominally 152 mm (6 inches) in diameter.

4.   PROCEDURE

4.1   Before any measurements of the core length are made, the apparatus shall be calibrated with suitable gauges so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.25 mm (0.01 inch), suitable corrections shall be applied to the core length measurements.

4.2   The specimen shall be placed in the measuring apparatus with the smooth end of the core, that is the end that represents the upper surface of a pavement slab or a formed surface in the case of other structures, placed down so as to bear against the three hardened steel supports. The specimen shall be so placed on the supports so that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the specimen.

4.3   Nine measurements of the length shall be made on each specimen, one at the central position and one each at the eight additional positions described in Section 2.4. Each of the nine measurements shall be read directly to the nearest 0.5 mm (0.02 inch).

   NOTE 1- If in the course of the measuring process, it is determined that the individual measurements vary by 5 mm (0.2 of an inch) or more from the average, the specimen shall be rotated slightly about its axis and another complete set of measurements made. The average of the two sets of readings shall be recorded.

5.   REPORT

   5.1   The individual observations shall be recorded to the nearest 0.5 mm (0.02 inch).
          The average of the nine measurements are expressed to the nearest 0.25 mm (0.01
          inch), and shall be reported as the length of the concrete core.

6.   REFERENCES

   AASHTO T- 148
   ASTM C 174

15.9 mm (5/8")

19.0 mm (3/4")

15.9 mm (5/8")

57.2 mm
(2 1/4") R

UPPER PLATE

63.5 mm
(2 1/2")

6.4 mm
(1/4")

19.0 mm
(3/4")

DETAIL OF
GUIDE

ISOMETRIC VIEW

254 mm (10")

152 mm (6")
Core

3 Steel
Balls

51 mm
(6") R

15.9 mm (5/8")

LOWER PLATE

69.8 mm   63.5 mm
(2 3/4") (2 1/2")

15.9 mm (5/8")

6.4 mm
(1/4")

304.8mm
(12")

323.8 mm
(12 3/4")

3 Steel Balls

3.2 mm
(1/8")

9.5 mm
(3/8")

4.8 mm
(3/8")

7.9 mm (0.312")

CROSS SECTION
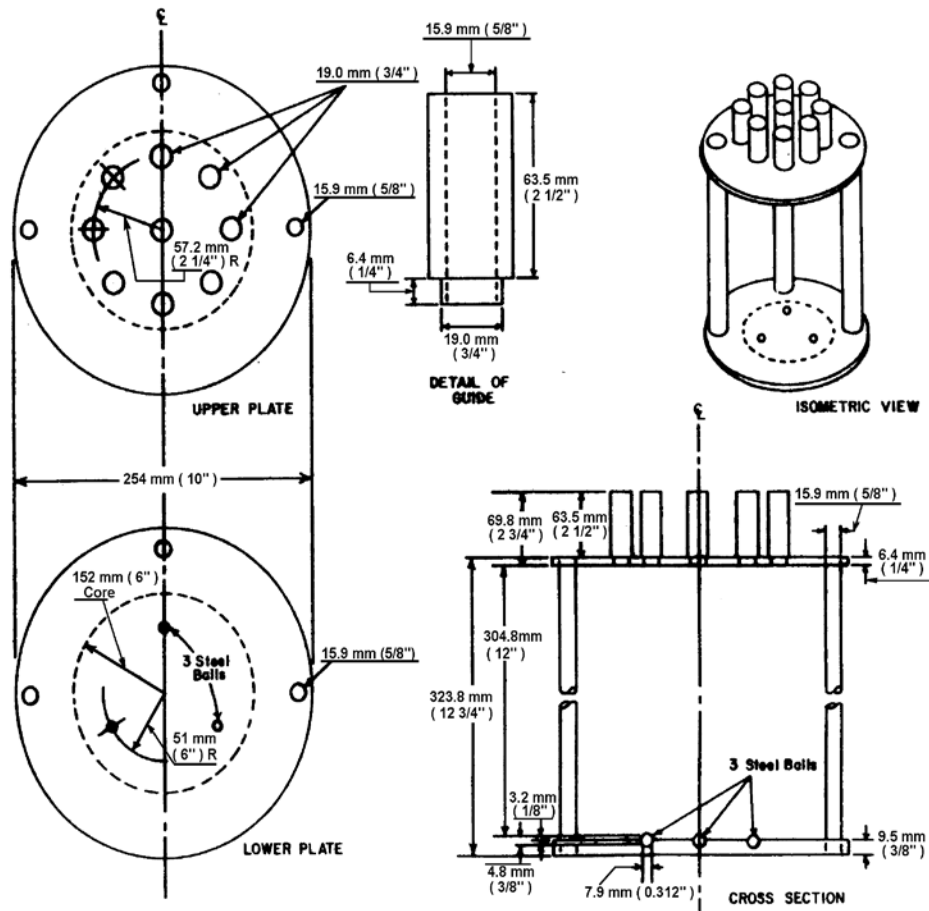
CONVERSION TABLE

3.2 mm = 1/8"	34.9 mm = 1-3/8"
4.8 mm = 3/16"	50.8 mm = 2"
6.4 mm = 1/4"	57.2 mm = 2-1/4"
7.9 mm = 5/16"	63.5 mm = 2-1/2"
9.3 mm = 3/8"	69.8 mm = 2-3/4"
9.8 mm = 0.386"	152.4 mm = 6"
12.7 mm = 1/2"	254.0 mm = 10"
15.9 mm = 5/8"	304.8 mm = 12"
19.0 mm = 3/4"	323.8 mm = 12-3/4"
25.4 mm = 1"	374.6 mm = 14-3/4"
28.6 mm = 1-1/8"	428.6 mm = 16-7/8"
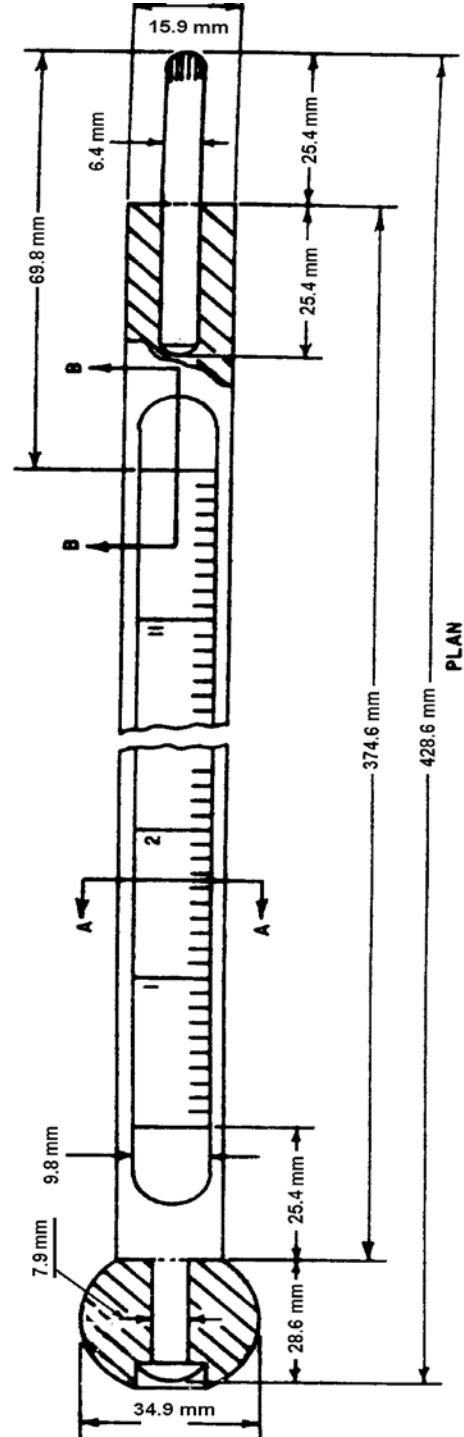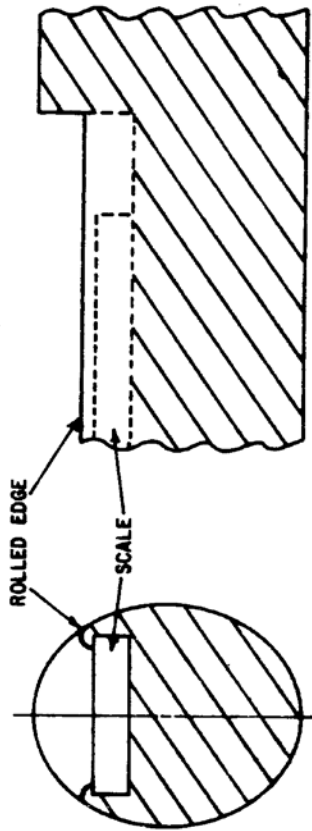
ROLLED EDGE

SCALE

SECTION A-A

SIDE VIEW
DETAIL
B-B

15.9 mm

6.4 mm

69.8 mm

25.4 mm

25.4 mm

374.6 mm

428.6 mm

PLAN

9.8 mm

7.9 mm

25.4 mm

28.6 mm

34.9 mm

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LABORATORY TESTING SECTION

Method of Test for

SIEVE ANALYSIS OF COARSE AND FINE AGGREGATE

This PTM is a modification of AASHTO T-27. The full standard is available from American Association of State Highway and Transportation Officials, 444 N. Capitol Street, N.W., Suite 249, Washington, D.C. 20001 (www.transportation.org).

The modifications to AASHTO T-27 are as follows:

6.   APPARATUS

6.4   Oven- An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F). Hot plates either electric or gas may be used when test results must be obtained quickly. Confirmation samples shall be tested using ovens as described in this section.

7.   SAMPLING

7.1   Sample the aggregate in accordance with PTM 607.

7.3   Fine Aggregate - The size of the test sample of aggregate, after drying shall have an approximate mass of 500 grams.

7.4   Coarse Aggregate- The mass of the test sample of coarse aggregate shall conform with the following:

AASHTO / PA Number	Minimum Mass of Sample	
	Kg	lb.
# 1	Usual inspection per section 850.2 (a) 1 & 2, Pub. 408	
# 3	20	44
# 5	10	22
# 57	10	22
# 67	10	22
# 7	10	22
# 8	5	11
# 10	1	2
2A	15	33
OGS	15	33

      7.7.1   Delete this section
      7.7.2   Delete this section
      7.7.3   Delete this section

8. PROCEDURE

8.4   (For Fine Aggregates) - Sieve for a sufficient period and in such a manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 1 minute of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply with an upward motion while holding the sieve in the other hand, at the rate of about 150 times per minute. Turn the sieve about one-sixth of a revolution at intervals of about 25 strokes.

(For Coarse Aggregates) - Sieve for a sufficient period and in such a manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 1 minute of continuous mechanical shaking as follows: Weigh the material retained on each individual sieve after the initial shaking period. Individually place each sieve with the material retained on the sieve back into the mechanical shaking device and sieve for an additional minute. In determining the sufficiency of sieving for sizes larger than 4.75 mm (No. 4) sieve, limit the material on the sieve to a single layer of particles.

Note- The Sufficiency of Sieving procedure is documented in PTM 608.

8.7   Determine the mass of each size increment by weighing on a scale or balance conforming to the requirements specified in Section 6.1 to the nearest 0.1 percent of the total original dry sample mass. The total mass of the material after sieving shall check closely with the original mass of sample placed on the sieves. If the amounts differ by more than 0.8 percent, based on the original dry sample mass, the results shall not be used for acceptance purposes.

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LABORATORY TESTING SECTION

Method of Test for

SOLIDS IN AGGREGATE FOR CONCRETE

1.   SCOPE

1.1   This method of test outlines the procedure for determining percent solids in bulk volumes of aggregate.

2.   PERCENTAGE OF SOLIDS

2.1   The percent solids in aggregate shall be determined by the following formula:

$$\text{Percentage Of Solids} = \frac{\text{Unit Weight} \times 100}{\text{Sp.Gr.} \times 1000(62.355)}$$

Where:

Sp.Gr.= the bulk specific gravity of the aggregate as determined by the appropriate method referred to in Section 3.1 or 3.2, of this test method.

1000 (62.355) = the mass in kilograms (pounds) of 1 m^3 (1 cu.ft.) of water at the standard temperature of 16.7ºC (62º F).

Unit Weight = the mass in kilograms per cubic meter (pounds per cubic foot) of the aggregate as determined by the method referred to in Section 3.3 of this test method.

NOTE 1 - For complete accuracy, unit weight shall be the mass of the air dried sample minus the mass of any contained moisture.

3.   METHODS OF TESTING

The specific gravity and mass of the aggregate shall be determined in accordance with the following methods of test:

3.1   Specific Gravity of Fine Aggregate- See Method of Test for Specific Gravity and Absorption of Fine Aggregate, AASHTO T-84.

3.2   Specific Gravity of Coarse Aggregate- See Method of Test for Specific Gravity and Absorption of Coarse Aggregate, AASHTO T-85.

3.3   Unit Weight of Aggregate- See Method of Test for Unit Weight of Aggregate, AASHTO T-19.

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LABORATORY TESTING SECTION

Method of Test for

ACID INSOLUBLE RESIDUE IN CARBONATE ROCK

1.   SCOPE

1.1   This method of test covers the procedure for determining in the laboratory the amount of siliceous and other hard resistant mineral grains retained on the 75 µm (No.200) mesh sieve that remain after fragments of carbonate rock have been dissolved in hot hydrochloric acid. This procedure includes the identification of the retained residue primarily to distinguish hard rock fragments and mineral grains such as quartz, chert, and feldspar from relatively soft minerals and rock fragments such as shale and argillite. This method of test is intended to be applied to limestone and dolomite aggregates intended for use in the wearing surfaces of bituminous and Portland cement concrete pavements in order to determine the relative skid resistant properties of the coarse aggregates.

2.   APPARATUS

2.1   Sieves- Sieves with square openings (of the following sizes) conforming to the requirements of AASHTO M-92. The required sizes are 75 µm, 106 µm, 150 µm, 180 µm, 300 µm, 425 µm, 600 µm, 1.18 mm, and 2.00 mm (No. 200, No. 140, No. 100, No. 80, No. 50, No. 40, No. 30, No. 16, and No. 10) in 76.2 mm and 152.4 mm (3-inch and 6-inch) diameters, and 9.51 mm and 2.00 mm (3/8 inch and No. 10) in 203.2 mm (8-inch) diameter.

2.2   Pans- Two 76.2 mm and 152.4 mm (3-inch and 6-inch) pans per sieve set of the same size.

2.3   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

2.4   Oven- An oven of sufficient size capable of maintaining a uniform temperature of 60 ± 5º C (140 ± 9ºF).

2.5   Container- A container composed of acid and heat-resistant material of at least 2000 mL capacity and provided with a loose cover (A 2000 mL Pyrex beaker with a pouring lip and watch glass cover is suggested).

2.6   Sieving cylinders- Plexiglas sieving cylinders consisting of Plexiglas cylinders into which the skirts of the 76.2 mm (3-inch) and 152.4 mm (6-inch) diameter sieves will fit tightly, firmly cemented to the center of a square Plexiglas base, and equipped with an

attachment for the aspirator approximately 25 mm (1 inch) below the top edge of the cylinder (Figures 1A & 1B). The joint between the cylinder and the base must be both water-tight and air-tight.

2.7   Hot plate or water bath

2.8   A spray bottle with a nozzle adjustable for fineness of spray for washing the residue.

2.9   Aspirator- A plastic aspirator attached to a sink faucet, and a rubber hose connected to the aspirator and faucet, used for the wet sieving procedure and decanting the sample after processing it through the blender.

2.10   Litmus paper for measuring solution pH

2.11   Reagent grade sodium bicarbonate

2.12   Wooden dowel- A wooden dowel, at least 12.7 mm (1/2 inch) in diameter and 203.2 mm (8 inches) long, for tapping the sieve stack during wet sieving.

2.13   Graduated Cylinder- A graduated cylinder of 1000 mL capacity or larger

2.14   Filtering Flasks- Several filtering flasks with a capacity of 1000 mL

2.15   Buechner Funnel- Porcelain California Modified Buechner funnel with a fixed perforated plate for vacuum, with a capacity of 750 mL and a plate diameter of 126 mm (5 inches) (Figure 2).

2.16   Filter Paper- No. 5 filter paper (110.0 mm (4.25 in.) in diameter)

2.17   Blender- A stainless steel blender of 16,000 rpm with a capacity of 1000 mL

2.18   Vacuum Pump

2.19   Vacuum Tubing- Vacuum tubing of a diameter sufficiently large to fit onto the filtering flasks, onto the rigid tubing in the rubber stoppers, and the fitting of the Buechner funnel.

2.20   Rubber Stoppers- One-hole rubber stoppers with rigid tubing inserted into the holes so that the filtering flasks may be connected to the Buechner funnel and the vacuum pump.

2.21   Wash Bottles

3.   SAMPLE

3.1   A representative sample of the aggregate shall be obtained from the material to be tested by the use of a sample splitter or by the quartering method. By rapid hand sieving, separate an adequate quantity of material passing the 9.51 mm (3/8 inch) sieve and retained on the 2.0 mm (No. 10) sieve. The sample for test shall be approximately 200 grams, when dry, and shall be the end result of the sampling method. The selection of samples of an exact pre-determined mass shall not be attempted.

4.   PROCEDURE

4.1   Wash the test sample over a 2.0 mm (No. 10) sieve and dry to constant mass at a temperature of $60 \pm 5°C$ ($140 \pm 9°F$). Record the mass of the sample to the nearest 0.1 gram. Record the mass of the container into which the carbonate matrix will be dissolved to the nearest 0.1 gram. Record the mass of the container and sample to the nearest 0.1 gram. (See the Acid Insoluble Residue worksheet at the end of this PTM).

4.2   After drying and weighing, place the test sample in the container and add sufficient distilled water to cover it (about 50 mL). Slowly add approximately 400 mL of diluted HCL (6N) with sufficient pauses to prevent the foaming solution from overflowing the container (Note 1). When the effervescence has subsided, stir and place the sample on a hot plate or water bath, keeping the temperature of the container slightly below boiling. (It may be necessary to apply heat gradually in order to prevent excessive effervescence). After the reaction ceases, as shown by the absence of bubbles being given off by the material, remove the container from the heat, add an additional 200 mL of diluted HCL (6N) and stir with a glass stirring rod. Continue adding acid and reheat the sample until the addition of acid does not cause effervescence.

Note 1 - This precaution applies particularly to those limestones and dolomites that contain appreciable amounts of organic carbon.

4.3   Remove the container from the heat and allow it to cool. Remove as much as possible of the solution in the container with a sink aspirator without disturbing the sediment at the bottom. Add a small amount of sodium bicarbonate to the remaining solution and wait for the reaction to subside. Check the pH of the solution with the litmus paper. If the solution is still acidic, add another small quantity of sodium bicarbonate to the solution. Repeat the check of solution acidity with the litmus paper. Continue to add small quantities of sodium bicarbonate to the solution until the solution becomes slightly basic, as indicated by the litmus paper.

4.4   Add distilled water to the container until it is almost full, and then stir the contents of the container. Allow the sediment in the container to settle to the bottom, and then remove as much of the solution as possible from the container with a sink aspirator without disturbing the sediment at the bottom. Repeat the rinse procedure with distilled water, allow the sediment in the

container to settle again, and then remove as much water as possible from the container without disturbing the sediment at the bottom of the container.

4.5   Wash the residue into a blender (Note 2) and run the blender for one minute at about 16,000 rpm.

> Note 2 - A blender with a stainless steel container is recommended. The purpose of this step is to disintegrate relatively soft particles such as mud pellets and shale fragments.

4.6   Assemble a stack of either 76.2 mm (3-inch) or 152.4 mm (6-inch) (Note 3) sieves on top of a sieving cylinder of the same size (Figure 3), and attach the sieving cylinder to the sink aspirator. Turn on the faucet to activate the aspirator, and then pour the contents of the blender over the top of the sieve stack slowly. Rinse any remaining sediment in the bottom of the blender container into the sieve stack with the water bottle.

> Note 3 - Use a 76.2 mm (3-inch) sieve set and cylinder if the total amount of acid insoluble residue appears to comprise 15% or less of the original sample. Use a 152.4 mm (6-inch) sieve set and cylinder if the total amount of acid insoluble residue appears to comprise more than 15% of the total sample.

4.7   Tap the sieves from the top down to the bottom of the stack with a wooden dowel in order to allow any water backed up on one or more of the sieves to pass through the entire sieve stack and into the sieving cylinder (Note 4). After the water originally in the blender container appears to have passed through the sieve stack and into the cylinder, use the spray bottle to spray across the top of each sieve to wash smaller grains sitting on the sieve through the sieve, then lift each sieve and spray the interior of the sieve skirts with the spray bottle to wash any grains clinging to the sieve skirt back into the sieve stack (Figures 4 & 5). After each sieve has been washed as much as possible with the spray bottle, remove the sieve from the sieve stack and place the sieve on one of the two pans assigned to that particular sieve stack, underneath the sieves that have already been removed from the stack. If the sieving cylinder fills up before the entire sieve stack has been washed, remove the sieves remaining on the cylinder, rest them temporarily on the second pan assigned to the sieve set, disconnect the cylinder from the sink aspirator, and decant the sieving cylinder into a container of sufficient size to hold the water decanted from the cylinder (a 2000 mL beaker with a pouring lip is such a suitable container). Reattach the sieving cylinder to the sink aspirator, replace the remaining sieves on the cylinder, wash the pan on which they were placed temporarily into the top of the sieve stack, and continue washing the remaining sieves into the sieving cylinder until all the sieves in the stack have been washed. At this point, all the sieves in the stack shall be resting on one of the pans assigned to that sieve set, and should be in order with the largest sieve at the top of the stack, and the smallest sieve at the bottom of the stack, resting on the pan.

Note 4 - It may be necessary to steady the sieve stack with one hand while tapping it with the dowel, in order to prevent the sieves from being knocked off the sieving cylinder.

4.8   Split the stack of sieves in half. Rest the bottom sieve in each half of the stack in one of the two pans assigned to that sieve set, and place them in a 60 ± 5 ºC (140 ± 9ºF) oven until the material retained on all of the sieves has dried to a constant weight.

4.9   Take a piece of the No. 5 filter paper, weigh it to the nearest 0.1 g, and record the mass. Place the filter paper on the perforated plate of the Buechner funnel, and wet down the Buechner funnel with a water bottle to keep the filter paper in place when the solution from the sieving cylinder is first poured into the funnel. Remove any air bubbles from underneath the filter paper gently with the use of a fingertip. Connect the Buechner funnel to the filtering flasks and the vacuum pump in the following order (Figure 6): Buechner funnel, connected to a decanting flask, connected to a calcium chloride flask (to remove moisture from the air before it gets pulled into the vacuum pump), connected to a chemically inert ON-OFF valve, which is connected to the vacuum pump. Pour as much of the solution from the sieving cylinder into the Buechner funnel as possible, and turn on the vacuum pump. As the level of solution in the Buechner funnel goes down, add more solution from the sieving cylinder, until all the solution from the sieving cylinder has been placed into the Buechner funnel. If any sediment remains in the bottom of the sieving cylinder, wash the sediment out with a wash bottle into the Buechner funnel. When all of the solution and sediment from the sieving cylinder has been poured into the Buechner funnel, and all the water has been pulled through the filter paper into the decanting cylinder, turn off the vacuum pump, disconnect the Buechner funnel from the decanting flask, and place the funnel on a tray in a 60 ± 5ºC (140 ± 9 ºF) oven until it has dried to a constant mass.

Note 5 - The use of the ON-OFF valve between the calcium chloride flask and the vacuum pump is strongly encouraged. If it becomes necessary to shut off the vacuum pump to empty or change the decanting flask, and if the connections between the Buechner funnel and the decanting flask are not broken VERY QUICKLY, the vacuum in the decanting and calcium chloride flasks will pull oil from the vacuum pump into the calcium chloride flask, unless there is a shut ON-OFF valve which provides a physical barrier. Once the system has been reassembled, and the vacuum pump turned on again, then the ON-OFF valve can be returned to the ON position to allow the system to evacuate again.

4.10   Remove the split sieve stack from the oven when it has dried to a constant mass. Reassemble the sieve stack in order of descending sieve size, with a pan at the bottom, and sieve the material to ensure that all aggregate particles have moved as far as they possibly can through the sieve stack (Note 6). Weigh the material retained on each sieve, and record the mass to the nearest 0.1 g. Add any material which came to rest in the pan to that which was retained on the filter paper in the Buechner funnel. Weigh the filter paper with the - #200 material on it, and record the mass to the nearest 0.1 g. Subtract the original mass of the filter paper from the combined mass of the - #200 material and the filter paper. This is the mass of the - #200 acid insoluble residue. Record this mass to the nearest 0.1 g.

> Note 6 - The 76.2 mm (3-inch) sieves will usually have to be hand-sieved over a piece of paper, since most normal mechanical sieving systems will not accommodate this diameter of sieve. The 152.4 mm (6-inch) sieves will usually fit into a mechanical sieving system, and should be sieved for no more than 15 minutes.

4.11   Examine the residue, and describe the residue with the aid of mineral and rock identification tests as are necessary and appropriate. Refer to the Standard Descriptive Nomenclature of Constituents of Natural Mineral Aggregate (ASTM Designation: C 294).

If necessary for the purposes of the study being performed, separate the coarse material [plus 75 µm (No. 200)] into two portions: (Type 1) siliceous material and hard resistant mineral grains, and (Type 2) Non-siliceous material and relatively soft, fine-grained aggregates. This shall be done by medium-power microscopic study. Determine the percent of each present by the point-count method.

Type 1 materials shall include the following (ASTM C 294): Silica minerals, chert, feldspars, ferromagnesian minerals, pyrite, magnetite, and other minerals having a hardness greater than Mohs No. 5, as well as coarse and fine-grained intrusive and extrusive igneous rock fragments.

Type 2 materials shall include the following (ASTM C 294): Calcite, dolomite, clay, marcasite, hematite, limonite, zeolites, shale, siltstone, mud pellets, argillite, slate, clay stone, serpentine, carbonaceous material, and the micas.

5.   CALCULATIONS

5.1   Calculate the amount of acid insoluble residue retained on the 75 µm (No. 200) sieve to the nearest 0.1% as follows:

$$A = \frac{B + C + D + E + F + G + H + I + J}{K} \times 100$$

Where:

A = Total percent of the acid insoluble retained on the 75 µm (No. 200) sieve

B = Mass of acid insoluble residue retained on the 2.00 mm (No. 10) sieve

C = Mass of acid insoluble residue retained on the 1.18 mm (No. 16) sieve

D = Mass of acid insoluble residue retained on the 600 µm (No. 30) sieve

E = Mass of acid insoluble residue retained on the 425 µm (No. 40) sieve

F = Mass of acid insoluble residue retained on the 300 µm (No. 50) sieve

G = Mass of acid insoluble residue retained on the 180 µm (No. 80) sieve

H = Mass of acid insoluble residue retained on the 150 µm (No. 100) sieve

I = Mass of acid insoluble residue retained on the 106 µm (No. 140) sieve

J = Mass of acid insoluble residue retained on the 75 µm (No. 200) sieve

K = Original Sample Mass

5.2   Calculate the amount of acid insoluble residue passing the 75 µm (No. 200) sieve to the nearest 0.1% as follows:

$$A = \frac{B}{C} \times 100$$

Where:

A = Total percent of the acid insoluble passing the 75 µm (No. 200) sieve

B = Mass of acid insoluble residue passing the 75 µm (No. 200) sieve

C = Original Sample Mass

5.3   Calculate the total percent of acid insoluble residue in the sample to the nearest 0.1% as follows:

$$A = B + C$$

Where:

A = Total percent of acid insoluble residue in the sample

B = Total percent of the acid insoluble retained on the 75 µm (No. 200) sieve

C = Total percent of the acid insoluble passing the 75 µm (No. 200) sieve

5.4 If the examination in Section 4.11 shows that there is more than a trace amount of Type 2 acid insoluble residue present, calculate the amount of siliceous material retained on the 75 µm (No. 200) sieve to the nearest 0.1% as follows:

$$A = \frac{B + C + D + E + F + G + H + I + J}{K} \times 100$$

Where:

A = Total percent of the Type 1 acid insoluble residue retained on the 75 µm (No. 200) sieve

B = Mass of siliceous material and resistant grains retained on the 2.00 mm (No. 10) sieve

C = Mass of siliceous material and resistant grains retained on the 1.18 mm (No. 16) sieve

D = Mass of siliceous material and resistant grains retained on the 600 µm (No. 30) sieve

E = Mass of siliceous material and resistant grains retained on the 425 µm (No. 40) sieve

F = Mass of siliceous material and resistant grains retained on the 300 µm (No. 50) sieve

G = Mass of siliceous material and resistant grains retained on the 180 µm (No. 80) sieve

H = Mass of siliceous material and resistant grains retained on the 150 µm (No. 100) sieve

I = Mass of siliceous material and resistant grains retained on the 106 µm (No. 140) sieve

J = Mass of siliceous material and resistant grains retained on the 75 µm (No. 200) sieve

K = Original Sample Mass

6.   REPORT

6.1   Report the total percent of acid insoluble residue retained on the 75 μm (No. 200) sieve. If there is more than a trace amount of Type 2 acid insoluble residue in the sample, also report the percentage of Type 1 acid insoluble residue present in the sample. Maintain in the source file a record of the percentages of acid insoluble residue both retained on and passing the 75 μm (No. 200) sieve, as well as the size distribution of the acid insoluble residue retained on the 75 μm (No. 200) sieve.

7.   REFERENCE:

ASTM D 3042

Insoluble Residues

Lab Number					Formulas
Wt. Beaker					W
Wt. Sample					Y
Total Weight					W + Y = Z

Weights after the Test Is Complete

Paper Wt. At Start					A
Paper Wt. After					B
- #200 on the Paper					B - A = C

Wt. + #10					F
Wt. + #16					G
Wt. + #30					H
Wt. + #40					I
Wt. + #50					J
Wt. + #80					K
Wt. + #100					L
Wt. + #140					M
Wt. + #200					N
Total Wt. + #200					F + G + H + I + J + K + L + M + N = P

Percent of Sample

% + #10					(F/Y) X 100
% + #16					(G/Y)X 100
% + #30					(H/Y) X 100
% + #40					(I/Y) X 100
% + #50					(J/Y) X 100
% + #80					(K/Y) X 100
% + #100					(L/Y) X 100
% + #140					(M/Y) X100
% + #200					(N/Y) X 100
Total % + #200					(P/Y) X 100
% - #200					(C/Y) X 100
Total % Insol.					(P + C)/Y X 100

Funnel #   _____ _____ _____ _____

Date: _____   Test Done By: _____
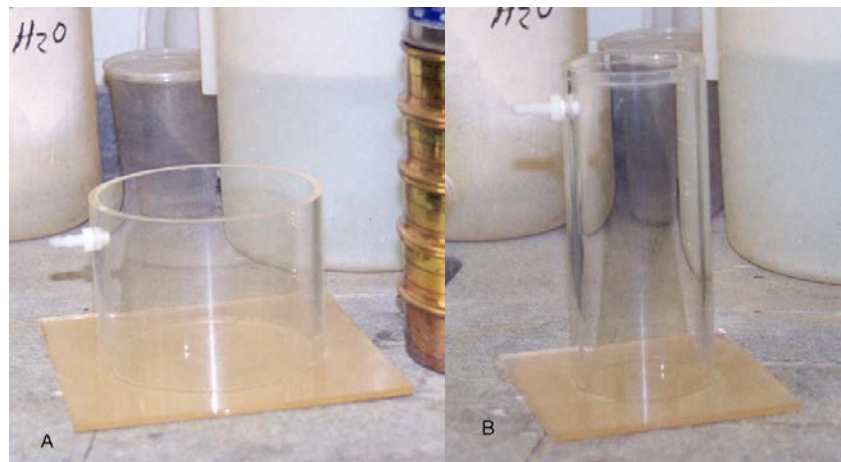
Figure **1A-** A 152.4 mm (6-inch) sieving cylinder
Figure 1B- A 76.2 mm (3-inch) sieving cylinder

Figure 2- A porcelain Buechner funnel with a capacity of 750 mL and a plate
with a diameter of 126 mm (5 inches).

Figure 3- A 152.4 mm (6-inch) sieving cylinder connected to a sink aspirator, with the sieve stack assembled on top of the cylinder.

Figure 4- Spraying through the top of the sieve

Figure 5- Spraying to clean off the interior of the sieve skirts

Figure 6- Vacuum set-up for the Buechner funnel **A.** Buechner funnel
B. Decanting flask **C.** Calcium chloride flask **D.** ON-OFF valve
E. Vacuum pump.

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LABORATORY TESTING SECTION

Method of Test for

FRIABLE PARTICLES

1.   SCOPE

        This method of test outlines the procedure for determining the amount of friable particles in coarse aggregate.

2.   APPARATUS

        2.1   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

        2.2   Containers- Rust-resistant containers of a size and shape that will permit the spreading of the sample on the bottom of the container in a thin layer.

        2.3   Sieves- Sieves conforming to the requirements of AASHTO M- 92. The required sieves are 9.5 mm, 4.75 mm, and 2.36 mm (3/8 in., No.4, and No.8).

        2.4   Drying oven- An oven providing free circulation of air and capable of maintaining a temperature of $110 \pm 5 \, ^{\circ}C$ ($230 \pm 9 \, ^{\circ}F$).

        2.5   Rubber gloves- Rubber gloves of such a thickness as to resist being easily abraded by the aggregate. The type of gloves normally used to wash dishes has been found to be suitable.

3.   SAMPLES

        3.1   Aggregate for this test method shall consist of material of the approximate mass given below, which is obtained by reducing the original sample through a sample splitter.

C.A. Gradation	Initial Sample Mass
#8	1200 g
#57	2200 g

3.2   The sample shall be washed to remove all material finer than the 75 µm (No.200) sieve, and then dried to substantially constant mass at a temperature of 110 $\pm$ 5ºC (230 $\pm$ 9ºF). The material used may consist of that remaining after completion of testing in accordance with PTM 100, providing this will yield enough material for the test.

4.   SAMPLE PREPARATION

4.1   After drying, the sample shall then be sieved over a 4.75 mm (No.4) sieve to remove all material finer than the 4.75 mm (No.4) sieve.

4.2   Weigh out the amount indicated below for each aggregate gradation.

C.A. Gradation	Amount
#8	1010 $\pm$ 5 g
#57	2010 $\pm$ 5 g

4.3   Break the sample down into the following two size fractions by sieving over the 9.5 and 4.75 mm (3/8" and No.4) sieves:

> a. + 9.5 mm (3/8") fraction
> b. - 9.5 mm to + 4.75 mm (3/8" to No.4) fraction.

4.4   Weigh each size fraction, and record the mass. Find the total initial mass, A, for each sample by adding together the weights of the two size fractions for each sample.

4.5   Place the + 9.5 mm (3/8"), and - 9.5 mm to + 4.75 mm (3/8" to No.4) size fractions for each sample in separate pans. If need be, split one size fraction between two pans. Material should form only a single layer on the bottom of the pan. Label each pan clearly with the sample identification number and the size fraction.

5.   TESTING FOR FRIABLE PARTICLES

5.1   Place distilled water in each pan so that at least 13 mm (1/2") of water covers the sample.

5.2   Allow the samples to soak for 24 ± 4 hours at room temperature.

5.3   At the end of the soaking period, examine the sample for friable particles as follows: Roll and squeeze particles individually between the thumb and forefinger in order to break the particle into smaller-sized pieces. Do not use the fingernails to break up particles, or press particles against a hard surface or each other. Any particles that can be broken with the thumb and forefinger into fines removable by wet sieving shall be classified as friable particles.

5.4   After the sample has been thoroughly checked, and as many particles have been broken up as possible, separate the fines and detritus from the remainder of the sample by wet-sieving over sieves as prescribed below:

Size Fraction	Sieve Used for Wet-Sieving
+ 9.5 mm (3/8")	4.75 mm (No.4)
- 9.5 mm to + 4.75 mm	2.36 mm (No.8)
(- 3/8" to + No.4)	

5.5   Dry the samples in an oven to a substantially constant mass at 110 ± 5° C (230 ± 9° F).

5.6   Allow the samples to cool to room temperature.

5.7   Combine all the size fractions for each sample, and reweigh each sample to get the final total mass, B.

5.8   Calculate the percent loss as follows:

$$\% \text{ loss} = \frac{(A - B)}{A} X\,100$$

Where:

A = initial total mass of the sample

B = final total mass of the sample

6.   REPORT

6.1   The report shall contain the sample identification number and the percent loss, which is reported as the percent of friable particles.

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LABORATORY TESTING SECTION

Method of Test for

AIR CONTENT OF HARDENED CONCRETE

1.   SCOPE AND PURPOSE

        1.1   This method of test describes two procedures for determining the volumetric percentage of entrained air voids in hardened concrete. In Procedure A, polished sections of concrete are examined and measurements are made with a stereoscopic microscope and a traversing stage. This method is a modification of ASTM Designation C 457, Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete.

        1.2   Procedure B utilizes a video camera and image analyzer to examine the specially prepared surface of the concrete sections.

        1.3   The geometric characteristics of the air void system, the entrained air content especially, are indicative of the resistance to scaling of moist concrete when subjected to freezing temperatures, particularly in the presence of the commonly used de-icing chemicals.

        1.4   All material in this test method not specifically designated as belonging to Procedure A or B, applies to both procedures.

2.   DEFINITIONS

        2.1   Air Void- A small space enclosed by cement paste and occupied by air (NOTE 1). This term does not refer to capillary or other openings of sub-microscopical dimensions or to voids within particles of aggregate.

        NOTE l- For special purposes, void systems of a satisfactory size distribution and spacing may be produced by the evolution of hydrogen resulting from the chemical reaction of metallic aluminum with cement and water.

        2.2   Entrained Air Void- An air void less than one millimeter and greater than 0.005 millimeters in diameter. Entrained air voids are typically spherical or nearly spherical in shape.

        2.3   Entrapped Air Void- An air void equal to or greater than one millimeter in its smallest dimension. Entrapped air voids are typically irregular in shape. Entrapped air voids are considered to make no significant contribution to the durability of concrete when subjected to freezing temperatures.

3.   APPARATUS

3.1   When using Procedure A the apparatus and materials for sample preparation and for measuring the geometrical characteristics of the air-void system shall meet or exceed the minimum requirements set forth in ASTM Designation C 457. The apparatus and materials required for sample preparation consist of power saws, polishing laps, and various abrasive compounds for grinding and polishing the sawed sections of the concrete. The measuring apparatus is essentially a stereoscopic microscope mounted above a moveable stage that has electrical and mechanical accessories that permit counting and measuring portions of the intervals traversed as the stage is moved back and forth under the microscope (Figure 1).

3.2   When using Procedure B, the following equipment and supplies are needed:

3.2.1   Saws, polishing laps, and abrasive compounds as given in Section 3.1

3.2.2   Wide, black, felt-tip marker for coating the polished surface of the concrete specimen

3.2.3   White, powdered, material such as wollastonite or gypsum that can be packed into the air voids of concrete. The particles of this powdered material must be finer than five micrometers (microns).

3.2.4   Mineral oil to use on the surface of the concrete specimens to remove excess white powder.

3.2.5   Metal spatula, rubber roller, and rubber scraper for placing the white powder in the voids. The roller is the kind used to spread ink for block printing and is often called a breyer. The rubber scraper is the kind used to scrape excess grout away when placing ceramic tile.

3.2.6   An Image Analysis System consisting of at least a high resolution video camera with a lens capable of producing 12x to 15x magnification, a video display, a computer for analyzing video images, and a graphics printer. The software provided for the computer must enable the operator to enhance the video image of the specimen surface so that the percent of the areas occupied by entrained and entrapped voids can be determined. The software should also provide information on void sizes and distribution and enable the operator to selectively eliminate features by shape or size as desired.

4.   SAMPLES

4.1   When the concrete in a pavement or a structure is to be tested by this method, obtain the sample of hardened concrete in accordance with AASHTO T-24. Cores shall have a diameter of at least 100 mm (four inches).

4.2   When a molded specimen of concrete is to be tested by this method the entire specimen shall be submitted.

4.3   When unusual circumstances do not permit samples to be obtained in accordance with Sections 4.1 and 4.2 above, samples shall be obtained as prescribed by the Petrographer, to ensure that samples suitable for testing will be obtained.

4.4   The samples shall be prepared in reasonable conformity to the procedure described in ASTM Designation C 457. The sample preparation consists essentially of sawing a slab of concrete, usually about 100 X 150 X 25 mm (4 x 6 x 1 inches), from the sample submitted. One side of the slab is then ground and polished on laps and mounted horizontally on the traversing stage.

4.5   When using Procedure B, additional specimen preparation is required.

4.5.1   After the specimen has been polished sufficiently, blacken the surface uniformly using the felt-tip marker. Allow the ink to dry out for at least five minutes. Rub your fingers across the specimen; if no ink comes off on your skin, it is dry.

4.5.2   Sprinkle the white powder onto the specimen surface and work it into the voids using a spatula, scraper, or rubber roller. Be sure that the smallest voids are filled by rubbing the powder back and forth across the specimen surface. Scrape off most of the excess powder using the rubber scraper. When working the powder into the voids and removing the excess, be careful not to rub too hard or you may scrape away the black coating from the pieces of aggregate.

NOTE 2- If you do remove any of the black coating from the aggregate, recoat it with a fine or medium tipped marker. This marker can also be used to cover up the white powder that has filled the voids in the aggregate since these are usually not of interest.

4.5.3   After completing Section 4.5.2, there will still be considerable excess powder on the surface of the specimen. To remove this, place a very small amount of mineral oil on a rubber roller and roll it across the specimen. This mineral oil will pick up and remove all or most of the excess powder. If some excess powder remains, repeat this operation.

5.   PROCEDURE A

5.1   Total Traverse Length- The total length of traverse required, which depends on the size of the coarse aggregate, is taken from the following table below (ASTM C 457). The number of traverses necessary to provide the required total length are plotted uniformly along one edge of the polished surface of the slab.

Minimum Length of Traverse

Nominal or Observed Max. Size of Aggregate [mm(in.)]	Minimum Length of Traverse [mm(in.)]
76.2 (3)	3048 (120)
38.1 (1-1/2)	2540 (100)
25.4 (1)	2413 (95)
19.1 (3/4)	2286 (90)
12.7 (1/2)	2032 (80)

5.2   Measurements (Short Method)- Under 100X magnification and oblique illumination, the number of entrained and entrapped air voids intercepted by the traverse are counted, the intercepted intervals of entrapped air voids and the total distance traversed are determined. The relationship between the entrained air content and the number of entrained voids per inch is shown in Figure 2. The entrapped air content (%) is calculated from the number and average chord length of the entrapped air voids.

$$A = \bar{l} \text{ x n x } 100$$

Where:

$\bar{l}$ = average chord intercept

n = number of voids per 25 mm (inch) of traverse

The total air content is the sum of the entrained and entrapped air void contents, expressed as percentages.

NOTE 3- The graph in Figure 2 was obtained by plotting the results of 163 linear traverse analyses (using the Rosival or long method of analysis). The best fit for these points was determined to be a second order curve with a correlation coefficient of 0.89. The equation of this curve is:

$$0.0253 \ X^2 + 1.6017 \ X + 0.1147 = y$$

5.3   Measurements (Long Method)- This is the referee method. Also, it is required when the size distribution of entrained air voids is abnormal, such as occurs when the voids are caused by the evolution of hydrogen in the mortar due to the presence of aluminum. In this method, under 100x magnification and oblique illumination, the intervals intercepted by each entrained and entrapped air void (their chord lengths) are determined, as well as the number of voids of each type and the total distance traversed. The volumetric percentage of each type of air void is a function of its average chord length and number of voids.

$$A = \bar{l} \ x \ n \ 100$$

Where:

$\bar{l}$ = average chord intercept

n = number of voids per 25 mm (inch) of traverse

6.   PROCEDURE B

6.1   Place prepared specimens under the video camera in a position to view the area of interest and focus the camera. The size of the area observed will depend on the magnification used. Level the upper surface of the specimen, if necessary, using pieces of modeling clay. This will reduce the need for frequent refocusing of the camera.

6.2   Obtain the image of the prepared surface on the display screen and adjust the gray levels to produce the sharpest contrast between the white voids and black background. Save this image.

6.3   Fill the white features in the image with some selected color to properly fill all of the voids. A two color approach is recommended.

6.3.1   Select the brightest void and fill it with a color (such as red). This will fill all of the voids of similar brightness. Then select one of the small, less bright, voids which are not filled with color and fill it with a contrasting color (such as blue). This will fill all of the remaining voids.

NOTE 4- By entering certain parameters, the operator can tell the computer not to count elongated features (such as cracks) as air voids.

6.4   Using a program for determining the percent of features, have the computer analyze the area occupied by the two colors of Section 6.3.1 and combine the results.

6.5   Move the specimen to expose a different area to the camera and repeat Sections 6.2 to 6.4. In order to obtain a good sampling of the overall air void system, at least 16 areas of approximate 50 sq. mm per area shall be analyzed per specimen. These areas shall be spread uniformly over the entire surface of the specimen and be evenly spaced from each other.

6.6   Have the computer total all of the results and calculate the entrained and entrapped air void content for the specimen and other parameters of interest. The amount of information obtained depends on the sophistication of the image analysis system being used.

6.7   Have the computer print out the information of interest.

7.   REPORT FORM TR-459, AIR CONTENT OF HARDENED CONCRETE.

7.1   For Procedure A, report Voids Per 25 mm (Inch), Total Traverse Length, Entrained Air, Entrapped Air, and Total Air (NOTE 5).

7.2   For Procedure B, report only entrained air, entrapped air, and total air.

NOTE 5- This same report form includes additional information obtained at the same time that the entrained air content is determined and is provided to permit an evaluation of the concrete.
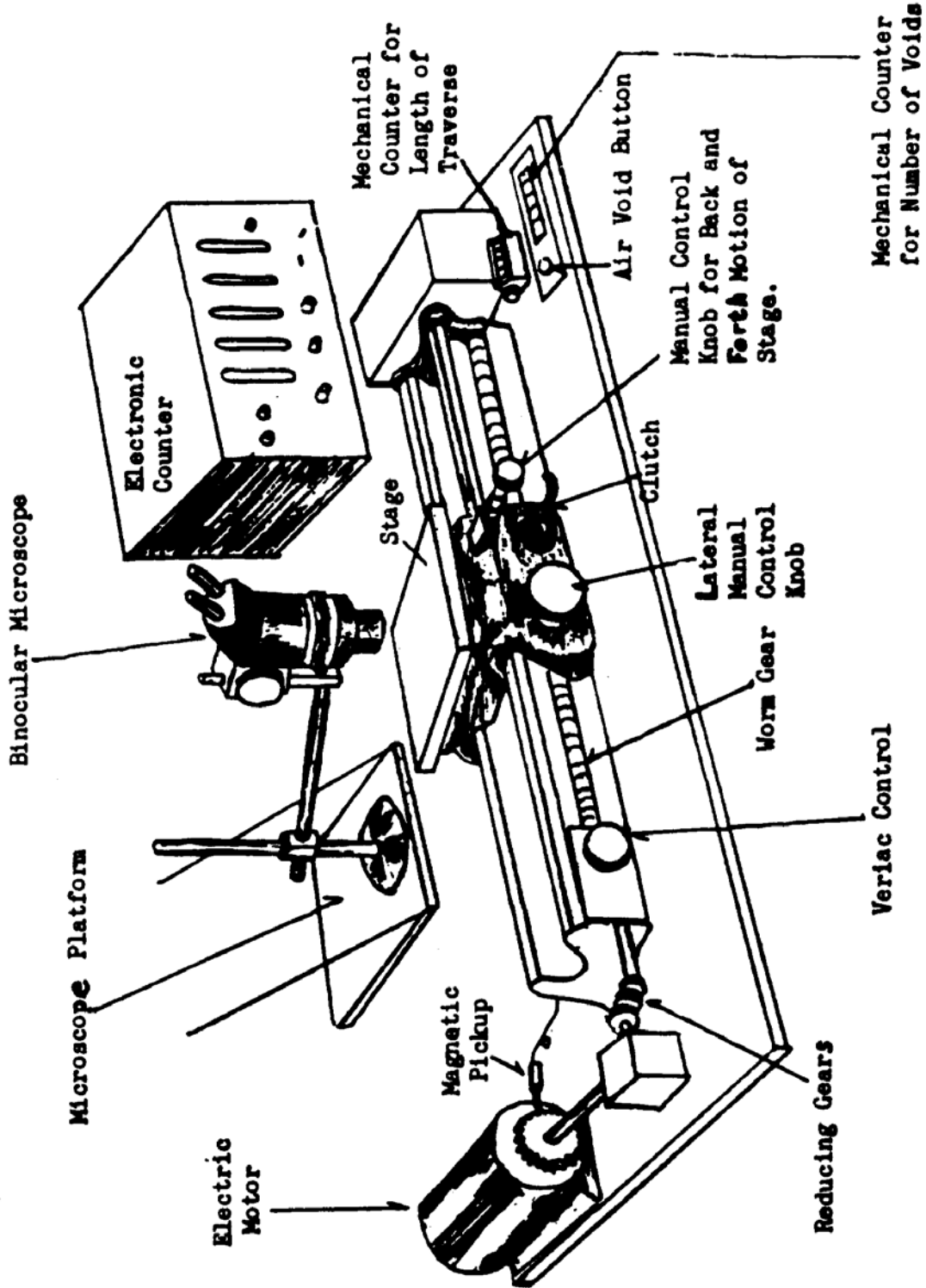
FIGURE 1
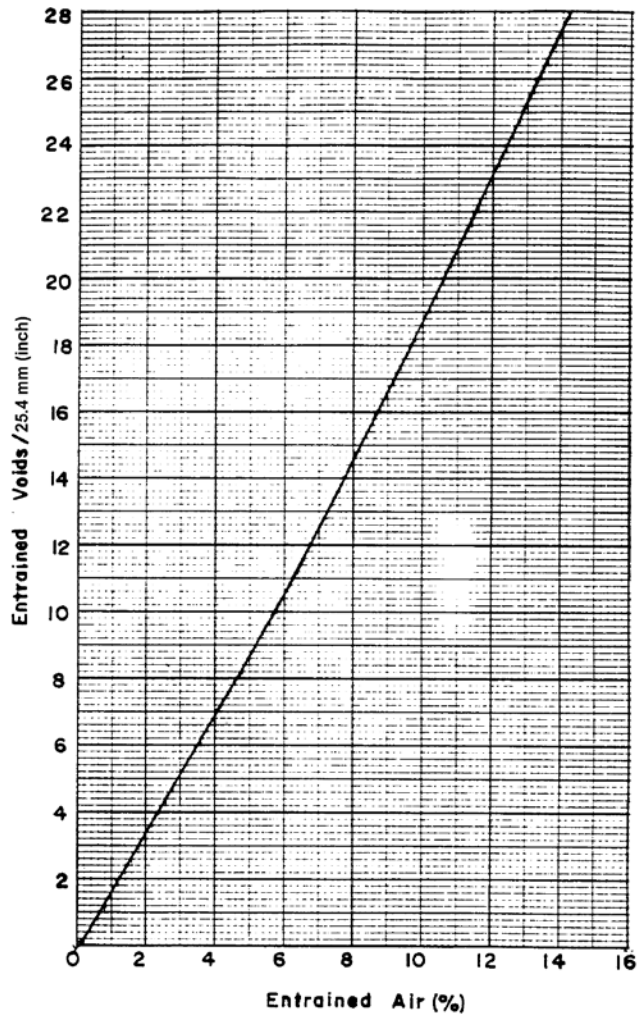
FIGURE 2

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LABORATORY TESTING SECTION

Method of Test for

CALIBRATION OF OUTPUT METER ON MOBILE CONCRETE PLANTS

1.   PURPOSE

        1.1   This method provides a procedure for obtaining a correction factor to be applied
to the output meter reading to determine the actual volume of concrete discharged.

2.   EQUIPMENT

        2.1   The required equipment is the same as that described in AASHTO T-121.

3.   PROCEDURE

        3.1   Weigh the empty calibration measure and record the mass (W_m).

        3.2   Record the output meter reading (R_1)

        3.3   Fill the calibration measure to approximately 90% of its capacity taking care that
the entire discharge of concrete enters the container.

        3.4   Record the output meter reading (R_2)

        3.5   Weigh the measure containing the concrete and record the mass (W_t).

        3.6   Determine the unit weight (W_u) of an additional sample of concrete in accordance
with AASHTO T-121.

4.   CALCULATIONS

    4.1   Calculate the metered volume of concrete (V_m) placed in the calibration measure by subtracting the first meter reading from the final reading.

$$V_m = R_2 - R_1$$

    4.2   Calculate the actual mass of the concrete in the measure.

$$W_a = W_t - W_m$$

    4.3   Calculate the actual volume (V_a) of concrete in the calibration measure by dividing the actual mass of the concrete by the unit weight (W) determined from this same batch of concrete.

$$V_a = \frac{W_a}{W}$$

    4.4   Calculate the metering correction factor (K) by dividing the calculated actual volume of concrete in the measure by the volume discharged as indicated by the output meter.

$$K = \frac{V_a}{V_m}$$

NOTE 1 - This method can be used only in conjunction with AASHTO T-121, Method of Test for Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete.

REFERENCES:

ASTM: C 685
AAHTO T-121

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LABORATORY TESTING SECTION

Method of Test for

ASSESSMENT OF CONCRETE TO STRAND BOND FOR PRESTRESSED
APPLICATIONS

1.   SCOPE

        1.1   This test method examines bond quality of seven-wire strand used in prestressed concrete applications by means of a destructive pullout test of a strand from a concrete prism. The method is developed for examination of both strand quality and concrete bond properties.

        1.2   This test method is applicable primarily under field conditions; however, controlled laboratory tests are also appropriate.

        1.3   The values stated in this test method are in pounds and inches unless otherwise noted.

2.   REFERENCED DOCUMENTS

        2.1   ASTM International. "C 39/C 39 – Compressive Strength of Cylindrical Concrete Specimens," West Conshohocken, PA: 2004.

.   2.2   ACI 318-02, Building Code Requirements for Structural Concrete and Commentary. American Concrete Institute, 2002.

        2.3   PCI, "PCI Design Handbook," Precast and Prestressed Concrete, Fifth Edition, Chicago, IL, 1999

3.   SIGNIFICANCE AND USE

        3.1   This test method is intended to be used to assess the adequacy of bond between concrete and seven wire prestressing strand using production concrete mixes and as-delivered strand under plant fabrication conditions. The test method allows for identification of potential bond problems due to changes in strand surface conditions, concrete mix proportions, or concrete constituents. The test method is intended for use by a precast/prestress plant to allow for initial mix design verification or initial strand supplier qualification prior to use in full production. The test would be performed during the mix prequalification phase. The test is not intended to be used during production.

4.   APPARATUS

        4.1.   *Molds for Test Specimens*- The molds for the test specimen shall measure 6.5-in. wide by 12-in. deep (Figure 1). The specimen length is equal to the bonded length, Lb, plus an additional 2-in. un-bonded length. The bonded lengths are tabulated relative to different strand diameters in Table 1. The molds shall be made of steel or wood and allow for easy removal after fabrication. The molds shall be made watertight after assembly around the prestressed strand. Special care shall be taken to seal areas where the strand extends from the mold. The molds shall be designed to hold the strand at the center of the cross-section.

Table 1: Specimen Bond Length						
Strand Designation	3/16	7/16	1/2	1/2 Special	9/16	0.60
Bond Length, L_b [in.] PCI*	22	26	30	32	34	36
Specimen Length [in.]	24	28	32	34	36	38

*Calculated per PCI Bridge Design Manual (8.3.1.5) using 60 strand diameters
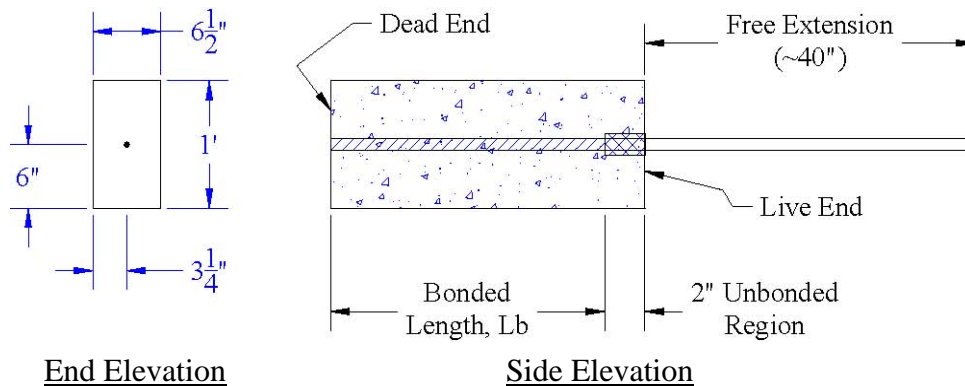
Figure 1: Test Specimen

        4.2   *Measuring Apparatus*- The movement of the strand with respect to the concrete shall be measured on the rear (dead) end. A dial gage or displacement transducer with a graduation of 0.001-in. and a minimum stroke of 0.5-in. shall be used. The load shall be measured with a calibrated load cell in-line with the strand being tested. Use of a jack pressure gage is not recommended unless the gage has been calibrated with a load cell and is capable of providing a resolution of +/- 20 lbs. A suitable displacement measuring apparatus is shown in Figure 2.
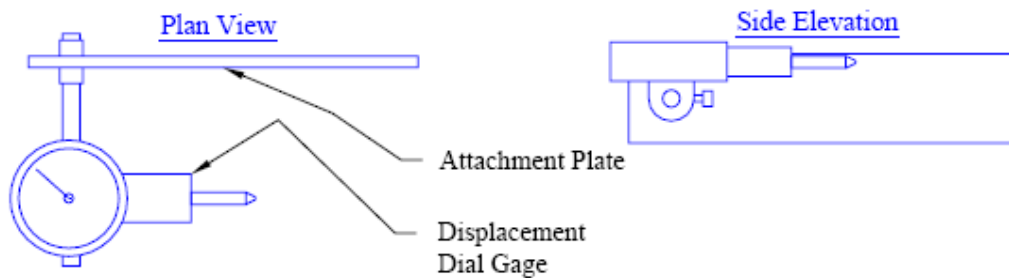
Figure 2: Measuring apparatus

4.3.   *Testing Apparatus* - The testing apparatus shall consist of a through-hole hydraulic jack or universal testing machine, a reusable strand chuck, and a bearing plate. The bearing plate shall have an adequate bearing area to prevent crushing of the concrete surface. The hydraulic jack shall have a controller that allows for a smooth load increase of 20 kips/min. A schematic of a usable testing configuration is shown in Figure 3. The jack shall have a minimum stroke of 4-in. to allow for full pullout.
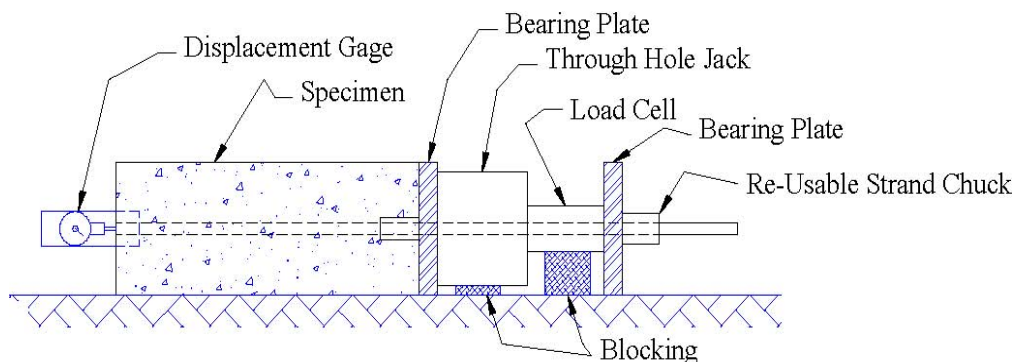
Figure 3: Test apparatus

5.   TEST SPECIMEN

5.1   The test specimens shall be cast in a horizontal orientation on the precast plant prestressing bed around the stressed strand. An initial jacking stress of 75% of the strand ultimate strength is recommended. For example, for a 270 ksi ½-in. special strand a jacking force of 33.8 kips is recommended. No additional reinforcement shall be used.
If possible, the specimens shall be situated at the end of the strand run, inline with the precast element that is being fabricated. Adequate free strand length shall be provided on the un-bonded end to allow for jacking (a length of 40 in. is recommended). A minimum of three specimens shall be fabricated for each combination of strand type and concrete mix design. All specimens shall be cast from the same batch of concrete using the same strand lot, within one (1) hour of each other and cured together.

5.2   Concrete shall be placed and vibrated using form or immersion-type vibrators. For self consolidating concrete mixes (slump > 10-in.) placement can be conducted in one lift without consolidation. Once the mold is filled, the top surface shall be finished with a steel trowel and covered to prevent loss of moisture. Curing methods shall conform to standard plant practice.

5.3   A minimum of six companion concrete cylinders, 4-in. by 8-in. or 6-in. by 12-in., shall be fabricated and tested according to ASTM C 39 to determine the compressive strength of the concrete at transfer and at the time of testing. The cylinders will be match cast and match cured with the specimens to ensure consistency between the specimen and cylinder strengths.

5.4   The initial prestress shall be transferred in accordance with plant procedures. Slow transfer of stress is recommended; however, flame cutting of strands can be used.

5.5   The release strength of the concrete shall conform to the design application. Initial testing, for the purpose of developing historical data of accepted and/or approved mix designs used for prestressed concrete beams must be performed when the concrete compressive strength at release is not less than 6800 psi or greater than 7500 psi. That strength is to be verified before release in accordance with the plant's normal procedures.

5.6   After release of prestress the strand shall be cut flush with the surface of the specimen at the dead end and a 40-in. length of strand shall be left on the live end (de-bonded side). The cut side shall be ground flat with an abrasive wheel to provide a smooth bearing surface for the displacement measurements.

5.7   Testing of the specimens shall take place within two (2) hours after release. Pullout tests of the three specimens shall be conducted sequentially over a duration of less than one (1) hour to ensure consistency in concrete strengths.

6.   PROCEDURE

6.1   The specimens shall be tested in the horizontal position. The displacement gage shall be attached to the strand at the dead end of the specimen as shown in Figure 3. At the dead end of the specimen the displacement gage shall be attached to one of the outer strand wires. Avoid the inner wire as relative slip may occur between the inner and outer wires of the strand resulting in an inaccurate measurement.

6.2   The jack and bearing plates shall be supported with blocking prior to loading to ensure that the strand is centered in the test setup. Apply a load at a maximum rate of 20 kips/min., or if displacement control of the ram is available, at a rate less than 0.02 in./min. Take proper safety precautions against potential flying debris that may be generated during failures. Safety guidelines are beyond the scope of this document and shall be discussed with the plant safety committee prior to use.

6.3   Record the applied load (in pounds) and displacements regularly such that a minimum of 10 points are recorded prior to a dead end displacement of 0.01-inch. Record the load to the nearest pound and the displacement to the nearest 0.001-inch. Be careful to note the load level when the dead end reaches a displacement of 0.01-inch, *Fi*, and 0.1-inch, *Fu*. Continue recording until: 1) a decrease in load by 25% is measured, 2) the strand fractures, or 3) a displacement of 0.5-in. is measured on the live end.

7.   CALCULATION

7.1   Bond quality is computed relative to lower bound transfer and development lengths measured for the chosen concrete properties and strand type. The lower bound estimate of transfer length is computed according to Equation 1. The lower bound bond length required to achieve the fracture strength of the strand can be computed according to Equation 2.

$$L_{ti} = \frac{f_{pi} \cdot A_s}{F_i} \cdot L_b \qquad\qquad Eq.1$$

$$L_{ult} = \frac{f_{pu} \cdot A_s}{F_u} \cdot L_b \qquad\qquad Eq.2$$

L_{ti} = Lower bound transfer length [in.]

L_{ult} = Lower bound bond length required to fracture strand [in.]

f_{pi} = Initial stress in strand at transfer [ksi]

f_{pu} = Ultimate strength of strand [ksi]

F_i = Measured force corresponding to 0.01-in. slip at dead end of specimen [kips]

F_u = Measured force corresponding to 0.10-in. slip at dead end of specimen [kips]

A_s = Cross-sectional area of strand [in.^{2}]

L_b = Bonded length of strand [in.]

7.2   To compare the bond qualities of the results with concretes of different strengths, compute a normalized transfer and ultimate bond length. Normalize the lengths relative to the tensile concrete strength by dividing the computed lengths by the square root of the concrete compressive strength as shown in Equations 3 and 4.

$$L_{ti-NORM} = \frac{L_{ti}}{\sqrt{f'_c}} \qquad\qquad Eq.3$$

$$L_{ult-NORM} = \frac{L_{ult}}{\sqrt{f'_c}} \qquad\qquad Eq.4$$

f'_c = Concrete compressive strength measured at the time of the pullout test [psi]

8.   REPORT

   8.1   Include in the report the following information:

- Date and Time of Concrete Placement
- Date and Time of Stress Transfer
- Date and Time of Pullout Test
- Concrete Mix Batch Weights
- Mix Design Identification No.
- Concrete Constituents
- Strand Size and Type
- Strand Manufacturer
- Strand Heat Number and Lot ID
- Strand Yield Strength [ksi] (from mill certification)
- Strand Ultimate Strength [ksi] (from mill certification)
- Concrete Compressive Strength at Release [psi] (average and standard deviation)
- Concrete Compressive Strength at time of Pullout Test [psi] (average and standard deviation)
- Initial Strand Jacking Stress [ksi]
- Strand Stress Prior to Transfer, fpi [ksi]
- Measured Pullout Force at Initial Slip, Fi [kips] per test
- Measured Maximum Pullout Force, Fu [kips] per test
- Failure mode
- Lower bound transfer and bond lengths
- Normalized transfer and bond lengths

9.   ACCEPTANCE

        9.1   Until historical data is generated using this test method it is recommended that passing performance be assessed relative to the performance of historically good mixes. For example, to qualify a new self consolidating concrete (SCC) mix the following procedure can be adopted. The SCC shall be considered passing if the average of the three (3) tests is greater than 90% of the average of a high early strength (HES) concrete that has historically good performance.

        9.2   With continued use of this test method it is expected that the results can be correlated directly with ACI/PCI transfer and development lengths.

10.   ACKNOWLEDGMENTS

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LABORATORY TESTING SECTION

Method of Test for

MAKING AND CURING CONCRETE COMPRESSION SPECIMENS IN
PRECAST AND PRE-STRESSED CONCRETE PLANTS

1.   SCOPE

       1.1   This method covers procedures for making and curing specimens of concrete
sampled from concrete being used in precast products, box culvert, and pre-stressed concrete
beam fabrication.

2.   APPARATUS

       2.1   Molds for Compression Test Specimens- The molds shall be cylindrical in shape,
machined metal for all products that are steam cured.

       2.2   For all remaining apparatus refer to AASHTO T-23, Section 4.

3.   SPECIMENS

       3.1   Size of Specimens- Compression test specimens shall be cylindrical, with a length
equal to twice the diameter. The standard specimen shall be a 152 mm by 305 mm (6" x 12")
cylinder when the nominal maximum size of the aggregate does not exceed 50 mm (2"). When
the nominal maximum size of the coarse aggregate does not exceed 25 mm (1"), the specimen
may be 102 mm by 203 mm (4" x 8") cylinders.

       3.2   Identification of Specimens- Compression Test specimens shall be identified as
described in Section 9. Specific methods of identification of specimen molds and specimens shall
be described in detail in the plant's Quality Control plan.

4.   SAMPLING CONCRETE

       4.1   Refer to AASHTO T-23, Section 6

5.   SLUMP AND AIR CONTENT

       5.1   Refer to AASHTO T-23, Section 7

6.   MOLDING SPECIMENS

       6.1   Refer to AASHTO T-23, Section 8

7.   CURING

7.1   Specimens for Checking the Strength of Concrete for Trial Mix Designs- Steel molds shall be placed on a rigid horizontal surface free from vibration and other disturbances. During the first 24 ± 2 hr. all test specimens shall be stored under conditions that maintain the temperature immediately adjacent to the specimens in the range of the beam curing cycle and under conditions that will prevent loss of moisture from the specimens. After 24 ± 2 hr. of curing under the above conditions, the specimens shall be removed from the molds and stored in the same atmosphere and curing conditions as those planned for the beam until the time of test.

> NOTE 1- A moist condition is that in which free water is maintained on the surface of the specimens at all times.

7.2   All specimens shall be placed next to the product, or may be suspended from the forms on a hanger or shelf designed for this purpose. Specimens shall receive the same cure as that specified for the product. The specimens shall be removed from the mold at the same time the forms are stripped.

7.3   Specimens shall be tested in the moisture condition resulting from the specified curing treatment.

> NOTE 2- For pre-stressed beams in lieu of actual curing with the beam, cylinders may be cured in curing chambers correlated in temperature with the beds. The correlation shall be constantly verified by the use of recording thermometers in the curing chambers and comparison with the temperature records of the beds, and by the use of the same methods of moisture retention for curing chambers and casting beds.

8.   CAPPING SPECIMENS

8.1   Refer to AASHTO T-231

8.2   Neoprene Caps- Use of neoprene caps shall be considered a suitable alternative for compression strength testing. When 102 mm x 203 mm (4" x 8") cylinders are used, neoprene caps are required. The material and procedure shall be in accordance with the Annex in this test method.

9.   IDENTIFICATION AND SECURITY OF COMPRESSION TEST SPECIMEN MOLDS AND COMPRESSION TEST SPECIMENS

    9.1   Identification of Specimen Molds

    9.1.1. Steel molds- Where steel molds are used, each mold must be scribed, engraved or otherwise permanently marked with a unique identification number on the outside of the mold. For Quality Control cylinders, the plant shall maintain as part of the Quality Control records the following information on a supplemental form (Note 2):

- Date molded (This may also be the Lot number where only a single mixture is used during a production shift for acceptance.)
- Mix Design Identification (Job Mix Formula)
- Beam, piece mark or other identification to provide a unique correlation of the molds and cylinders to the product produced.
- A series number (e.g. 1, 2, 3, …n) or other means to identify the number of specimens molded.
- Name of the plant's Quality Control technician who molded the specimens.
- Name of the Department representative who witnessed the molding of the specimens

    9.1.2. Plastic molds- Where plastic molds are used, the information identified in Section 9.1.1. must be marked by the plant's Quality Control personnel on each individual compression test specimen mold using a permanent marker having a color other than that of the mold to provide sufficient visible contrast to the naked eye, prior to molding. In addition, the Department's inspector shall apply either their signature or inspection stamp to the mold.

Note 2- The Department's representative will record the information in the 'Remark's' section of the Electronic Quality Management System (EQMS) Plastic Test Entry screen.

    9.2   Identification of Specimens- Immediately after the compression test specimens are removed from their molds, the plant's Quality Control technician (in the presence of a Department representative), shall transcribe the information identified in Section 9.1.1 above to the cylinders, including the cylinder mold identification number when steel molds are used, using a permanent marker with the exception of the Department representative's name or stamp. (The Department representative will stamp or sign each cylinder (Note 3).

Note 3- Where cylinders are molded in sufficient quantity to provide for verification of form release strengths by the plant, up to two cylinders may be de-molded and tested by the plant without verification or inspection by the Department when this activity is performed outside the normal or typical inspection shift. In all other cases, identification of the compression strength specimens must be performed in the presence of a Department representative.

ANNEX
Compressive Strength of Cylindrical Concrete Specimens
Using Un-bonded (Neoprene) Caps

A1.   SCOPE

A1.1 Un-bonded Neoprene caps must meet the requirements of ASTM C 1231 or as indicated below. Neoprene caps are not to be used for concrete mixtures with compressive strengths above 12000 psi.

A2.   TEST SPECIMENS

A2.1 Test specimens shall be either 152 mm by 305 mm (6" x 12") or 102 mm x 203 mm (4" x 8"). Neither end of a cylinder shall depart from perpendicularity to the axis by more than 0.5 degrees (approximately 1/8" in 12").

A2.2   Requirements for Neoprene Pads:

F'c, Compressive Strength,[1] psi	Shore A Durometer Hardness	Use / Maximum Reuses[2]
Less than 1500		Not Permitted
Less than 6000	50	100
>6000 to 7000	60 or 70	100
>7000 to 12000	70	50
[1] - F'c is the 28-day strength requirement as indicated on the shop drawings.		
[2] - Reject pads if cracks or splits in either surface exceed 3/8" in length regardless of depth.		

A3.   PRECAUTIONS

A3.1 Concrete cylinders tested with neoprene caps rupture more intensely than comparable cylinders tested with sulfur-mortar caps. As a safety precaution, the cylinder testing machine must be equipped with a protective cage.

A3.2   The loading rate for some testing machines may have to be adjusted when using neoprene caps.

A4.   CALCULATION

A4.1   The compressive strength shall be calculated as described below:

The compressive strength of the specimen shall be calculated by dividing the maximum load carried by the average cross-sectional area, and shall be expressed to the nearest 10 psi. CAMMS performs all rounding automatically; therefore, no rounding shall be done on the issued CAMMS report. If CAMMS is not used for reporting the compressive strength values, rounding shall be performed using the following format:

Report the compressive strength value to the nearest 10 psi. If the final integer value of the calculated compressive strength value is between 0 psi to 4 psi, the reported value shall be rounded down. If the value is from 5 psi to 9 psi, the reported value shall be rounded up.

A5.   REPORT

A5.1   The report shall contain the following items:

- Identification number
- Diameter and length, inches
- Cross-sectional area, square inches
- Maximum load, in pounds
- Compressive strength calculated to the nearest 10 psi
- Type of fracture, if other than the usual cone
- Defects in either the specimen or caps, if noted
- Age of the specimen

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LABORATORY TESTING SECTION

Method of Test for

TIME OF SETTING OF CONCRETE MIXTURES BY
PENETRATION RESISTANCE

1.   SCOPE

    l.1   This method covers determination of the time of setting of concrete with a slump greater than zero by testing mortar sieved from the concrete mixture. The method is suitable for use only when tests of the mortar fraction of the concrete will provide the information required. Since the hardening of concrete is a gradual process, any definition of time of setting must necessarily be arbitrary. The temperature of storage of the specimens employed in this test is to be selected by the user. Times of initial and final setting of concrete are determined in accordance with this method on the basis of a rate of hardening test using penetration resistance needles on mortar sieved from the concrete mixture.

    1.2   This method can also be used for determining the effects of variables such as temperature, cement, mixture proportions, additions, and admixtures upon the time of setting and hardening characteristics of concrete. It may also be used as a part of a performance specification to determine compliance with specified time of setting requirements.

2.   DEFINITIONS

    2.1   Time of initial setting - The elapsed time, after initial contact of cement and water, required for the mortar sieved from the concrete to reach a penetration resistance of 3447 kPa (500 psi).

3.   APPARATUS

    3.1   Containers for Mortar Specimens - Rigid, watertight, non-absorptive, non-oiled containers, either cylindrical or rectangular in cross-section. The minimum lateral dimension shall be 152 mm (6 in.) and the height at least 152 mm (6 in).

        NOTE 1- The container(s) for the mortar from each concrete mixture shall provide enough mortar surface for ten undisturbed readings of penetration resistance. See Section 6.2 for clear distance requirements for needle impressions.

3.2   Penetration Resistance Apparatus- Spring reaction-type apparatus, graduated from 138 kPa to 4826 kPa (20 to 700 psi.) in increments of 138 kPa (20 psi.) or less. The needle provided with the apparatus shall have a bearing area of 6 mm (1/4 in.) and the shank shall be scribed peripherally at a distance 25 mm (1 in.) above the bearing face.

3.3   Tamping Rod - Round, straight, steel rod 16 mm (5/8 in.) in diameter and approximately 600 mm (24 in.) in length, having the tamping end rounded to a hemispherical tip, the diameter of which is 16 mm (5/8 in.).

3.4   Pipette - Pipette or a suitable instrument for drawing off free water from the surface of the test specimens.

4.   PREPARATION OF MORTAR SPECIMENS

4.1   From the concrete mixture under test select a representative sample of concrete of sufficient volume to provide enough mortar to fill the test container(s) to a depth of at least 140 mm (5 ½ in).

4.2   Remove essentially all of the mortar from the sample of concrete by sieving it through a 4.75 mm (No. 4) sieve onto a non-absorptive surface.

4.3   Thoroughly remix the mortar by hand methods on the non-absorptive surface and place it in the container(s) and compact by rodding. Rod the specimen by means of the tamping rod held so as to penetrate the mortar with the round end. Rod the mortar once for each 25 mm (1 in.) of top surface area of the specimen and distribute the strokes uniformly over the cross section of the specimen. After completion of the rodding, tap the sides of the containers slightly with the tamping rod to close voids left by the tamping rod and to further level the surface of the specimen. Upon completion of specimen preparation, the mortar surface shall be at least 13 mm (1/2 in.) below the top edge of the container to provide space for the collection and removal of bleeding water and to avoid contact between the mortar surface and the protective covering specified in Section 5.

5.   STORAGE OF MORTAR SPECIMENS

5.1   Store and maintain the specimens at the desired temperature of test. To prevent excessive evaporation of moisture, keep the specimens covered with a suitable material such as damp burlap or a tight-fitting, water-impermeable cover for the duration of the test, except when bleeding water is being removed or penetration tests are being made. The specimens shall be shielded from the sun.

6.   PROCEDURE

6.1   Remove bleeding water from the surface of the mortar specimens just prior to making a penetration test by means of a pipette or suitable instrument. To facilitate collection of bleeding water, tilt the specimen carefully to an angle of about 12 degrees from the horizontal by placing a block under one side of the specimen, two minutes prior to the removal of the bleeding water.

6.2   Bring the bearing surface of the needle into contact with the mortar surface. Gradually and uniformly apply a vertical force downward on the apparatus until the needle penetrates the mortar to a depth of 25 mm (1 in.) as indicated by the scribe mark. The time required to penetrate to the 25 mm (1 in.) depth shall be approximately 10 seconds. Record the force required and the time of application, measured as the elapsed time after initial contact of the cement and water. In subsequent penetration tests take care to avoid areas where the mortar has been disturbed by previous tests. The clear distance between needle impressions shall be at least 13 mm (½ in.). The distance between any needle impression and the side of the container shall be not less than 25 mm (1 in).

6.3   Make penetration tests at hourly intervals for normal mixtures and normal temperatures, the initial test being made after an elapsed time of 3 to 4 hours. For accelerated mixtures or high temperatures, it may be advisable to make the initial test after an elapsed time of 1 or 2 hours and subsequent tests at hour intervals. For low-temperature conditions or retarded concrete mixtures, the initial penetration test may be deferred for an elapsed time of 4 to 6 hours, and perhaps longer. Subsequent tests may be made at intervals of 1 hour, unless the rate of increase in penetration resistance indicates that shorter intervals are desirable.

6.4   Not less than six penetration resistance determinations shall be made for each rate of hardening test. The time intervals between penetration resistance determinations shall be such as to give a satisfactory rate of hardening curve, as indicated by equally spaced points. Continue the tests until a penetration resistance of at least 3447 kPa (500 psi) is reached.

7.   REPORT

7.1   The report shall include the following:

7.1.1   Data on the Concrete Mixture:

7.1.1.1   Type and proportions of cement, fine aggregate, coarse aggregate (including maximum size and grading of aggregates), and the ratio of net water content to cement content

7.1.1.2   Name, nature, and percentage of active ingredients by mass of cement , or of any addition or admixture used

7.1.1.3   Air content of the fresh concrete and the method of determination

7.1.1.4   Consistency of the concrete as determined by the slump or other test for consistency

7.1.1.5   Temperature of the mortar after sieving

7.1.1.6   Record of the ambient temperature during the test period

7.1.1.7   Date of the test

7.1.2   Time of Setting - The time of initial set shall be reported in hours and minutes to the nearest minute.

REFERENCE:

ASTM Designation C 403

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LABORATORY TESTING SECTION

Method of Test for

MEASURING THE RESISTANCE OF 50 mm x 50 mm (2" X 2")
CUBE SPECIMENS OF MORTAR TO SLOW FREEZING AND THAWING IN BRINE

1.   SCOPE

        1.1   This method of test covers the procedure for determining the resistance of 50 mm x 50 mm (2" x 2") cube specimens of mortar to alternate freezing and thawing while immersed in a brine of 10% by mass calcium chloride (USP or better) in water. It is intended to provide information as to the acceptability of concrete patching materials and grouts.

2.   APPARATUS

        2.1   Container- A suitable container (NOTE 1) of sufficient size to permit at least 6 specimens to be surrounded on 5 sides by not less than 13 mm (1/2") of the salt solution at all times during freezing and thawing.

        NOTE 1- A plastic dishpan may be found suitable

        2.2   Freezing Apparatus- The freezing apparatus shall consist of a suitable chamber in which the specified container, salt solution, and specimens may be subjected to the specified freezing temperature of -18 ± 3 °C (0 ± 5 °F). The apparatus shall contain the necessary refrigerating equipment for maintaining this temperature range.

        2.3   Thawing Area- The thawing area shall be relatively dust-free and have a temperature range of 24 ± 8 °C (75 ± 15 °F) to complete the thawing of the test specimens and salt solution within a 7 ± 1 hour period (NOTE 2).

        NOTE 2- Ordinary room temperature usually is sufficient for this purpose, but a 15 watt infra-red lamp may be used to accelerate the thawing. When one of these lamps is used, it shall be placed at a distance of at least 178 mm (7") from the test specimens and salt solution. The lamp may, however, be used immediately after removing the container from the freezing chamber.

3.   TEST SPECIMENS

        3.1   The specimens for use in this test usually are 50 mm x 50 mm (2" x 2") cubes made and cured in accordance with the applicable requirements of the Standard Method of Test for Compressive Strength of Hydraulic Cement-Mortars (Using 50 mm (2") Cube Specimens) ASTM Designation: C 109 (NOTE 3).

NOTE 3- Due to the composition of some materials, (especially premixed aggregate-cement compounds), a standard method of sample preparation cannot always be used. In those instances, the manufacturer's recommended procedure shall be used.

3.2   First, two (2) cubes are made using PENNDOT approved Type 1 Cement, Ottawa sand, and air entraining agent. Then (2) cubes are made with the product under consideration. All samples will be tested at the same time in accordance to ASTM Designation C 109. The cubes made with the PENNDOT approved Type 1 Cement shall be used for comparison, and as an aid in determining the acceptability of the product for its resistance to freezing and thawing.

3.3   After the initial 22 ± 2 hour storage in the moist closet, remove the specimens from the molds and individually identify by either number or other marking. Immerse the specimens in clean water in the storage tanks of the moist closet. Unless another age is specified, keep the specimens in the storage tanks for 13 days ± 6 hours to complete the 14 day curing period.

4.   PROCEDURE

4.1   At the end of the specified curing period (Section 3.3), the specimen shall be removed from the storage tanks, surface dried with a damp cloth or towel, and weighed with the mass being recorded to the nearest 0.1 g (0.004 ounces). The specimens shall be protected from loss of moisture at all times by completely covering with a damp cloth or towel.

4.2   Place the specimens at random locations within the container and cover with the specified salt solution so that all specimens are surrounded on 5 sides by not less than 13 mm (1/2") of the solution (NOTE 4).

NOTE 4- At no time during the test shall the salt solution be less than 64 mm (2½") in depth.

4.3   Place the container inside the freezing chamber for a period of 16 ± 2 hours. Maintain the temperature of the freezing chamber at -18 ± 3 °C (0 ± 5 °F) for the freezing period.

4.4   After the 16 ± 2 hour freezing period, remove the container and permit the contents to thaw at a temperature of 24 ± 8 °C (75 ± 15 °F) for a period of 7 ± 1 hours.

4.5   Alternately freeze and thaw the specimens as specified in Sections 4.3 and 4.4. At the end of the thawing phase of each five cycles, remove the specimens, one at a time, rinse with clean water to remove all traces of brine, surface dry with a damp cloth or towel, and weigh. Record the mass to the nearest 0.1 g (0.004 ounces) and return the specimens to random positions in the container. Care shall be taken to prevent loss of moisture during the weighing operation by covering completely the samples with a damp cloth or towel if not returned directly to the container.

4.6   Unless a different number of cycles have been specified, the test specimens shall be subjected to 25 cycles of alternate freezing and thawing (NOTE 5).

NOTE 5- Testing shall be terminated if during testing a loss greater than that anticipated or other wise designated is encountered.

5.   CALCULATIONS

5.1   Calculations shall he made upon the completion of each 5 cycles to determine the percent loss during those cycles. Determine the total percent loss at the end of the testing period.

5.2   Calculate the percent of loss by using the following formula:

$$L = \frac{W - X}{W} \times 100$$

Where:

L =   Percent Loss

W =   Mass of the specimen at 0 cycles

X =   Mass of the same specimen after completion of each testing period (5 cycles, then at 10 cycles, etc., up to and including final cycle).

5.3   To be acceptable, the average percent loss of the cubes made with the product being evaluated must be 8% or less, at the end of 25 cycles.

6.   REPORT

6.1   The report shall include the following data for both the standard cubes and the cubes made with the product under consideration:

A.   Curing Process, (if other. than that specified in Sections 3.1 and 3.3)

B.   Mass at 0 cycles

C.   Mass and percent of loss after each 5 cycles

D.   Source of the cement used in the standard cubes: Plant and Bin Number

E.   Actual amount of water added to the mass of the material under test to make the mortar cubes.

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LABORATORY TESTING SECTION

Method of Test for

CALIBRATION OF MOBILE MIXERS USED FOR
LATEX MODIFIED MORTAR (LMM) AND LATEX MODIFIED CONCRETE (LMC)

1.   PURPOSE

        1.1   This method provides a procedure for the calibration of mobile mixers used in
                placing latex modified mortar and concrete.

2.   EQUIPMENT

        2.1   Necessary equipment includes 8 L (2 gal.), 76 L (20 gal.), and 114 L (30 gal.)
                containers. A balance meeting the requirements of AASHTO M-231, Class G2.

3.   PROCEDURE

        3.1   Cement:

                3.1.1   Check the aggregate bins to insure that they are empty and clean.

                3.1 2   The ground strap shall be down.

                3.1.3   Run cement out of the bin to the charge belt.

                3.1.4   Begin recording masses and times when the cement mass is close to 43.5
                        kg (95.88 lbs.) and is consistent.

                3.1.5   Record masses and times on the Field Calibration Sheet (Field Calibration
                        Sheet is appended to this PTM).

                        NOTE 1- If the calibration of cement is performed with aerators on, these
                        aerators must be on during placement.

3.2   Fine Aggregate (F.A.):

3.2.1   Load the fine aggregate bin(s).

3.2.2   Run the fine aggregate out of the bin to the charge belt.

3.2.3   Check the bin(s) to insure aggregate is flowing evenly and is not packing or "hanging up".

3.2.4   Determine the F.A. discharge rate (mass/sec.) as follows:

Total design mass / Number of bags = mass/bag

Mass/bag + F. A. moisture mass = Actual mass

F. A. moisture mass = mass/bag x % moisture

Actual mass / time = mass/sec

NOTE 2 - This mass of fine aggregate is the saturated surface dry mass (S.S.D.) and must be adjusted to include aggregate moisture (% moisture from CS-4220A, Batcher-Mixer Slip).

3.2.5   Record the first mass under SAND on the Field Calibration Sheet (Field Calibration Sheet is appended to the PTM) when it nears the required amount of fine aggregate as calculated under Section 3.2.4 above.

3.2.6   Run the aggregate until at least three (3) consecutive trials are consistent and acceptable (refer to the design and specification for allowable tolerances).

3.2.7   Record the fine aggregate mass and corresponding time on the Field Calibration Sheet.

3.2.8   Record the dial settings on the Field Calibration Sheet.

3.2.9   Insure that the settings are secured.

3.3   Coarse aggregate (C.A. when the F.A. bin is emptied) applies to Latex Modified Concrete:

   3.3.1   Empty the mobile mixer of fine aggregate.

   3.3.2   Load the coarse aggregate bin.

   3.3.3   Run coarse aggregate out of the bin to the charge belt.

   3.3.4   Check the bin to insure aggregate is flowing evenly and is not packing or "hanging up".

   3.3.5   Determine the C.A. discharge rate (wt./sec.) similar to the F.A. procedure as stated in Section 3.2.4.

   3.3.6   Record the first mass under STONE on the Field Calibration Sheet (Field Calibration Sheet is appended to this PTM) when it nears the required amount of coarse aggregate as determined in Section 3.3.5 above.

   3.3.7   Run the aggregate until at least three (3) consecutive trials are consistent and acceptable (refer to the design and specification for the allowable tolerances).

   3.3.8   Record the coarse aggregate mass and corresponding time on the Field Calibration Sheet.

   3.3.9   Record the dial setting on the Field Calibration Sheet.

   3.3.10 Insure that the setting is secured.

        NOTE 3 - Masses of both fine and coarse aggregates are saturated surface dry (S.S.D.) masses and must be adjusted during calibration to include moisture (% moisture from CS-4220A, Batcher-Mixer Slip).

3.4   Coarse Aggregate (C.A.) when the F.A. bin is not emptied: applies to Latex Modified Concrete:

   3.4.1   Leave the F.A. bin intact or recharge if necessary.

   3.4.2   Load the coarse aggregate bin.

3.4.3   Run aggregate out of the bin to the charge belt and insure that the aggregate is flowing evenly and is not packing or "hanging up".

3.4.4   Start with the last dial setting as a guide if available or applicable.

3.4.5   Determine the aggregate discharge rate (wt./sec).

3.4.6   Determine the required aggregate mass (C.A. and F.A.) for calibration (Suggest using 10 sec.).

3.4.7   Record the first mass under STONE on the Field Calibration Sheet when it nears the required amount of aggregate as calculated by calibration (Section 3.3.6. above).

Note 4- (After STONE, that mass includes sand and stone).

3.4.8   Run the aggregate until at least three (3) consecutive trials are consistent and acceptable. (Refer to the specification for allowable tolerances). Important: Adjust only the coarse aggregate dial.

3.4.9   Record the aggregate mass and corresponding time on the Field Calibration Sheet.

3.4.10   Record the stone dial setting on the Field Calibration Sheet.

3.4.11   Insure that the dial setting is secured.

NOTE 5 - Masses of both fine and coarse aggregates are saturated surface dry (S.S.D.) and must be adjusted for calibration to include moisture (% moisture from CS-4220A, Batcher-Mixer Slip).

3.5   Latex:

3.5.1   Set the gauge to design the discharge rate (liters/min.) (gals/min.) determined from the design and cement discharge time recorded in Section 3.1.

3.5.2   Weigh the latex to insure that the gauge is accurate.

3.5.3   Discharge the latex until at least three (3) trials are consistent.

3.5.4   Record the latex gauge settings on the Field Calibration Sheet.

3.6   Water:

3.6.1   Run the water flow meter at settings between 0 and 7.5 L/min. (0 and 2 gpm).

3.6.2   When the flow has stabilized, insert the container in midstream and start timing. At the end of prescribed time, remove the container from the flow.

3.6.3   Weigh the water to insure accuracy of the flow meter.

3.6.4   Run at least three (3) trials at this flow rate (liters/min) (gals/min).

3.6.5   Record the rate on the Field Calibration Sheet.

NOTE 6 – The R.P.M. of the mobile mixer shall be maintained at the operating speed throughout calibration (obtained from the metal plate on the truck).

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FIELD CALIBRATION SHEET FOR LATEX MOBILE MIXERS

County _____
S.R. & Sec. _____
Contract No. _____

Truck Ident. _____
Mixer Ser. No. _____
RPM _____
Date _____

CEMENT	Trials	1	2	3	4	5	6	Totals
Cement Mass								
Meter Count (Whole no.)								
Seconds (to 0.1 secs.)								

Total Meter Count	Total Cement Mass	Factor (to 4 decimals)	Mass / Cu Meter	CEMENT METER COUNT
÷	=	X	=	
Total Seconds	Total Cement Mass	Factor (to 4 decimals)	Mass/ Cu Meter	TIME
÷	=	X	=	

SAND

Total Design Mass (1)	No. Cu Meter of Cement	Mass / Cu Meter	Sand Moisture Mass (2)	Actual Sand Mass
÷	=	+	=	
Actual Sand Mass	Time (from Cement calib.)	Mass / Sec.	Calibration time (sec.)	Calibration Mass
÷	=	X	=	

Calibration of Sand Dial	Trial 1	2	3	4	5	6	SAND DIAL SETTING
Sand Mass							
Time (constant)							
Sand Dial Setting (3)							

STONE

Total Design Mass (1)	No. Cu Meter of Cement	Mass / Cu Meter	Stone Moisture Mass (4)	Actual Stone Mass
÷	=	+	=	
Actual Stone Mass	Time (from Cement calib.)	Mass / Sec.	Calibration time (sec.)	Calibration Mass
÷	=	X	=	

Calibration of Stone Dial	Trial 1	2	3	4	5	6	STONE DIAL SETTING
Stone Mass							
Time (constant)							
Stone Dial Setting (3)							

LATEX

Design Liter/Cu Meter Cement	Time (from Cement calib.)	G.P.M.	Gauge Setting
X 60÷	=		

Total Design Mass (1)	No. Cu Meter of Cem.	Mass/Cu Meter	Time (Cem. calib.)	Mass / Sec.	Calib. Time (sec.)(5)	Calculated Mass
÷	=	÷	=	X	=	

Calibration of Latex Gauge	Trial 1	2	3	4	5	6	LATEX GAUGE SETTING
Gauge Setting Fan Gauge							
Time (constant)							
Latex Mass (6)							

WATER

Calib. of Gauge or Flowmeter	Trial 1	2	3	4	5	6	WATER GAUGE SETTING
Gauge Setting kg /Min. (7)							
Time (minutes)							Max. kg /Min.
Theo. Mass (Setting X X Time)							Min. kg /Min.
Actual Water Mass (6)							Des. kg /Min.

(over)

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(1)   From approved Mix Design (TR-4221-A), Mix Design Worksheet

(2)   Mass/cu.meter X   % moisture in sand = Sand Moisture Mass

(3)   Adjust the dial setting until the masses for 3 consecutive trials (minimum) are
        consistent and compare to the calibration mass within the tolerances stated in the
        special provisions.

(4)   Mass/cu.meter X % moisture in stone= Stone Moisture Mass.

(5)   Use the TIME from the cement calibration to the nearest second.

(6)   Acceptable if within the tolerances given in the special provisions as compared to the
        calculated mass and are consistent for 3 trials minimum.

(7)   Selected gauge setting shall be between the minimum and maximum flow rates (kg./
        minute) as determined from the modified CS-4220A, Batcher-Mixer slip form.

(8)   Calculation of the Maximum, Minimum, and Design Water Gauge Setting:

        Design Water based on the average of Maximum and Minimum Water-Cement ratios.

        Maximum
        Design   Water-Cement ratio X mass of Cement/ cubic meter = Total mass of
        Minimum   Water

        Total kg. of water   =
        kg. of latex X % water in latex   = – _____
        Total aggregate moisture   = –   _____
                                                              Maximum
                                              = kg.   Design Water to be
                                                      Minimum   added

EXPLANATORY NOTES (CONTINUED)

$$\frac{\text{kg. } \frac{\text{Maximum}}{\text{Design}} \text{ water to be added X 60}}{\text{kg. of cement X Calibration time for kg. of cement}} = \text{kg. p.m. } \frac{\text{Maximum}}{\text{Design}} \frac{\text{Water}}{\text{Gauge}}$$

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LABORATORY TESTING SECTION

Method of Test for

ABRASION RESISTANCE OF CONCRETE OR MORTAR BY THE ROTATING-CUTTER
METHOD

1.   SCOPE

     1.1   This method covers a procedure for determining the resistance of either concrete
or mortar to abrasion.

2.   SIGNIFICANCE AND USE

     2.1   This method gives an indication of the relative wear resistance of mortar and
concrete based on testing of cored or fabricated specimens. The results of tests by this method
have not been correlated with field performance. It is useful, however, for comparing different
materials or treatments. It has been found instructive to test the specimens by ASTM C 666 after
abrasion testing.

3.   APPARATUS

     3.1   Abrasion Device - A drill press or similar device with a chuck capable of holding
and rotating the abrading cutter at a speed of 220 rpm and exerting a constant pressure of 4.4 kg
on the test specimen surface.

     3.2   Rotating Cutter - A rotating cutter shall be used in which twenty-four No. 1
Desmond-Huntington grinding dressing wheels are mounted. The overall diameter of the cutter
or the diameter of the circular abrade area is 89 mm (3-1/2 in). Care shall be taken to achieve
constant contact between the rotating cutter and the entire test specimen surface. If the dressing
wheels have one rounded edge, they shall be mounted with the rounded edge toward the vertical
shaft. The individual grinding wheel dressers on the horizontal shaft of the cutter shall be
repositioned whenever a change in the diameter of the outer cutters becomes apparent. This is
accomplished by reversing each set of dressing wheels to bring the smaller diameter cutters
toward the vertical shaft. The cutters shall be reversed at least every 45 minutes of running time.

          3.2.1   In making a test, the rotating cutter is held in a raised position, the
specimen is clamped securely in position, and the motor started. The rotating cutter is then
lowered into contact with the specimen for a specified time, after which the cutter is raised.

     3.3   Balance - A balance meeting the requirements of AASHTO M-231, Class G2.

4.	SAMPLING

4.1	Cores shall be taken in accordance with AASHTO T-24. The cores shall be at least 100 millimeter (4 inches) in diameter. Not less than three cores shall be taken for each condition to be tested.

5.	LABORATORY PREPARED SPECIMENS

5.1	The specimens used in this test shall be of any size and shape that can be accommodated by the abrasion device and the balance provided. The surface to be tested shall be either formed or finished and shall be positioned in the plane of contact of the cutter.

6.	PROCEDURE

6.1	Determine the mass of the specimen to the nearest 0.1 g.

6.2	Fasten the specimen securely in the abrasion device so that the surface to be tested is normal to the shaft.

6.3	Mount the rotating cutter device in the abrasion device.

6.4	Start the motor and lower the cutter slowly until the cutter just comes in contact with the surface of the specimen.

6.5	Continue abrasion with a load of approximately 4.4 kg on the specimen for four minutes after contact between the cutter and the surface. At the end of the four minute abrasion period, remove the test specimen from the device and determine its mass. If desired, the test specimen may be returned to the device for additional abrasion for two minute periods. The minimum test schedule shall involve one, four minute period conducted on three separate areas of representative surfaces of the concrete or mortar.

6.6	For concrete that is highly resistant to abrasion additional testing may be required. Doubling the applied load, or the time, or both, should provide more comprehensive information on such concrete.

7.   REPORT

    7.1   The report shall include the following information:

        7.1.1   Description of surface

        7.1.2   Size of specimen

        7.1.3   Type of finish

        7.1.4   Age of the concrete and details of finishing and curing if available

        7.1.5   Load and time of the abrasion used in the test

        7.1.6   The individual losses and average loss per unit area (kg/m^2)

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING AGGREGATES FROM THE ROADWAY

1.   SCOPE

        1.1   This method is suitable for sampling fine or coarse aggregates placed on a roadway surface. This method supersedes AASHTO T-2, Section 4.3.4 *Sampling from Roadway (Bases and Subbases)* for this purpose. These roadway surfaces include but are not limited to:

- Subgrade
- Previously placed and compacted aggregate
- Previously placed and compacted subbase lifts or courses

        1.2   Samples taken in accordance with this method are suitable for the following purposes:

- Determining the control of the product
- Determining the quality of the product
- Control of the placement operations
- Acceptance or rejection of the material in accordance with specifications

2.   EQUIPMENT

        2.1   Square bladed shovel (spade shovels are not suitable for this method)

        2.2   Containers- Bags or buckets of sufficient size, quantity, and strength to hold each sample increment without contaminating or losing any of the material.

        2.3   Miscellaneous markers and/or tags to identify each sample container.

3.   PROCEDURE

        3.1   Select each sample increment location in accordance with PTM 1. Use the shovel provided to obtain the sample at the selected sampling location after the material has been struck off (Note 1).

        3.2   Take sample increments that are to be tested in accordance with PTM 100 or PTM 616 prior to compaction, grading, trimming, or any contact by equipment that could adversely affect test results.

3.3   Take care in obtaining the sample increment. Position the shovel blade as near vertical as possible and push the blade of the shovel downward into the uncompacted material as far as possible then pull the handle back to load the blade of the shovel with material. Do not push the blade in a horizontal direction across the surface in a scraping or skimming manner. Remove the material and place the material into the sample container. Avoid any material from the underlying layer. A metal template can be placed over the sampling area to aid in obtaining sample increments of approximately equal mass. Take each sample increment from the full layer depth or until a sample increment of sufficient mass has been placed into the container. The mass for each sample increment taken is determined by nominal aggregate size, test methods used, and the amount of tests required or specified. The number of increments required is determined by the specifications and sample type.

> Note 1- Take precautions to obtain samples that will show the true nature and condition of materials represented by each increment. Scrape away any crushed and broken aggregate from the aggregate surface caused by the placing operation. Take sample increments more than 300mm (12 inches) from a supported edge and more than 600mm (24 inches) from any unsupported edge. When multiple shovels of material are needed to obtain the required mass for an increment of material for testing, move randomly throughout the material from where the selected hauling unit that has been struck off. Repeat Step 3.3 above at each random location as often as necessary to obtain sufficient mass for the increment. Use good judgment and keep in mind the purpose and intent of the samples as described in Step 1.2 above.

4.   IDENTIFICATION

4.1   Clearly and legibly identify each container with the following information or complete the appropriate Department form referred to in Section 4.1.10:

4.1.1 Increment number and total number of increments
4.1.2 Name of the sampler
4.1.3 Sample location(s)
4.1.4 Type of material and its use
4.1.5 Date the sample was taken
4.1.6 Source of supply or Supplier Code
4.1.7 Sampler's phone number
4.1.8 CMS or ECMS Number
4.1.9 State Project Number
4.1.10 Completed department form, TR-447, Sample Identification, if the sample(s) are to be sent to the Laboratory Testing Section. Department form CS-4126A can be used for field verification samples (n = 3) and must accompany the samples to the testing location.

4.1.11 Any special provisions or test values pertaining to the material sampled which must be followed or met. The special provisions or test values must also be attached to the TR-447 or CS-4126A forms.

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LABORATORY TESTING SECTION

Method of Test for

ESTIMATING CONCRETE COMPRESSIVE STRENGTH BY THE MATURITY METHOD

1.   SCOPE

1.1.   This test method provides a procedure for estimating concrete compressive strength by means of the maturity method. The maturity method is based on strength gain as a function of temperature and time.

1.2.   The maturity method consists of three steps:

1. developing strength-maturity relationship,

2. estimating in-place strength, and

3. verifying strength-maturity relationship.

2.   REFERENCED DOCUMENTS

2.1.   ASTM C 1064 – Temperature of Freshly Mixed Hydraulic-Cement Concrete

2.2.   ASTM C 1074 – Standard Practice for Estimating Concrete Strength by the Maturity Method

2.3.   PTM No. 601 – Sampling Fresh Concrete

2.4.   PTM No. 604 – Compressive Strength of Molded Concrete Cylinders

2.5.   PTM No. 611 – Making and Curing Concrete Compression and Flexural Test Specimens in the Field

3.   TERMINOLOGY – DEFINITION OF TERMS SPECIFIC TO THIS PTM

3.1.   Refer to ASTM C 1074 for the definition of the following terms used in this PTM: equivalent age, maturity, maturity index, maturity method, strength-maturity relationship, and temperature-time factor. Refer to Publication 408, Section 704, Table A for the definitions of the following terms used in this PTM: upper age limit and lower age limit

4.   SIGNIFICANCE AND USE

4.1.   This test method can be used to estimate the concrete compressive strength of placed cement concrete to determine when to perform critical construction operations including, but not limited to, saw cutting, removing formwork, backfilling, moving equipment, breaking cylinders, or opening to traffic.

5.   APPARATUS

5.1.   Maturity Meter. Commercially available battery-powered maturity meter(s) or an equivalent system which automatically reads and records the temperature from the temperature sensors, and computes and displays the maturity index in terms of a temperature-time factor or both a temperature-time factor and equivalent age.

5.1.1.   Displays the maturity index in terms of temperature-time factor or equivalent age according to ASTM C 1074.

5.1.2.   The maturity meter temperature monitoring and recording must be accurate to within ± 2°F when calibrated as per manufactures recommendations. Verify calibration prior to use on a project and, as a minimum, on an annual basis (NOTE 1).

NOTE 1: Verification of the temperature monitoring and recording by the maturity meter can be done by placing a temperature sensor in a controlled temperature water bath and reading the temperature sensor with the maturity meter. Use at least three different temperatures within the range of expected cement concrete temperatures for verification.

5.2.   Temperature Sensors. Provide disposable or reusable temperature sensors or devices suitable for embedment in cement concrete and capable of accurate measurement of the cement concrete temperature at the indicated or selected embedment location. Provide sensors or devices capable of being connected to data-loggers or that record and store temperature data as a function of time. Provide sensors or devices compatible with and capable of being monitored and recorded by the selected and provided maturity meter.

5.3.   Use the same brand and type of maturity meters and temperature sensors in the field as those used at the batch plant to develop the strength-maturity relationship of the cement concrete mix design.

6.   PROCEDURE FOR DEVELOPING STRENGTH-MATURITY RELATIONSHIP

6.1.   At the batch plant prior to construction, mold a minimum of 12 cylinders, 6 inch by 12 inch, according to PTM No. 611, from a batch of concrete of at least 4 cubic yards for each proposed mix design. In order to simulate project conditions, do not take a sample from the batched 4 cubic yards until the estimated travel time from the batch plant location to the average project location has elapsed.

6.2.   It is probable that two or three concrete batches and strength-maturity relationship curves for each mix design may be needed to cover the ranges of the water-cement ratio, air content, slump, and admixture dosage rates anticipated.

6.3.   Test and record the plastic cement concrete properties according to PTM No. 611 for slump and air content and ASTM C 1064 for temperature.

6.4.   For maturity temperature readings, use two cylinders and one temperature sensor per cylinder. Embed sensors at the vertical and horizontal center of cylinders during molding. Activate the data acquisition equipment.

6.5.   Unless otherwise directed, cure the specimens according to PTM No. 611 Section 11.1 for the first 24 ± 2 hours. After the first 24 ± 2 hours, moist cure specimens for all test ages at a constant temperature within a range of 73 ± 3 F.

6.6.   For all cement concrete, test two cylinders for compressive strength according to PTM No. 604 at each 1, 3, 7, 14, 28, and 56 (as required), days of age and record the corresponding individual and average maturity index value at each age.

6.7.   Prepare the strength-maturity relationship curve, as a graph of the Average Compressive Strength vs. the Average Maturity Index. Determine the maturity value at which the desired strength value is attained.

6.8.   Submit a copy, at least 2 weeks before the first concrete pour, of each developed strength-maturity relationship curve to the Representative for review and approval.

7.   PROCEDURE FOR ESTIMATING IN-PLACE STRENGTH

7.1.   Assure the concrete mix and materials being tested in the field are the same as the concrete mix and materials that were used to establish the strength-maturity relationship curve at the batch plant. Monitor the concrete batching and mixing operations for any changes in material types and material proportions differing from the approved concrete mix design.

7.2.   Use the same type temperature sensors, loggers, and maturity meter that were used in establishing the strength-maturity relationship curve.

7.2.1.   Embed at least two temperature sensors for each pour per day: Embed one sensor where maturity is expected to develop the slowest at, or near, an exposed outer edge, and a second sensor in the concrete poured from the last load of the day. Embed sensors at least 2 inches to 4 inches from any existing concrete or an exposed outer edge.

7.2.2.   When all of the in-place temperature sensors, for each pour, each day, have reached or exceeded the maturity value corresponding to the desired strength value on the strength-maturity relationship curve, it can be assumed that the concrete has reached the minimum strength required. The strength value will correspond if the concrete was properly placed and cured, and was exposed to approximately the same early-age temperatures as those of the mix used to develop the strength-maturity relationship. If the concrete has been exposed to different placement, curing and temperature conditions, the strength value will not correspond directly to the developed strength-maturity relationship curve. Condition adjustments may require development of a new strength-maturity relationship curve.

8.   PROCEDURE FOR VERIFYING STRENGTH-MATURITY RELATIONSHIP

NOTE 2: Field verify the concrete mix weekly in the presence of a Department Representative, as outlined below. Monitor the concrete batching and mixing operations for any changes in material types and material proportions than the approved concrete mix design. Generate a maturity database and maturity model for the concrete mix. To demonstrate compliance, submit weekly copies to the Representative for review.

8.1.   Obtain a sample of field concrete according to PTM No. 601. Perform slump and air content tests according to PTM 611 and temperature tests according to ASTM C 1064 and record results.

8.2.   Mold a total of six test cylinders, 6 inch by 12 inch, including four cylinders for compressive strength at two different test ages and two cylinders for recording temperature history.

8.3.   During molding of the two cylindrical specimens for temperature history recording, embed a temperature sensor at the vertical and horizontal center of the cylindrical specimen and activate the maturity meter or data acquisition equipment.

8.4.   Unless otherwise directed, cure the specimens according to PTM No. 611 Section 11.2 for the first 24 ± 2 hours. After the first 24 ± 2 hours, unmold the specimens and continue curing according to PTM No. 611, Section 11.2 at a constant temperature with the pavement or structure the specimens represent for both test ages (average of 2).

8.5.   Test two cylinders for compressive strength according to PTM No. 604 at a lower limit age, then test two specimens for compressive strength at an upper limit age. The limits should bracket the desired strength estimation age on the strength-maturity relationship curve. Record the actual compressive strength determined by the destructive testing and the estimated compressive strength determined by the strength-maturity relationship curve.

8.6.   Compare the actual strength values obtained with the predicted strength values from the strength-maturity relationship curve as developed in Section 6.7. If the test results are within ± 10% of the predicted strength values, the strength-maturity relationship curve is considered verified. Otherwise, the strength-maturity relationship curve will have to be reestablished. For all testing after the strength-maturity relationship curve failed to verify, and until a new curve is re-established, test all concrete according to Publication 408, Section 704 or other applicable Section or contract special provision.

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LABORATORY TESTING SECTION

Method of Test for

QUANTITATIVE EXTRACTION OF BITUMEN FROM
BITUMINOUS PAVING MIXTURES

l.   SCOPE

        1.1   This method covers procedures for the quantitative determination of bitumen in hot-mixed paving mixtures, mixtures containing liquid bituminous materials, and pavement samples. This method is a modification of AASHTO T-164. Contact the Innovation and Support Services Division, Laboratory Testing Section for copies of the AASHTO or ASTM test methods referred to in this PTM.

        1.2   The extracted aggregate may be used for sieve analysis according to PTM No. 739.

        NOTE 1- Although bitumen, by definition, is material soluble in carbon disulfide, 1,1,1-Trichloroethane is used in this method for safety reasons. Toluene or Trichloroethylene may also be used.

        NOTE 2 - Terpene type solvents may be substituted for 1,1,1-Trichloroethane in Method A providing the following steps have been taken:

                1. Follow all steps in Sections 8.2.1 and 8.3.1 modified for Terpene use.

                2. A trial extraction of a sample with a known asphalt content has been performed using the modified procedures yielding satisfactory results (± 0.1 percent).

        1.3   This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.   SUMMARY OF METHOD

        2.1   The paving mixture is extracted with 1, 1, 1-Trichloroethane using the extraction equipment applicable to the particular method. The bitumen content is calculated by taking the difference between the mass of the original sample, and the combined mass of the extracted aggregate, moisture content, and ash from an aliquot part of the extract. A bitumenometer may be used to determine the bitumen content.

3.   APPARATUS

3.1   Oven- Capable of maintaining the temperature at 163 ± 5ºC (325 ± 9 ºF).

3.2   Pan- Flat pan, 300 mm (12 in.) long, 200 mm (8 in.) wide, and 25 mm (1 in.) deep.

3.3   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

3.4   Hot Plate- Electric, with an adjustable heating rate.

3.6   Graduated Cylinder- 1000 or 2000 mL capacity

3.7   Ignition Dish- 125 mL capacity

3.8   Desiccator

3.9   Analytical Balance- An analytical balance conforming to the requirements of AASHTO M-231, Class B.

3.10   Muffle furnace or gas burner capable of maintaining temperatures between 500 and 660 C (932 and 1220 F).

4.   REAGENTS

4.1   Ammonium Carbonate- Saturated solution of reagent grade ammonium carbonate $(NH_4)_2CO_3$.

4.2   1,1,1-Trichloroethane- Conforming to Federal Specification O-T-620 a (Int. Amd. 3); Refer to Sec. 17.1 (Method D) for an additional requirement when the bitumenometer is used for bitumen content.

> NOTE 3- The solvents shall be used only under a hood in a well-ventilated area, since they are all toxic to some degree. The maximum acceptable concentration for an eight hour exposure for 1,1,1-Trichloroethane is 500 ppm.

> CAUTION: 1,1,1-Trichloroethane in the presence of heat and moisture may form acids that are extremely corrosive to certain metals, particularly, when subjected to contact over lengthy periods of time. Proper precautions shall be taken to not allow the solvents to remain, even in small quantities in the effluent tanks of aluminum vacuum extractors.

5.   WATER DETERMINATION

5.1   Determine the water content of a representative portion of the mixture according to AASHTO T-110, Test for Moisture or Volatile Distillates in Hot-Mix Asphalt.

5.2   Calculate the mass of water in the sample (W_2) by multiplying the moisture content by the mass of the sample.

> NOTE 4- The Water Determination Test is conducted only when water is known to be present or if its presence is suspected.

6.   PREPARATION OF SAMPLE

6.1   If the mixture is not sufficiently soft to separate with a spatula or trowel, place the mixture in a large flat pan and warm until it can be handled at the following temperature 163 ± 5 ^{o}C ($325 \pm 9 ^{o}$F). Separate the particles of the mixture as uniformly as possible using care not to fracture the mineral particles. Care shall be taken to avoid overheating the sample or leaving the sample in the oven for too long a period. Thoroughly mix the sample and form into a flat pile. Quarter the sample to the required size of sample for the extraction test.

6.2   Recommended approximate sizes of the sample are given in the test methods.

> NOTE 5- In no case shall the selection of a predetermined mass be attempted.

> NOTE 6- When the required minimum mass of the sample is greater than the allowable maximum mass for the method used, divide the sample into equal portions for testing. The masses for calculations will be the sum of like masses of the test portions.

6.3   Weighing of the extraction test apparatus and/or samples shall be done on a balance meeting the requirements of Section 3.3.

6.4   Mixtures containing liquid bituminous materials (such as cutbacks and emulsified asphalt) shall be cured before testing.

6.4.1   All bituminous mixtures containing emulsified asphalt and cutback asphalt (except stockpile patch mixes containing emulsified asphalt) shall be spread on a tray of sufficient size to hold the total sample, one layer deep. Place the sample in an oven maintained at $163 \pm 5 ^{o}$C ($325 \pm 9 ^{o}$F) for one-half hour, remove and weigh. Place the sample back in the oven and remove at half-hour intervals until the sample has reached a constant mass. Approximately one to two hours are required. Proceed with the extraction.

6.4.2   Stockpiled patch mixes containing emulsified asphalt shall be cured for 15 minutes at $163 \pm 1.5 ^{o}$C ($325 \pm 9 ^{o}$F), either in an oven or on a hot plate, mixing occasionally.

6.4.3 Stockpiled patch mixes containing polypropylene fibers shall be cured in an oven, overnight at $88 \pm 5.5\ ^{o}$C (190 ± 10°F). Also, the extracted aggregate shall be dried to a constant mass at $88 \pm 5.5\ ^{o}$C (190 ± 10° F).

6.5 Mixtures containing tar (FB-1, FB-2, and some stockpile patch mixes) do not require curing. The sample is extracted by an approved method and the resulting bitumen content corrected for insoluble tar as determined in the remaining part of this section.

6.5.1 Apparatus

6.5.1.1 125 mL Erlenmeyer flask

6.5.1.2 Air cooled condenser, 7 mm glass tube approximately 500 mm (20 in.) long.

6.5.2 Procedure- Prepare a Gooch crucible according to AASHTO T-44 (Section 7) and follow the procedure in AASHTO T- 44 Sections 9 and 10 with the following change:

6.5.2.1 Transfer approximately 2 grams of the tar used to make the mix into a tared 125 mL Erlenmeyer Flask. Weigh accurately to the nearest 0.001 g. Add 100 mL of 1, 1, l-Trichloroethane and place the air condenser into the top of the flask. Place the flask on a hot plate and reflux for 30 minutes. Determine the percent soluble as stated in AASHTO T-44, Section 10.

6.5.2.2 Calculations- Divide the percent bitumen, as determined by extraction, by the percent soluble to find the correct bitumen (tar) content.

6.5.3 In lieu of this procedure, the percent soluble may be obtained from the Laboratory Testing Section, Harrisburg.

METHOD A (CENTRIFUGE METHOD)

7. APPARATUS

7.1 In addition to the apparatus listed in Section 3, the following apparatus is required for Method A.

7.1.1 Extraction apparatus- Consisting of a bowl approximating that shown in Figure 1, which may be revolved at controlled variable speeds up to 3600 rpm. The apparatus shall be provided with a container for catching the solvent thrown from the bowl and a drain for removing the solvent. The apparatus shall be provided with explosion proof features and installed in a hood to provide ventilation.

NOTE 7 - Similar apparatus of a larger size may be used.

7.1.2   Filter ring- A heavy, weighty, smooth, white medium fast filter paper (Eaton-Dikeman Grade 627 has been found satisfactory for this purpose) of a diameter at least equal to the bowl seating surfaces outside diameter and to internally exceed the bowl sealing surfaces width by at least 25.4 mm (1 in).

7.1.3   2000 mL Florence flask

7.1.4   Bitumenometer, 750 or 1500 mL

8.   PROCEDURE

8.1   Weigh an approximate 500 to 2500 gram sample into the bowl to the nearest 0.1 gram. In no case shall the wearing course and binder samples be less than 500 and 1000 grams, respectively.

NOTE 8- In the case of Heavy Duty Bituminous Concrete Base Course and Heavy Duty ID-2 Binder, the mass of the sample shall not be less than 1400 grams.

8.2   Cover the sample in the bowl with 1,1,1-Trichloroethane and allow sufficient time for the solvent to disintegrate the sample (not over 1 hour). Place the bowl containing the sample and the solvent in the extraction apparatus. Dry and weigh the filter ring and place it around the edge of the bowl. Clamp the cover on the bowl tightly and place a 2000 mL Florence flask under the drain to collect the extract:

OR

8.2.1   Cover the sample in the bowl with Terpene solvent and let the sample digest for a minimum of 30 minutes. During this period, probe the sample with a metal rod at ten minute intervals. Place the bowl containing the sample and solvent in the extraction apparatus. Dry the bowl. Clamp the cover on the bowl tightly and place the 2000 mL Florence flask under the drain to collect the extract.

8.3   If using the procedure in Section 8.2: Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain. Allow the machine to stop, add 200 mL of solvent and repeat the procedure. Use sufficient 200 mL solvent additions (not less than three) so that the extract is clear and not darker than a light straw color. Collect the extract and the washings in a 2000 mL Florence flask.

8.3.1   If using the procedure in Section 8.2.1: Start the centrifuge revolving and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain. Allow the machine to stop, add 300 mL of solvent and repeat the procedure. Use three (3) 300 mL solvent additions. Remove the 2000 mL Florence flask with the extract for use in Section 8.5. Place a container under the drain, charge the bowl with 500 mL of tepid water and extract. Repeat using five (5) 300 mL tepid water washings.

NOTE 9- The number of water washings may be decreased if the extraction of samples of known asphalt content indicate satisfactory results (± 0.1 percent).

8.4   Remove the filter ring from the bowl and dry in air. Remove as much of the mineral matter adhering to the filter ring is as possible and add the mineral matter to the aggregate in the bowl. Dry the ring to constant mass in an oven at $163 \pm 5\ ^{\circ}$C ($325 \pm 9\ ^{\circ}$F). Dry the contents of the bowl to a constant mass in an oven at $163 \pm 5\ ^{\circ}$C ($325 \pm 9\ ^{\circ}$F).

NOTE 10- The sample shall be dried until further drying at $163 \pm 5\ ^{\circ}$C ($325 \pm 9\ ^{\circ}$F) does not alter the mass 0.1 percent, the precision of weighing.

8.5   Agitate the extract in the Florence flask thoroughly by swirling to insure uniform dispersion and immediately measure 100 mL into a previously weighed ignition dish. Pour the remaining extract liquid into the graduate, and record the volume (V). Evaporate the extract liquid in the ignition dish to dryness on a hot plate. Burn the residue at a dull red heat (500 to 600 $^{\circ}$C), cool, and add 5 mL of saturated ammonium carbonate solution $(NH_4)_2CO_3$ per gram of ash. Digest at room temperature for one hour. Dry the ash in an oven at $110 \pm 5\ ^{\circ}$C ($230 \pm 9\ ^{\circ}$F) to a constant mass, cool in a desiccator, and weigh to 0.001 gram on an analytical balance.

8.6   An alternate procedure is to use a bitumenometer, following the procedure in Sections 19.5 and 20.

9.   CALCULATIONS

9.1   Calculate the mass of mineral matter in the total volume of extract as follows:

$$\text{grams total ash} = G \text{ x } \frac{V + 100}{100}$$

Where:

G = Mineral matter in grams

V = Volume of the extract after removing the aliquot in milliliters

9.2   Calculate the percentage of bitumen in the sample as follows:

$$\% \text{ Bitumen content of a dry sample} = [(W_1 - W_2) - (W_3 + W_4 + W_5)] \text{ x } \frac{100}{(W_1 - W_2)}$$

Where:

W_1 = mass of the sample

W_2 = mass of water in the sample

W_3 = mass of the extracted mineral matter

W_4 = mass of mineral matter in the extract

W_5 = mass of mineral matter on the filter ring

NOTE 11 - Add the increase in the mass of the filter ring to the masses of the recovered aggregate and the ash in the recovered bitumen.

METHOD C (MARYLAND METHOD)

10. APPARATUS

    10.1   In addition to the apparatus listed in Section 3, the following apparatus is required for Method C.

        10.1.1   Extraction apparatus- Consisting of metal containers, condenser lid and stand similar to that shown in Figure 2.

        10.1.2   A basket for the sample as shown in Figure 2. A 4.75 mm (No. 4) or heavier screen shall be placed in the basket to support the sample.

        10.1.3   Filter Cloth- (A 16 xx Swiss stencil cloth available from the Atlas Silk Screen Supply Co., 1733 Milwaukee Ave., Chicago, IL 60647 is suitable for this purpose) with approximately 85 µm openings (No.185 mesh), shaped to cover completely the inside of the basket.

        10.1.4   Thermometer-, Accurate to 0.1 ^{o}C (0.2º F), covering a temperature range of 19 to 27 ^{o}C (66 to 80 ^{o}F), conforming to the requirements for a 17C (17F) thermometer as prescribed in ASTM Specification E-1.

        10.1.5   Scraper- To loosen asphalt and fine bituminous mixture on the bottom of the extractor.

        10.1.6   Rubber Gloves, Gas Mask, Trowel, Rubber Tubing, etc.

11. REAGENT

    11.1   1,1,1-Trichloroethane.

12.   PREPARATION OF SAMPLE

        12.1   Samples do not have to be heated prior to extracting but shall be thoroughly dry. The sample size shall be between 3,500 and 11,000 grams. Weigh the basket assembly, place the sample in the basket, and obtain the total mass to the nearest gram.

13.   PROCEDURE

        13.1   Place the basket with the sample in the extractor. Pour 1150 to 1250 mL of Trichloroethane over the sample. Put the extractor lid tightly in place and allow water to circulate freely through the condenser on the top. Apply heat from a gas ring burner.

        13.2   Reflux the samples for 1.5 to 3 hours until all the bitumen is extracted from the aggregate. Shut down the extractor after 1.5 hours and inspect the sample. Mix the sample with a trowel and continue extraction to completion.

                NOTE 12- The sample is completely extracted when upon inspection, no discoloration is found either on the aggregate or on the surface of the trowel which has thoroughly mixed the sample.

        13.3   Drain the extract from the extraction and wash clean the extractor apparatus with fresh solvent. Recover the extract in a 2000 mL Florence flask. Agitate the extract liquid in the 2000 mL graduate and record the volume. Remove the sample basket and dry in air. The basket shall be dried on a hot plate or oven at $163 \pm 5\ ^{o}C$ ($325 \pm 9\ ^{o}F$) to a constant mass. Determine the ash recovered bitumen as described in Section 8.5.

        13.4   When using the bitumenometer method of bitumen determination use the procedure as stated in Section 19.5.

14.   CALCULATIONS

        14.1   Calculate the percentage bitumen in the sample as described in Section 9, if the ash method is used, or as in Section 20 when using the bitumenometer.

METHOD D (IMMERSION-REFLUX METHOD)

15.   SCOPE

        15.1   This method of test is intended for the determination of the percentage of bitumen in a paving mixture in which the aggregate size does not exceed 63 mm (2.5 inches) (NOTE 13). The sample is first immersed in hot solvent, for rapid disintegration of the mixture and extraction of the bitumen, and is then thoroughly washed by refluxing to complete the extraction. The

percentage of bitumen is determined by calculation from the specific gravities and the volume of the materials in the extract, using a pycnometer. The mineral matter recovered from either test can be used for the sieve analysis.

> NOTE 13 - These methods are adaptable to paving mixtures in which aggregate size is up to 90 mm (3.5 inches) by employing an extractor four times larger than that described herein and a larger pycnometer (bitumenometer) of 1500 mL capacity. The larger apparatus accommodates samples of up to 7000 grams of sample with a larger size aggregate.

16.   APPARATUS

16.1   In addition to the apparatus listed in Section 3, the following apparatus is required for Method D.

16.1.1   Extraction apparatus- (Figure 3) Consisting of an extraction kettle of stainless steel or borosilicate glass, with a perforated basket and condenser. The underside of condenser shall be covered with numerous rounded knobs to distribute condensed solvent uniformly onto the surface of the sample. The suspension of the basket shall be arranged to support the basket 12.5 mm (0.5 inches) above the bottom of kettle for immersion of the sample in solvent, a minimum of 75 mm (3 inches) above the bottom of the kettle for refluxing. The apparatus preferably shall be used under a hood to provide ventilation.

16.2   Cloth Filter Sacks for lining the basket

16.3   Bitumenometer (Pycnometer)- Approximately 750 mL capacity, as shown in Figure 3, calibrated to the nearest 0.1 mL. A 1500 mL capacity pycnometer is required for the larger sized extractor.

16.4   Thermometer- Accurate to 0.1 ^{o}C (0.2^{o} F), covering a temperature range of 19 to 27 ^{o}C (66 to 80 ^{o}F), conforming to the requirements for a 17C (17F) thermometer as prescribed in ASTM Specification E-1.

16.5   Cold Water Bath, Metal Funnel, Washing Bottle, Brush, Spatula, etc.

17.   SOLVENT

17.1   1,1,1-Trichloroethane- For the bitumenometer method of extract analysis, the specific gravity of solvent must be known within 0.001, and must remain constant through the extraction process. This is considered very important. If the solvent has proper inhibitor(s), the specific gravity should not change. This can be verified by extracting mixtures of known bitumen contents or by subjecting the solvent to the extraction process (without a sample) and measuring the specific gravity before and after the process.

18.   PREPARATION OF SAMPLE

18.1   If the mixture is not sufficiently soft to separate with a spatula or trowel, place 2000 to 5000 grams in an oven at 163 ^{o}C (325 ^{o}F) for a maximum of two hours, or on a hot plate over low heat, until it can be handled. Use care not to fracture the mineral particles. Thoroughly mix, form into a flat pile, and quarter to the required size of sample. Insert a filter sack in the extractor basket and weigh the filter and basket with the tared pan to determine the total tared mass. Weigh into the filter sack a representative sample of mix not less than 500 grams if the maximum aggregate size is less than 12.7 mm (0.5 inches). If the maximum aggregate size is 12.7 to 63.5 mm (0.5 to 2.5 inches), the mass of the sample shall not be less than 1000 grams. While transferring the mix onto the filter sack, any fine mix sticking to the inside of the spatula shall be scrapped and included with the sample for extraction. All weighing shall be to nearest 0.1 gram. Larger samples up to 7000 grams may be tested by using a larger apparatus. In no case, however, shall the selection of a sample of a predetermined mass be attempted.

NOTE 14 - In the case of Heavy Duty Bituminous Concrete Base Course and Heavy Duty ID-2 Binder, the mass of the sample shall not be less than 1500 grams.

19.   PROCEDURE

19.1   Attach the suspension rod to the loaded basket and set the assembly into the extraction kettle. Pour carefully approximately 600 mL of solvent over sample. The extractor can be filled with the solvent prior to suspending the loaded basket in the extraction kettle. Set the condenser cover in place on the kettle. Provide a flow of cold water through the condenser cover.

19.2   Raise the basket to the immersion level, i.e. 12.5 mm (0.5 inch) above the bottom of the kettle, by inserting the support pin through the upper hole of the suspension rod. Place the extractor on the hot plate or over a burner and adjust the heating rate so that solvent is maintained at a gentle boil. Avoid vigorous boiling which might wash fines over the sides of the basket. Continue heating the sample during the immersion position for 15 to 30 minutes, depending upon composition, size, and age of sample.

19.3   Raise the basket to the refluxing level, a minimum of 75 mm (3 inches) above the bottom of the kettle, by inserting the pin through the lower hole of the suspension rod. Increase the heat and maintain active boiling for 15 to 30 minutes, or until solvent dripping from the basket appears colorless. If a stainless steel kettle is used, solvent can be examined by lifting the basket out of the condenser assembly.

19.4   Remove the extractor from the heat source and allow the extractor to cool for several minutes. Lift the basket out of the condenser assembly. Remove the filter sack, distribute its contents onto the tared pan in which the sample was originally weighed, dry on hot plate over low heat, or in an oven at 163 $\pm$ 5 ^{o}C (325 $\pm$ 9 ^{o}F) to a constant mass, with the filter sack on top of the aggregate. Use care not to char the sack. Place the extractor basket onto the pan, and weigh the assembly of aggregate, filter sack, extractor, and tared pan. Subtract the total tared mass from the mass of this assembly and record this weight as the mass of extracted aggregate.

19.5   While the aggregate is being dried, set the covered kettle in a cold water bath 50 to 120 mm (2 to 4 inches) deep to hasten cooling to approximately 27 ^{o}C (80 ^{o}F). Transfer the extract to the bitumenometer, using a funnel. Wash down the inside of the kettle with solvent, adding enough additional solvent to fill the bitumenometer to the base of the neck. Air bubbles must be eliminated. Adjust the temperature of the bitumenometer contents to 25 ^{o}C (77.0 ^{o}F) (NOTE 15). Insert the volume adjustment stopper, fill the stopper capillary and apply the overflow cap. Dry the outside of the bitumenometer and weigh to the nearest 0.1 of a gram (NOTE 16). Subtract the mass of the bitumenometer from this mass and record as the mass of the extract. Record the actual temperature of the extract to the nearest 0.1 ^{o}C (0.2 ^{o}F) at the time of weighing.

> NOTE 15 – A correction can be applied for extract temperatures differing from 25 ^{o}C (77.0 ^{o}F), between 23 and 27 ^{o}C (74 and 80 ^{o}F). Corrections for solvents can be computed from their specific gravity and coefficient of expansion. If a 750 mL bitumenometer is used, the following corrections have been determined to be adequate: add 1.23 grams to the mass of the extract for each degree ^{o}C above 25 ^{o}C (0.7 g per degree above 77 ^{o}F), and subtract 1.23 grams from the weight for each degree below 25 ^{o}C (0.7 g per degree below 77 ^{o}F).

> NOTE 16 - The mass of the bitumenometer filled with the extract liquid shall be taken very carefully. Variations of $\pm$ 0.5 gram in mass can affect the asphalt content determination by $\pm$ 0.1 percent.

20.   CALCULATIONS

20.1   Calculate the percentage bitumen in the sample using one of the following procedures:

PROCEDURE 1

% bitumen = [G_2/(W_1(G_3-G_2))] x [G_3(V_1-((W_2+W_3-W_1)/G_1))+W_3-W_1] x 100

Where:

G_1 = Specific gravity of the solvent at 25 ^{o}C (77.0 ºF)
    (within 0.001)

G_2 = Specific gravity of the bitumen at 25 ^{o}C (77.0 ºF)
    (within 0.01)

G_3 = Specific gravity of the aggregate fines at 25 ^{o}C (77.0º F) (within 0.1)

V_1 = Volume of the bitumenometer at 25 ^{o}C (77.0º F)

W_1 = Mass of the original dry sample

W_2 = Mass of the extract

W_3 = Mass of the extracted aggregate

NOTE 17- The formula above corrects for the amount of fines contained in the extract.

NOTE 18- It is very important that the specific gravity values of solvent and bitumen are very accurate. The bitumen content will vary by approximately $\pm$ 0.1 percent for the following variations in the measurements of specific gravities:

specific gravity of the solvent $\pm$ 0.001
specific gravity of the bitumen $\pm$ 0.01

NOTE 19 - If the specific gravity values of aggregate fines are not known, the following values may be used:

stone   2.70
gravel 2.60
slag   2.95

20.2   Calculate the mass of fines in the extract as follows:

$$W_4 = (G_3/(G_3-G_2)) \times [W_1-W_3-G_2(V_1-((W_2-W_1+W_3)/G_1))]$$

Where:

W_4 = Mass of the fines in the extract

PROCEDURE 2

Percent Bitumen Calculation

Specific Gravity of Bitumen ($\pm$ 0.01) at 25 C (77.0 F)	G_2 =
Specific Gravity of Aggregate Fines ($\pm$ 0.1) at 25 C (77.0 F)	G_3 =
Specific Gravity of Solvent ($\pm$ 0.001) at 25 C (77.0 F)	G_1 =
Volume of Bitumenometer at 25 C (77.0 F)	V_1 =
Weight of Original Sample	W_1 =
- Weight of Extracted Sample	W_3 =
Weight of Extraction Loss or weight of bitumen and fines:	$W_c = W_1-W_3$
Weight of Bitumenometer and Extracted liquid	W_a =

- Weight of Bitumenometer	$W_b =$	
Weight of Extracted Liquid	$W_2 = W_a - W_b$	
Weight of Extracted Liquid	$W_2 =$	
- Weight of Extraction loss or weight of bitumen and fines	$W_c =$	
Weight of Solvent	$W_d = W_2 - W_c$	

$$\frac{\text{Weight of Solvent }(W_d)\ (\quad)}{\text{Sp. Gr. Of Solvent }(G_1)\ (\quad)} = \text{Volume of Solvent }(V_a)$$
in the Bitumenometer

Volume of Bitumenometer	$V_1 =$	
- Volume of Solvent	$V_a =$	
Volume of Extraction Loss or Volume of Bitumen & Fines:		
	$V_b = V_1 - V_a$	
Volume of Extraction Loss	$V_b =$	
x Sp. Gr. Of Aggregate Fines	$G_3 =$	
Algebraic Term (Weight of Extraction Loss)	$a_1 = V_b \times G_3 =$	
Algebraic Term (Weight of Extraction Loss)	$a_1 =$	
- Weight of Extraction Loss	$W_c =$	
Algebraic Term (Weight of Bitumen)	$a_2 = a_1 - W_c =$	
Specific Gravity of Aggregate Fines	$G_3 =$	
- Specific Gravity of Bitumen	$G_2 =$	
Algebraic Term (Weight of Bitumen)	$a_3 = G_3 - G_2 =$	

$$\frac{\text{Algebraic Term (Weight of Bitumen) }(a_2)\ (\ )}{\text{Algebraic Term (Sp. Gr. Of Bitumen) }(a_3)(\ )} = \text{Volume of Bitumen in Sample }(V_c)$$

Volume of Bitumen in Sample	$V_c =$	
x Specific Gravity of Bitumen	$G_2 =$	
Weight of Bitumen in Sample	$W_e = V_c \times G_2 =$	

$$\frac{\text{Weight of Bitumen in Sample }(W_e)\ (\ )}{\text{Weight of Original Sample }(W_1)\ (\ )} \times 100 = \underline{\quad}\% \text{ of Bitumen in Sample}$$

Weight of Original Sample	$W_1 =$	
- Weight of Bitumen	$W_e =$	
Weight of Total Aggregate in Sample	$W_f =$	$W_1 - W_e =$

Weight of Extraction loss (bitumen and fines)	$W_c =$	
- Weight of Bitumen	$W_e =$	
Weight of Fines in Sample	$W_4 =$	$W_c - W_e =$

PROCEDURE 3

Percent Bitumen Calculation

20.3   If the ash method is used, calculate the percent bitumen in the sample as described in Section 9.

MODIFIED METHOD D (IMMERSION-REFLUX-CENTRIFUGE)

21   SCOPE

21.1   This method of test is intended for the determination of asphalt content of bituminous mixtures in which the aggregate size does not exceed 63mm (2.5 inches). The sample is first immersed in hot solvent, for rapid disintegration of the mixture and extraction of the bitumen. The sample is thoroughly washed by refluxing, the extract liquid is run through a centrifuge to trap the fines.

22.   APPARATUS

22.1   In addition to the apparatus listed in Section 3, the following apparatus is required for Modified Method D.

22.1.1   Extraction apparatus (Figure 3)- Consisting of an extraction kettle of stainless steel or borosilicate glass, with a perforated basket and condenser. The underside of the condenser shall be covered with numerous rounded knobs to distribute condensed solvent uniformly onto the surface of the sample. The suspension of the basket shall be arranged to support the basket 12.5 mm (0.5 inches) above the bottom of the kettle for immersion of the sample in solvent, a minimum of 75 mm (3 inches) above the bottom of the kettle for refluxing. The apparatus preferably shall be used under a hood to provide ventilation.

22.1.2   Cloth Filter Sacks for lining the basket

22.1.3   Centrifuge- High-speed (3000 rev./min or higher). A continuous flow type with a metal thimble to catch the fines.

23.   SOLVENT

23.1   normal-Propyl Bromide (*n*PB), conforming to ASTM D6368

24.   PREPARATION OF SAMPLE

24.1   If the collected mixture sample is not sufficiently soft to separate with a spatula, scoop, or trowel, place the collected mixture sample in an oven at $163 \pm 5°C$ ($325 \pm 9°F$) for a maximum of 2 hours, or on a hot plate over low heat, until it is sufficiently soft to separate. Thoroughly mix, form into a flat pile, and quarter the mixture sample. Use care not to fracture the mineral particles. The minimum mass of the test sample shall be the result of quartering from a larger mixture sample and shall conform to the minimum mass requirements in Table 1.

Table 1		
Superpave or SMA Mixture Nominal Maximum Aggregate Size (NMAS), mm	**Other Asphalt Mixtures or Material Classes**	**Minimum Mass of Test Sample, g**
12.5 or smaller	FJ-1, FJ-1C, FJ-4, FB-1W, FB-2W, FB-3 Modified, Micro-Surfacing, Ultra-Thin Friction Course, Cold Path	500
19	ATPBC, FB-1B, FB-2B, FB-Modified	1000
25 or greater		1500

25. PROCEDURE

25.1 Insert a filter sack in the extractor basket and determine the total tare mass of the filter, basket, suspension rod, and pan to the nearest 0.1 g.

25.2 Prepare the test sample according to Section 24. Using a scoop, add the minimum mass of test sample according to Table 1 into the filter sack. Scrape any fine mixture particles that stick to the inside of the scoop with a spatula and include the fine particles in the filter sack with the mixture test sample for extraction.

25.3   Attach the suspension rod to the basket and set the assembly into the extraction kettle. Carefully pour 700 ± 50 ml of solvent over the sample. The extractor can be filled with solvent prior to suspending the loaded basket. Set the condenser cover in place on the kettle. Provide a flow of cold water through the condenser cover.

25.4   Raise the basket to the immersion level, 12mm (0.5 inches) above the bottom of the kettle by inserting the support pin through the upper hole of the suspension rod. Place the extractor on the hot plate and adjust the heat rate so that the solvent is maintained at a gentle boil. Avoid vigorous boiling which might wash fines over the sides of the basket. Continue heating with the sample in the immersion position for a minimum of 30 minutes.

25.5 Raise the basket to the reflux level, a minimum of 75mm (3 inches) above the bottom of the kettle by inserting the pin through the lower hole of the suspension rod. Increase the heat and maintain active boiling for a minimum of 30 minutes, or until solvent dripping from the basket appears colorless. If a stainless steel kettle is used, the solvent can be examined by lifting the basket out of the condenser assembly.

25.6 Remove the extractor from the hot plate and lift the basket out of the condenser assembly. Remove the suspension rod and basket from the condenser assembly. Remove the filter sack, distribute its contents into the pan and dry on a hot plate over low heat, or in an oven at $163°C \pm 5°C$ ($325°F \pm 9°F$) to a constant mass, with the filter sack on top of the aggregate. Use care not to char the filter sack.

25.7 When the aggregate is dry, place the extractor basket and the suspension rod assembly into the pan. Weigh and record the mass of the aggregate, filter sack, suspension rod assembly and pan to the nearest 0.1 g.

25.8 While the aggregate is being dried, allow the kettle to cool to approximately $27°C$ ($80°F$). To hasten cooling set the kettle in a cold water bath 50 mm to 120 mm (2 to 4 inches) deep.

25.9 Place a pre-weighed thimble in the centrifuge. Run the extract liquid through the centrifuge 3 times. Wash the material in the thimble using a final wash of approximately 200 ml of clean solvent or enough wash solvent until the wash runs clear.

25.10 Dry the thimble and material in an oven at $163 C \pm 5°C$ ($325 F \pm 9°F$). Record the weight of the thimble and material.

26. CALCULATIONS

Calculate the percentage bitumen in the sample using the following procedure:

1. Wt. of pan + basket + filter + sample   _____

2. Wt. of pan + basket+ filter   _____

A. 1-2 = Wt. of original sample   _____

3. Wt. of pan + basket + filter + aggregate _____

4. Wt. of pan + basket + filter   _____

B. 3-4 = Wt. of aggregate in the pan   _____

5. Wt of aggregate in the thimble   _____

6. Wt. of the thimble   _____

C. 5-6 = Wt. of aggregate in the thimble   _____

Calculation for Percent Bitumen:

$$\frac{A-(B+C)}{A} \times 100 = \% \; AC$$

27.   PRECISION

The following data shall be used for judging the acceptability of the results (95 percent probability).

27.1   Duplicate results by the same operator should be considered suspect if they differ by more than the following amounts:

	repeatability
standard deviation, percent	0.12
bitumen content, percent	0.34

27.2   The result submitted by one laboratory should not be considered suspect unless the result differs from that of another laboratory by more than the following amounts:

	reproducibility
standard deviation, percent	0.20
bitumen content, percent	0.56

NOTE 20- The precision statement is derived from 10 laboratories testing 4 samples with 3 replicates per test.

28.   REFERENCE

AASHTO Method T-164   ASTM Method D 2172

Attachments: Figures 1 thru 4; Table 1.
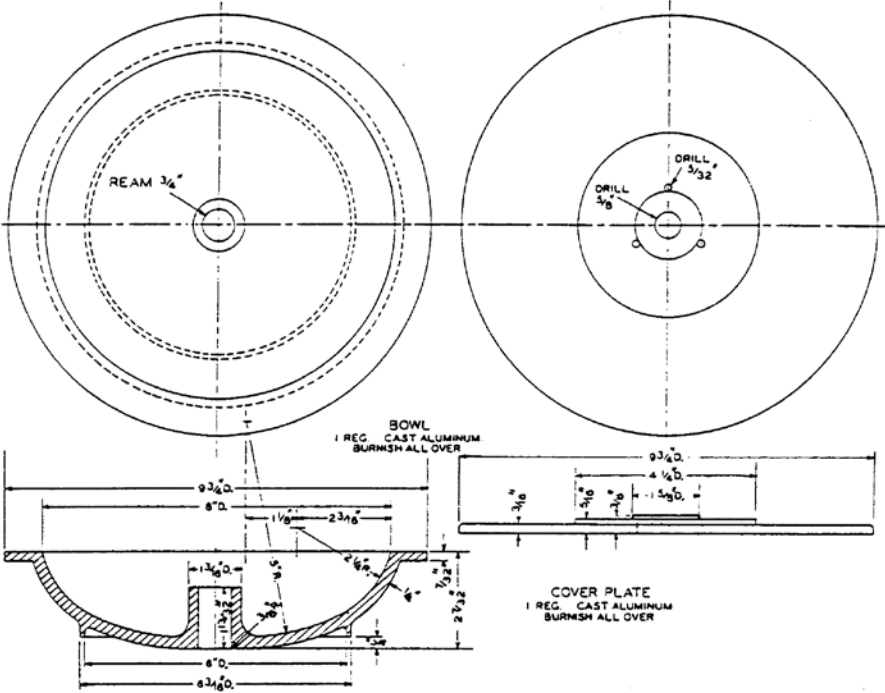
NOTE—See Table 1 for metric equivalents.

Figure 1 - Extraction Unit Bowl

FLANGE 3/4" WIDE — DRAIN SPOUT

TO BE 1/2" I.D. TUBE 4" LONG
LOCATED AT CENTER OF REAR
JUST ABOVE SUPPORT FLANGE

NOTE:
LID SHOULD FIT NEATLY
INSIDE KETTLE & REST
ON FLANGE

STENCIL CLOTH FILTER
APPROX .185 MESH

CONDENSING LID

TO HAVE 10 ROWS OF FINS, 12 FINS TO A ROW.
FINS TO BE 1/2" SQ. WITH 3/8" SPACING.
STAGGER FINS IN ALTERNATE ROWS.

U.S. STANDARD NO 4 SIEVE

1" FLANGE

BASKET
2 HANDLES

KETTLE

DRAIN

1/2" NIPPLE 5" LONG AS NEAR
CORNER & BOTTOM AS POSSIBLE.
DRAIN TO BE FLUSH WITH INSIDE
SURFACE SO NOT TO TRAP ANY
LIQUID. FOR DRAIN COCK USE
STD. 1/2" GATE VALVE WITH
1/2" NIPPLE & 45° ELBOW

CONSTRUCTION

KETTLE LID AND BASKET TO BE
OF 302-18-8, 16 GAUGE ST. STEEL

STAND MADE FROM 1" X 1" X 1/8" ANGLE IRON

See Table 1 for metric equivalents.

1" LIP
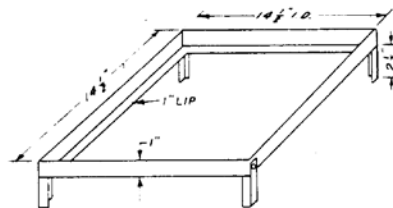
FRONT LEGS FIXED WITH SINGLE PIN
TO ALLOW LEGS TO FOLD BACK WHEN
DRAINING THE EXTRACTOR.

FIG. 2

EXTRACTION KETTLE
*18 GAUGE STAINLESS STEEL OR
HEAVY BOROSILICATE GLASS

SUSPENSION ROD
PLATED STEEL

BASKET WITH PERFORATED
BOTTOM
CAST ALUMINUM

BOTTOM VIEW
SHOWING CONDENSATION WELTS
CONDENSER COVER
CAST ALUMINUM

SUPPORT PIN
PLATED STEEL
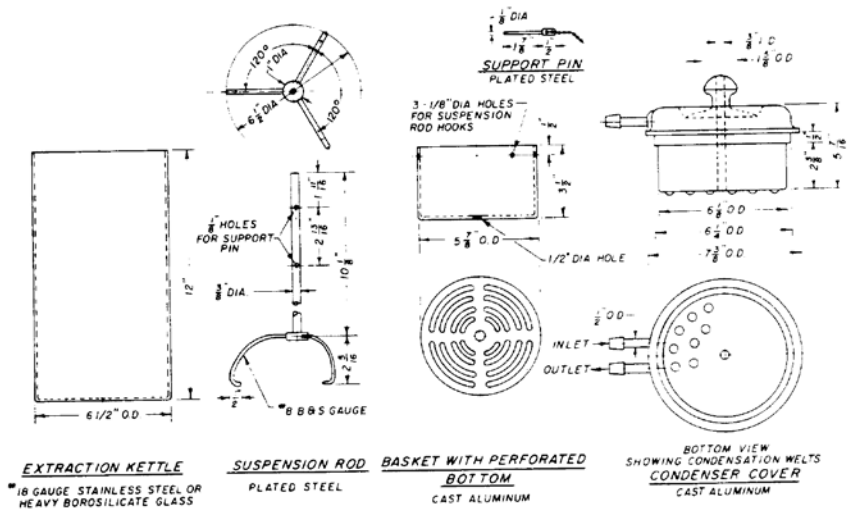
NOTE—See Table 1 for metric equivalents.

FIG. 3
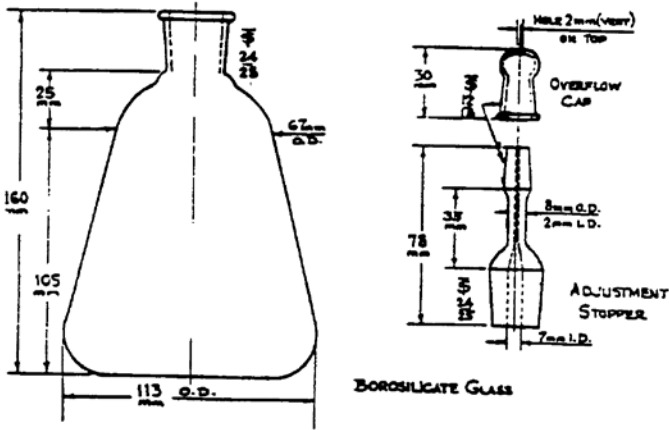
Figure 4 - Bitumenometer, 750ml Capacity

TABLE 1   Metric Equivalents for Figures

Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, in.	SI Equivalent, mm	Inch-Pound Units, in.	SI Equivalent, mm
1/8	3.2	1¹¹/₁₆	43	5⁷/₈	149
3/16	4.8	1¾	44	6	152
7/32	5.6	2³/₁₆	55	6⅛	155
1/4	6.3	2⁷/₃₂	56	6³/₁₆	157
5/16	7.9	2⁵/₁₆	59	6¼	159
3/8	9.5	2½	64	6½	165
1/2	12.7	2⅝	69	7³/₈	187
5/8	15.9	2¹³/₁₆	72	8	207
3/4	19.0	3	76	9¾	247
1	25.0	3¾	96	10	254
1⅛	28.6	4	102	10⅛	257
1³/₁₆	30.2	4¼	108	12	305
1¹³/₃₂	35.7	5	127	14	355
1½	38.0	5⁷/₁₆	138	14½	370
1⅝	41.0				

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LABORATORY TESTING SECTION

Method of Calibration for

VOLUMETER

1.   SCOPE

This method is intended to determine the volume of the volumeter.

2.   APPARATUS

2.1   Volumeter- Of an appropriate capacity

2.2   Thermometer- ASTM 17 C (17 F) having a range of 19 to 27 ^{o}C (66 to 80 ºF), graduated in 0.1 ^{o}C (0.2 º F) subdivisions

2.3   Water Bath- Thermostatically controlled so as to maintain the bath temperature at 25 ± 0.5 ^{o}C (77 F ± 0.9º F)

2.4   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

2.5   Distilled Water- Freshly-boiled distilled water

3.   SIGNIFICANCE

3.1   It is essential that all equipment is calibrated accurately. Exercise care in calibrating the equipment. All subsequent tests are dependent on the calibrated equipment. It is also important to calibrate all equipment and material at the same temperature as will be used in conducting the test. All air bubbles shall be eliminated prior to weighing. All weights shall be made to the nearest tenth (0.1) of a gram. The maximum permissible variation in temperature shall not exceed ± 0.1 ^{o}C (± 0.2º F) from the specified temperature.

4.   PROCEDURE

4.1   Weigh the clean, dry volumeter (metal pycnometer). Fill the volumeter with freshly-boiled distilled water, cover, and immerse the volumeter for one hour in a distilled water bath maintained at 25 ^{o}C (77º F). Remove the cover, and eliminate any air bubbles that are

present. If necessary add distilled water to fill the volumeter. Cover and make certain that the capillary tube is filled with water, wipe the volumeter dry, and weigh.

5.   CALCULATIONS

5.1   Calculate the volume of the volumeter as follows:

$$(WV_o + W_a) - WV_o = Vv_o$$

Where:

W V_o = mass of the volumeter in grams

W_a = mass of the water in grams

V V_o = volume of the volumeter in mL's

NOTE 1- The mass of the volumeter in grams plus the mass of the water in the volumeter in grams, minus the mass of the volumeter in grams, equals the volume of the volumeter in mL's.

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LABORATORY TESTING SECTION

Method of Calibration for

BITUMENOMETER

1.   SCOPE

        1.1   This method is intended to determine the volume of the bitumenometer.

2.   APPARATUS

        2.1   Bitumenometer- Minimum capacity of 700 mL

        2.2   Thermometer- ASTM 17 C (17 F) having a range of 19 to 27 ℃ (66 to 80℉), graduated in 0.1℃ (0.2℉) subdivisions

        2.3   Water Bath-Thermostatically controlled so as to maintain the bath temperature at 25 C ± 0.5℃ (77 ± 0.9℉)

        2.4   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2

        2.5   Distilled Water- Freshly-boiled distilled water

3.   SIGNIFICANCE

        3.1   It is important to calibrate all equipment and material at the same temperatures as will be used in conducting the test in order to have expressions such as 25/25℃ (77/77℉), and thereby eliminating unnecessary calculations. All air bubbles shall be eliminated prior to weighing. All weights shall be made to the nearest tenth (0.1) of a gram. The maximum permissible variation in temperature shall not exceed ± 0.1℃ (± 0.2℉) from the specified temperature.

4.   PROCEDURE

        4.1   Weigh the clean, dry bitumenometer. Fill the bitumenometer with freshly-boiled distilled water, insert the stopper-capillary, and immerse the bitumenometer in a water bath maintained at 25℃ (77℉) for one hour. Raise the bitumenometer making certain that the

capillary tube is filled to the top and no air bubbles are present. Wipe off the top of the stopper-capillary tube, above the tube. Remove the bitumenometer from the water bath and wipe it dry with a dry cloth and weigh.

5.   CALCULATIONS

Calculate the volume of the bitumenometer as follows:

$$(W\,B_r + W_a) - WB_r \;=\; Vb_r$$

Where:

$W\,B_r$ = mass of the bitumenometer in grams

W_a = mass of the water in grams

$V\,B_r$ = volume of the bitumenometer in mL's

NOTE 1-The mass of the bitumenometer in grams plus the mass of water in the bitumenometer in grams, minus the mass of the bitumenometer in grams, equals the volume of the bitumenometer in mL's.

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LABORATORY TESTING SECTION

Method of Test for

MARSHALL CRITERIA FOR COMPACTED BITUMINOUS SPECIMENS

1.   SCOPE

        1.1   This method is used for the application of Marshall design and control criteria of compacted bituminous concrete specimens prepared with asphalt cement, asphalt cutback or tar, and aggregates.

        1.2   This method is a modification of ASTM D 1559 that was discontinued in 1998. The modifications consist of the use of an automatic recording apparatus to yield a complete stress/strain diagram, use of an automatic compaction hammer instead of the manually operated hammer, and more detailed specifications for the mixing and compaction temperatures. The method has been further modified to include determination of the VMA (voids in mineral aggregate), VFA (voids filled with asphalt), percent Air Voids, and density of the compacted specimen. A provision has been made for use of a 152 mm (six inch) diameter specimen mold.

2.   APPARATUS FOR A 102 MM (FOUR INCH) DIAMETER SPECIMEN

        2.1   Specimen Mold Assembly- 9 mold cylinders, 101.6 mm (4 in.) inside diameter by 87.31 mm (3-7/16 in.) high, equipped with base plates and extension collars, conforming to the details shown in Figure 1.

        2.2   Specimen Extractor- A specimen extractor for extracting the specimen from the mold is recommended. The specimen can be extracted from the mold with a plunger and hammer, but damage to the specimen may occur.

        2.3   Mechanical Compactor and Compaction Hammer- A mechanical compactor complete with 110, 220, or 110/220 VAC 186.5 Watt (1/4 hp minimum) motor, chain lift, frame, automatic hammer release, and mold holder. A compaction hammer with a flat, circular tamping face, 98.4 mm (3-7/8 in.) diameter with a 4.5 kg (10 pound) sliding weight with a free fall of 457 mm (18 inches).

        2.4   Compaction Pedestal- The compaction pedestal shall consist of an 200 by 200 mm (8 by 8 inch) high wooden post capped with a 300 by 300 by 25 mm (12 by 12 by 1 inch) steel plate. The wooden post shall be oak, yellow pine, or other wood having a dry mass of 673 to 769 kg (42 to 48 pounds) per cubic meter (foot). The post may be constructed with a solid piece of

lumber or it may be laminated by gluing. The wooden post shall be secured by four angle brackets to a solid concrete slab. The steel cap shall be centrally located on the top of the post and shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

2.5   Specimen Mold Holder- The specimen mold holder shall conform to the details of Figure 2. It shall be mounted so that the circular hold-down section is located centrally over the compaction pedestal.

2.6   Breaking Head- The breaking head, conforming with the details shown in Figure 3, consists of upper and lower circular segments, or test heads, having an inside radius of curvature of 50.8 mm (2.0 inches) accurately machined and plated. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the mounting plate for the upper segment shall be positioned to direct the two segments together without binding or loose motion on the guide rods.

2.7   Automatic Testing Apparatus- The Automatic testing apparatus records the stress/strain diagram and permits determination of the stability and flow of the bituminous concrete specimen. It shall have a vertically moving crosshead that moves uniformly at a rate of 50.8 mm (2.0 inches) per minute, a load cell for measurement of the applied load, and a means for recording and measuring the movement of the breaking heads. The equipment shall be capable of recording full scale loads of 11.1, 22.2, and 44.5 kN (2500, 5000, and 10,000 lbs).

2.8   Oven- A circulating, air oven shall be provided for heating aggregates, bituminous materials, specimen molds, and other miscellaneous equipment to the required mixing and molding temperatures. The oven shall be capable of maintaining temperatures within a range of -15 ℃ (5 ℉) up to a maximum of 177 ℃ (350℉).

2.9   Water Bath- The water bath shall be at least 150 mm (6 inches) deep, have sufficient inside area so that the 102 mm (4 inch) diameter specimens can be placed in the water with a minimum clearance of 13 mm (1/2 inch) on all sides. The bath shall be thermostatically controlled to maintain the bath temperature at 60 ± 1.0℃ (140 ± 1.8℉) uniformly throughout the bath and shall have a perforated false bottom or be equipped with a shelf for supporting the specimens 50.8 mm (2 inches) above the bottom of the bath.

2.10   Bitumenometer- A glass pycnometer of approximately 750 mL capacity (Figure 4, PTM 702).

2.11   Volumeter- A cylindrical metal pycnometer fitted with a cover having a concave taper on the upper side and a capillary vent at the center of the cover and the taper. The fit between the upper rim of the volumeter and the underside of the flange on the cover shall be a

bearing fit and no motion shall be detectable between these pieces when the outer edge of the cover is firmly pressed at various points. The volumeter shall be a nominal 101.6 mm (4 inches) deep. An inside diameter of 133.4 to 165.1 mm (5-1/4 to 6-1/2 inches) is suitable.

2.12   Sieve Shaker and Sieves- The sieve shaker shall be mechanically operated and the sieves shall conform to the specifications for sieves under AASHTO M-92.

2.13   Miscellaneous Equipment

2.13.1 Pans- Flat bottom pans or other suitable containers for heating of the aggregate

2.13.2 Asphalt Containers- Gill-type metal cans, pouring pots, or saucepans may be used as containers for the asphalt when it is heated to the mixing temperature in the oven

2.13.3 Mixing Bowls- At least two hemispherical stainless steel bowls, with flat bottoms, having sufficient capacity for hand mixing of individual batches of bituminous concrete

2.13.4 Mixing Tool- A stainless steel trowel (garden type) or spatula for mixing and spading of the bituminous mixture

2.13.5 Hot Plates- Electric hot plates, 200 mm (8 inches) in diameter with low, medium, and high heat control for heating of the apparatus and materials

2.13.6 Thermometers- For determining the temperature of aggregates, bitumen, and bituminous mixtures. Armored-glass or dial type thermometers with metal stems are recommended. The range shall be 10 to 260ºC (50 to 500ºF) with a sensitivity of 3ºC (5 ºF).

2.13.7 Thermometers- An ASTM 20C (20F) thermometer or a thermometer graduated in 0.1ºC (0.2ºF) divisions for the water bath with a range of 57 to 65˚C (134 to 148˚F)

2.13.8 Balance- A balance conforming to the requirements of AASHTO M-231, Class G2. A beam or dial balance graduated from 0 to 10 grams in 0.1gram increments. Brass weights (1.0 to 1,000 grams, which meet the requirements of NIST Handbook 44 (2000 edition) Table 2, Section 2.23).

2.13.9   Gloves- For handling hot equipment

2.13.10 Crayons- Lumber crayons, preferably a yellow color for marking and identifying specimens

2.13.11   Scoop-A metal scoop with a flat bottom

2.13.12   Spoon-A large heavy- duty spoon for placing the mixture in the specimen molds

3.   APPARATUS FOR A 152 MM (SIX INCH) DIAMETER SPECIMEN

3.1   Specimen Mold Assembly- Nine (9) mold cylinders, 152.4 mm (6 inches) in inside diameter by 114.3 mm (4-1/2 inches) height, equipped with a base plate and extension collars, conforming to the details of Figure 4.

3.2   Compactor and Pedestal- The compactor and pedestal shall conform to the specifications of Sections 2.3 and 2.4 with the exceptions that the hammer shall have a mass of 10.2 kg (22.5 pounds), the face shall be 149.2 mm (5-7/8 inches) diameter, and the mold hold down shall conform to the details of Figure 5.

3.3   Breaking Head-The breaking head shall conform to the details of Figure 6.

3.4   Testing Apparatus-The testing apparatus shall conform to the requirements of Section 2.7.

3.5   Oven-The oven shall conform to the requirements of Section 2.8.

3.6   Water Bath-The water bath shall conform to the specifications of Section 2.9, with the exception that the bath shall be at least 228.6 mm (9.0 inches) deep.

3.7   All other equipment- All other equipment shall conform to the requirements of Sections 2.11, 2.12, and 2.13, with the following exceptions: (a) The mixing bowls shall be of a standard 12.3 liter (13 quart) size and be approximately 160 mm (6-1/4 inches) deep. (b) The volumeter shall be at least 108 mm (4-1/4 inches) deep and shall have an inside diameter of 187.3 to 190.5 millimeters (7-3/8 to 7-l/2 inches).

4.   TEST SPECIMENS

     4.1   Number of Specimens- Prepare at least three specimens for each combination of aggregates and bitumen.

     4.2   Preparation of Aggregates- Dry aggregates to a constant mass at 100 to 149ºC (230 to 300ºF). Separate the dried and cooled aggregate by dry sieving. The following sieve fractions are required:

Passing	Retained
75 μm (#200)	Pan
150 μm (#100)	75 μm (#200)
300 μm (#50)	150 μm (#100)
600 μm (#30)	300 μm (#50)
1.18 mm (#16)	600 μm (#30)
2.36 mm (#8)	1.18 mm (#16)
4.75 mm (#4)	2.36 mm (#8)
9.5 mm (3/8")	4.75 mm (#4)
12.5 mm (1/2")	9.5 mm (3/8")
19.0 mm (3/4")	12.5 mm (1/2")
25.0 mm (1")	19.0 mm (3/4")
37.5 mm (1½")	25.0 mm (1")

     NOTE 1- Fine aggregate is sieved through a series of sieves from 4.75 mm (No. 4) through 75 μm (No. 200). No. 8 and No. 57 aggregates are sieved through a series of sieves from 37.5 mm (1-1/2") through the 2.36 mm (No. 8), with the minus 2.36 mm (No. 8) aggregate retained in the pan.

     4.3   Mixing and Compacting Temperatures- The mixing and compaction temperatures shall be the maximum temperature $\pm$ 3º C (5 º F) stated on the affidavit. As an alternative, the viscosity [Pa.s (Poises)] at 60ºC (140 ºF) and the viscosity m^2/sec.(cSt) at 135º C (275º F) can be plotted on Form TR-4253, Viscosity-Temperature Chart, and connected by a straight line. The mixing temperature shall be as such to yield a viscosity of 170 x 10^{-6} $\pm$ 20 x 10^{-6} m^2/sec.(170 $\pm$ 20 cSt). The compaction temperature shall be as such to yield a viscosity of 280 x 10^{-6} $\pm$ 30 x 10^{-6} m^2/sec.(280 $\pm$ 30 cSt). These temperatures apply only to asphalt cements. In the case of emulsions or cutbacks, the requirements of Bulletins 25 and 27 shall, respectively, apply. The corresponding viscosities for tar shall be the Engler Specific Viscosities of 25 $\pm$ 3 for mixing and 40 $\pm$ 5 for compacting.

     4.4   Preparation of Mixtures- For each test specimen, weigh into separate pans the

amount required of each aggregate size fraction to produce a batch that will result in a compacted specimen of 63.5 ± 1.6 mm (2.5 ± l/16 inches) in height for 102 mm (four inch) diameter specimens, and 95.3 ± 1.6 mm (3.75 ± 1/16 inches) for 152 mm (six inch) diameter specimens. Place the mixing bowl, pans of aggregate, and the mixing tool in an oven at the required temperature and bring these items listed to the required temperature. Weigh the required amount of asphalt (plus 5 to 10 grams to allow for bitumen which will adhere to the sides of the can) into a suitable container, such as a gill type can, and place it in the oven containing the mixing bowl, pans of aggregate, and tools for a period of 30 to 45 minutes. Charge the heated mixing bowl with the heated aggregate and place on a hot plate to maintain the required temperature. Dry mix the heated aggregates thoroughly. Form a crater in the center of the mixed aggregate and weigh the required amount of asphalt into the mixing bowl. At this point, the temperature of the aggregate and bituminous material shall be within the limits of the established mixing temperature as per Section 4.3. Mix the bitumen and aggregate rapidly until thoroughly coated.

4.5   Compaction of Specimens- Heat the cleaned specimen mold assembly in an oven at 93.3 to 148.9ºC (200 to 300ºF) and place the compaction hammer on a hot plate for preheating. Place a piece of filter paper or paper toweling cut to size in the bottom of the mold. Place approximately one-half of the batch in the mold assembly mounted on the compaction unit and spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Place the second half of the mixture in the mold assembly and repeat the foregoing procedure. Level the top of the bituminous mixture and place a piece of filter paper or paper toweling cut to size on top of the mixture. The temperature of the mixture immediately prior to compaction shall be within the limits of the compaction temperature established in Section 4.3. Apply 50 blows with the 4.5 kg (10 pound) hammer for 102 mm (4 inch) diameter specimens (75 blows for heavy duty mixes) and 75 blows with the 10.2 kg (22.5 pound) hammer for 152 mm (6 inch) diameter specimens (112 blows for heavy duty mixes). The blows shall be applied to the upper face of the specimen with a free fall of 457.2 mm (18 inches). Remove the extension collar and the specimen mold from the base plate, invert the specimen mold, replace the extension collar and apply the same number of blows to the other face of the specimen. Upon completion of compaction remove the extension collar and the base plate. Place the specimen mold on a firm surface and allow the specimen to cool to room temperature. Place the specimen mold assembly in the specimen extractor and mechanically force the specimen from the mold. The specimen may be removed with a plunger and a hammer, but damage to the specimen is apt to occur. Carefully transfer the specimen to a smooth, flat surface and allow it to cool at room temperature.

5.   TESTING OF COMPACTED MARSHALL SPECIMENS

        5.1   Calculations- The Department of Transportation Form TR-4265, Marshall
Specimen Work Sheet, is used for the calculation of the VMA, VFA, Density, and Percent Air
Voids of the specimen. These calculations must be performed before the compacted specimen is
destroyed by determination of stability and flow of the specimen. Refer to PTM's 703, 709, 715,
716, and AASHTO T-209. The actual sequence of calculation is as follows:

        1.   Enter the sample number, bituminous concrete specifications, type of aggregate,
and the total asphalt content on the work sheet. Weigh the dry specimen. Also weigh the
saturated surface dry specimen.

        2.   Weigh the saturated surface dry specimen plus water required to fill the
volumeter. Use of a tare weight for the mass of the dry and empty volumeter will permit direct
determination of these values.

        3.   Calculate the volume of water in the volumeter.

        4.   Enter the calibrated volume of the volumeter (PTM 703) and subtract the volume
of water in the volumeter from the specimen weight to obtain the volume of the specimen.

        5.   The mass of the specimen is divided by the volume of the specimen to yield the
specific gravity of the specimen or its density in kilograms per cubic meter. Refer to PTM's 715
and 716.

        6.   Divide the mass of the specimen by the Maximum Theoretical Specific Gravity
(AASHTO T-209) of the loose mixture to obtain the theoretical volume of the specimen.

        7.   The actual volume of the specimen (Step 4) minus the calculated theoretical
volume of the specimen equals the volume of the air voids (mL) in the specimen. This value is
divided by the volume of the specimen and multiplied by 100 to give the Percent Air Voids in the
specimen.

        8.   The mass of the specimen multiplied by the percent effective asphalt in the
specimen (PTM 709) gives the mass of the effective asphalt in the specimen. Dividing this value
by the specific gravity of the asphalt at 25ºC (77ºF) yields the volume of effective asphalt in the
specimen.

        9.   The volume of the effective asphalt plus the volume of the air voids in the
specimen gives the volume of VMA. This value divided by the volume of the specimen and

multiplied by 100 gives the Percent VMA in the specimen.

10.   The volume of the effective asphalt in the specimen divided by the volume of VMA multiplied by 100 gives the Percent VFA in the specimen.

11.   The difference between the saturated surface dry mass and the dry mass gives the mass of water absorbed by the specimen which is also equal to the volume of the absorbed water in milliliters.

12.   The volume of the water absorbed divided by the volume of the specimen and multiplied by 100 gives the Percent Water Absorption (by volume).

5.2   Determination of Stability and Flow

5.2.1   Bring the specimen to test temperature by immersion in a water bath for 45 minutes at the required temperature. Thoroughly clean the guide rods and the inside of the breaking head. Heat the test heads to 21 to 38 ℃ (70 to 100℉) by immersion in the water bath. Remove the specimen from the water bath and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen and place the assembly in position on the testing machine so that the center of the breaking head is directly under the load button of the testing machine.

5.2.2   Place a sheet of the standard Marshall graph paper or a roll of similar paper on the tester, lower the pen, and adjust the pen to zero. For a detailed description of the operation of automatic recording testers, refer to PTM's 723, 724, and 728.

5.2.3   Additional specimens may be tested and recorded on the same Marshall chart, especially if the tester is adaptable to the use of multicolored felt tip pens.

5.2.4   The elapsed time from removal of the specimen from the water bath to completion of the test shall not exceed 30 seconds.

5.2.5   The report shall include the following information for each specimen tested. This data shall be recorded on the Marshall chart and include firm identification of the data for each specimen.

5.2.5.1 Height of the specimen to the nearest 1.5 mm (1/16 of an inch).

5.2.5.2 Corrected maximum load in newtons (pounds)(see Table No. 1). It is desirable that the chart load in newtons (pounds) and the correction factor be shown on the chart as verification of the corrected maximum load.

      5.2.5.3 Flow value, in tenths of a millimeter (hundredths of an inch) measured at the initial point of maximum load. When the load produces a "flat" at the maximum, the flow is read at the initial point and it is NOT reported as an average of the minimum and maximum flow.

      5.2.5.4 Mixing Temperature

      5.2.5.5 Compaction Temperature

      5.2.5.6 Test Temperature

6.   REFERENCES

ASTM D 1559
PTM 703
PTM 709
PTM 715
PTM 716
AASHTO T-209

Table 1

STABILITY CORRELATION RATIO

102 mm (4 in.) Diameter Specimens			152 (6 in.) Diameter Specimens		
Specimen Height mm	Specimen Height Inches	Correlation Ratio	Specimen Height mm	Specimen Height Inches	Correlation Ratio
57.2	2 1/4	1.19	88.9	3 1/2	1.12
58.7	2 5/16	1.14	90.5	3 9/16	1.09
60.3	2 3/8	1.09	92.1	3 5/8	1.06
61.9	2 7/16	1.04	93.7	3 11/16	1.03
63.5	2 1/2	1.00	95.3	3 3/4	1.00
65.1	2 9/16	0.96	96.8	3 13/16	0.97
66.7	2 5/8	0.93	98.4	3 7/8	0.95
68.3	2 11/16	0.89	100.0	3 15/16	0.92
69.9	2 3/4	0.86	101.6	4	0.90

Note 2- The recorded stability for each specimen shall be multiplied by the appropriate correlation ratio for the specimen height to convert the stability value to that of a specimen of standard height.

114.30 mm (4 1/2")

COLLAR

69.85 mm
(2 3/4")

104.78 mm (4 1/8") ID

7.15 mm
(9/32")

109.14 mm (4 19/64")

108.74 mm (4 9/32")

6.35 mm
(1/4")

MOLD

87.31 mm
(3-7/16")

101.73 mm - 101.47 mm
(4.005" - 3.995")

114.30 mm (4 1/2") OD

101.20 mm (3 63/64")

14.29 mm
(9/16")

BASE PLATE

3.18 mm
(1/8")

120.65 mm (4 3/4")
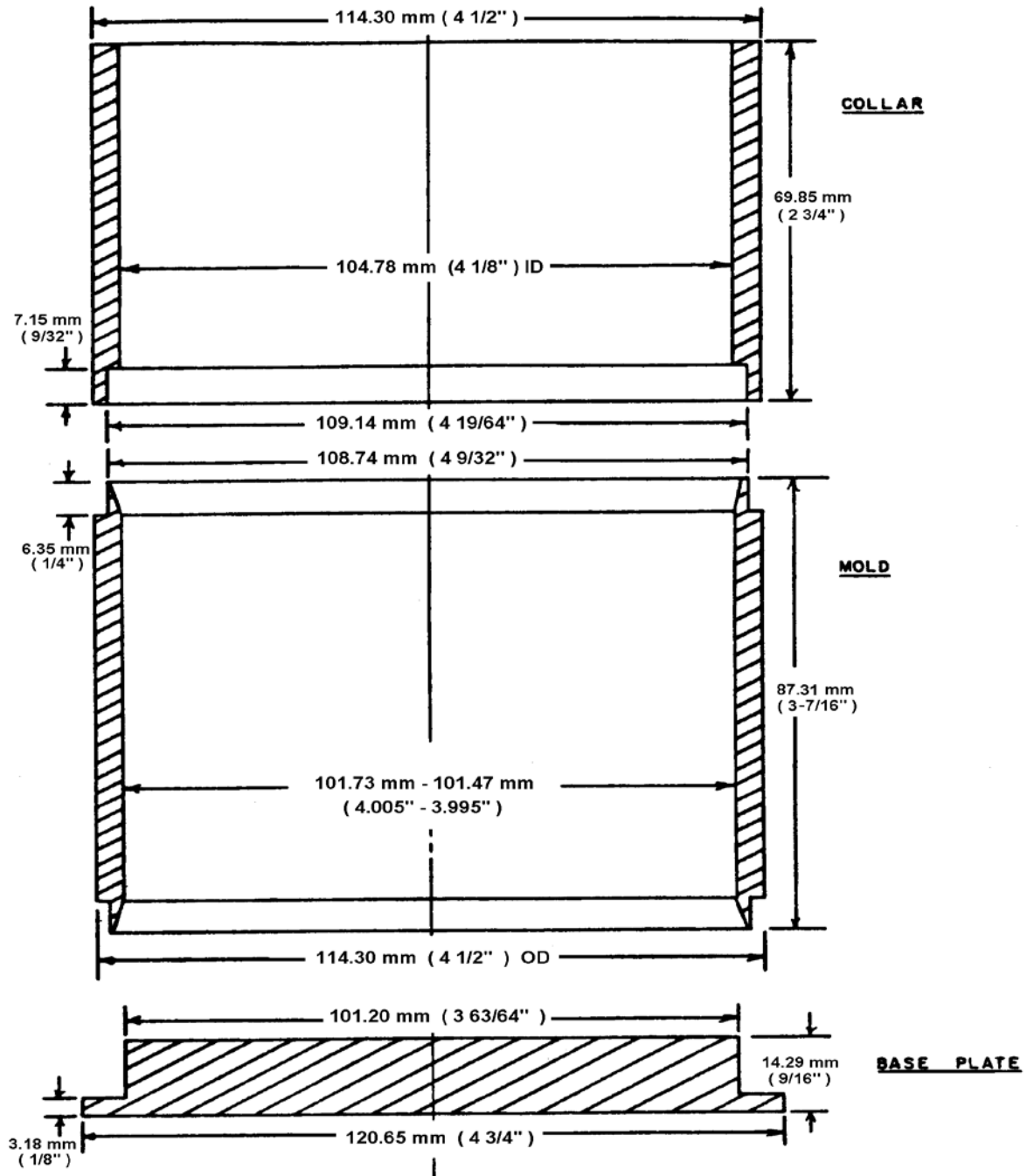
101.60 mm (4") COMPACTION MOLD
FIG. 1

COMPRESSION SPRING

6.35 mm
(1/4")

105.57 mm (4 5/32")

12.70 mm (1/2")

115.10 mm (4 17/32")

139.70 mm (5 1/2")

GUIDE BUSHING

GUIDE POST

NOTE: GIUDE POST THREADED INTO PEDESTAL CAP.
DIMENSIONS OF GUIDE POST, GUIDE BUSHING
AND COMPRESSION SPRING NOT CRITICAL.
ONLY REQUIREMENT IS THAT COMPACTION
MOLD IS HELD FIRMLY.
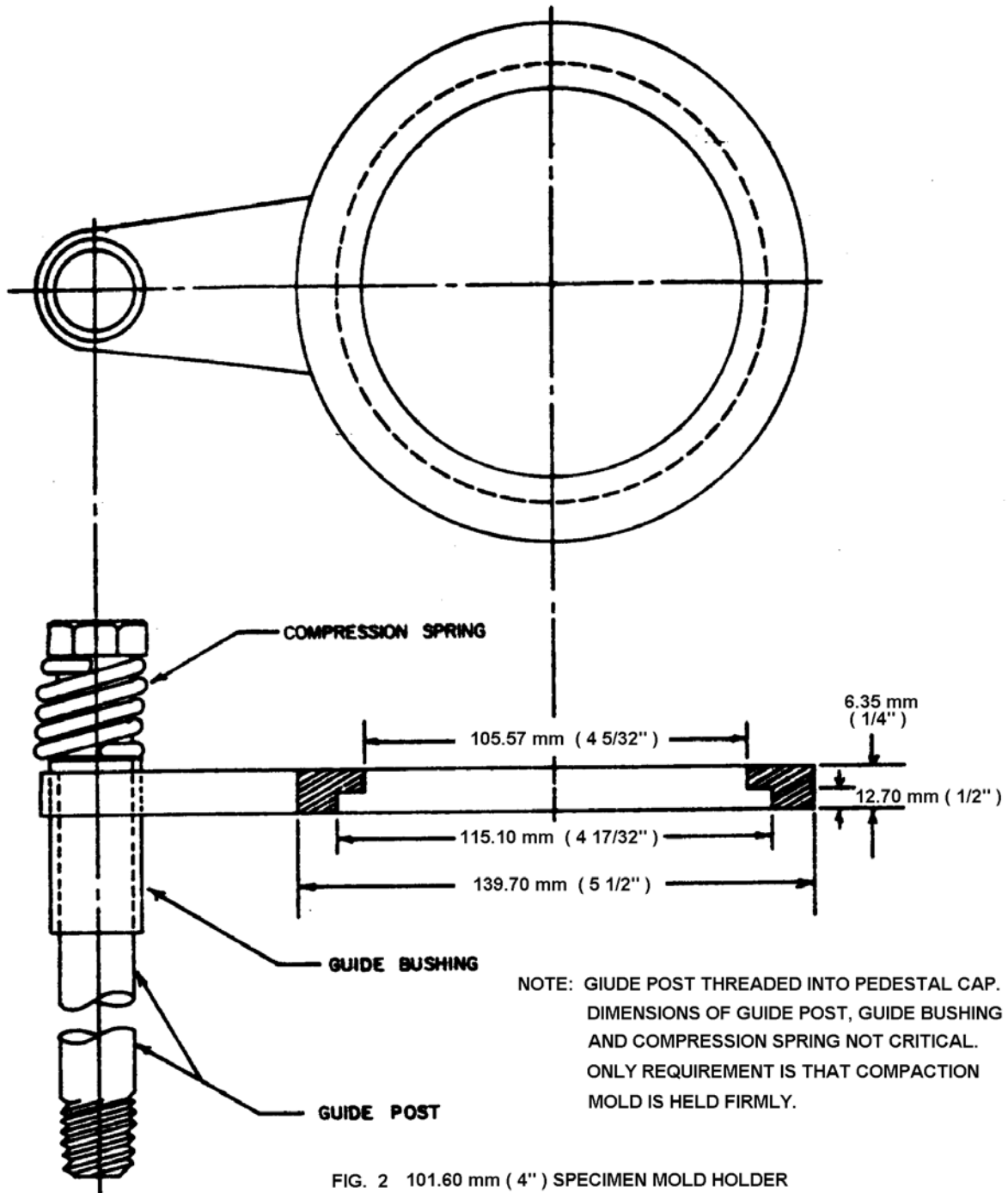
FIG. 2   101.60 mm (4") SPECIMEN MOLD HOLDER
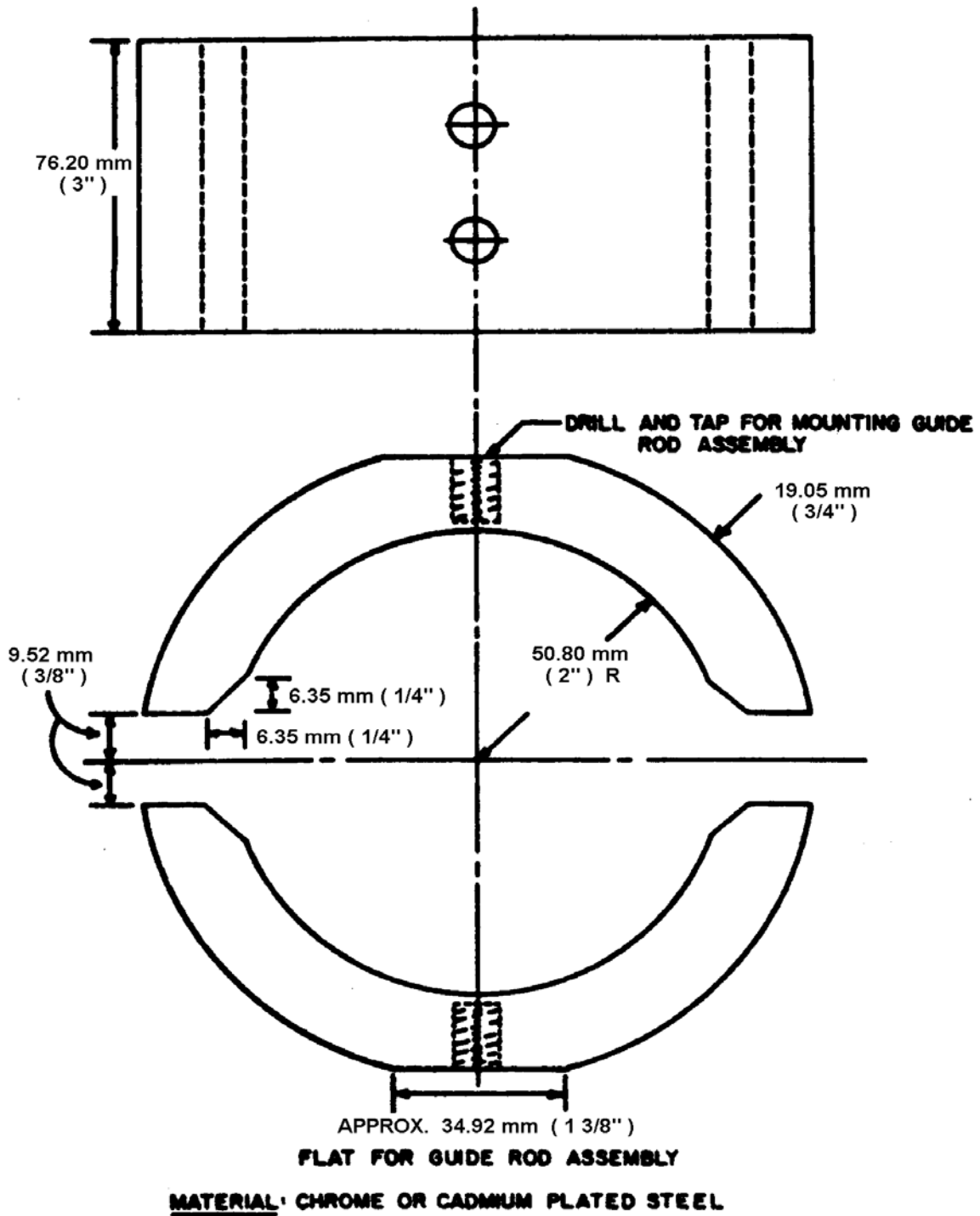
Figure 3 - 101.60 mm (4") Compression Ring

165.10 mm (6 1/2")

COLLAR

82.55 mm
(3 1/4")

158.75 mm (6 1/8")

7.15 mm
(9/32")

159.45 mm (6 9/32")

159.15 mm (6 17/64")

6.35 mm
(1/4")

MOLD

114.30 mm
(4 1/2")

152.53 mm - 152.27 mm
(6.005" - 5.995")

165.10 mm (6 1/2")

151.61 mm (5 31/32")

12.70 mm
(1/2")

BASE PLATE

6.35 mm
(1/4")

171.45 mm (6 3/4")
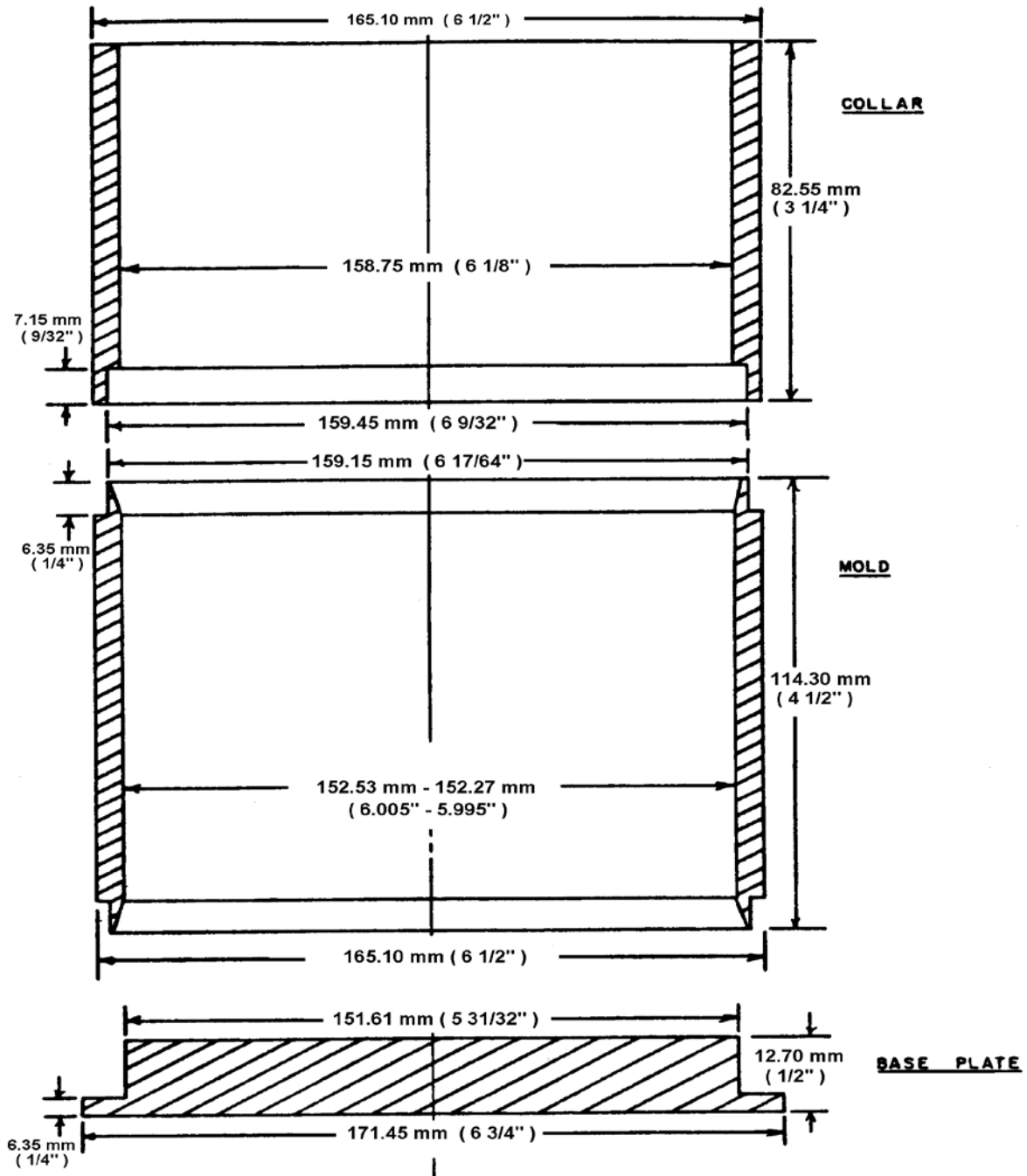
FIG. 4   152.4 mm (6") COMPACTION MOLD

COMPRESSION SPRING

6.35 mm
(1/4")

158.75 mm (6 1/8")

12.70 mm (1/2")

166.69 mm (6 9/16")

190.50 mm (7 1/2")

GUIDE BUSHING

NOTE: GIUDE POST THREADED INTO PEDESTAL CAP.
DIMENSIONS OF GUIDE POST, GUIDE BUSHING
AND COMPRESSION SPRING NOT CRITICAL.
ONLY REQUIREMENT IS THAT COMPACTION
MOLD IS HELD FIRMLY.

GUIDE POST
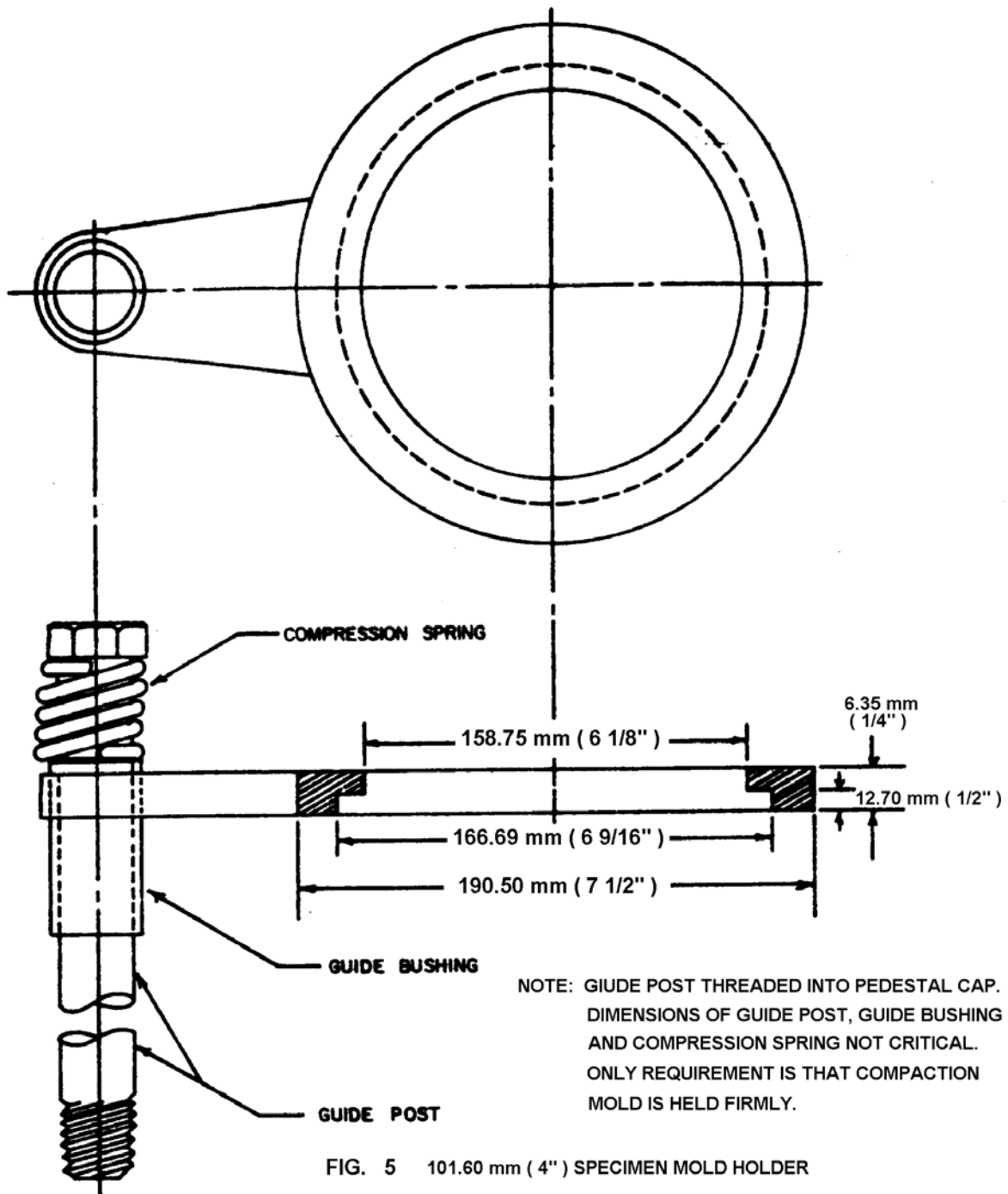
FIG. 5   101.60 mm (4") SPECIMEN MOLD HOLDER
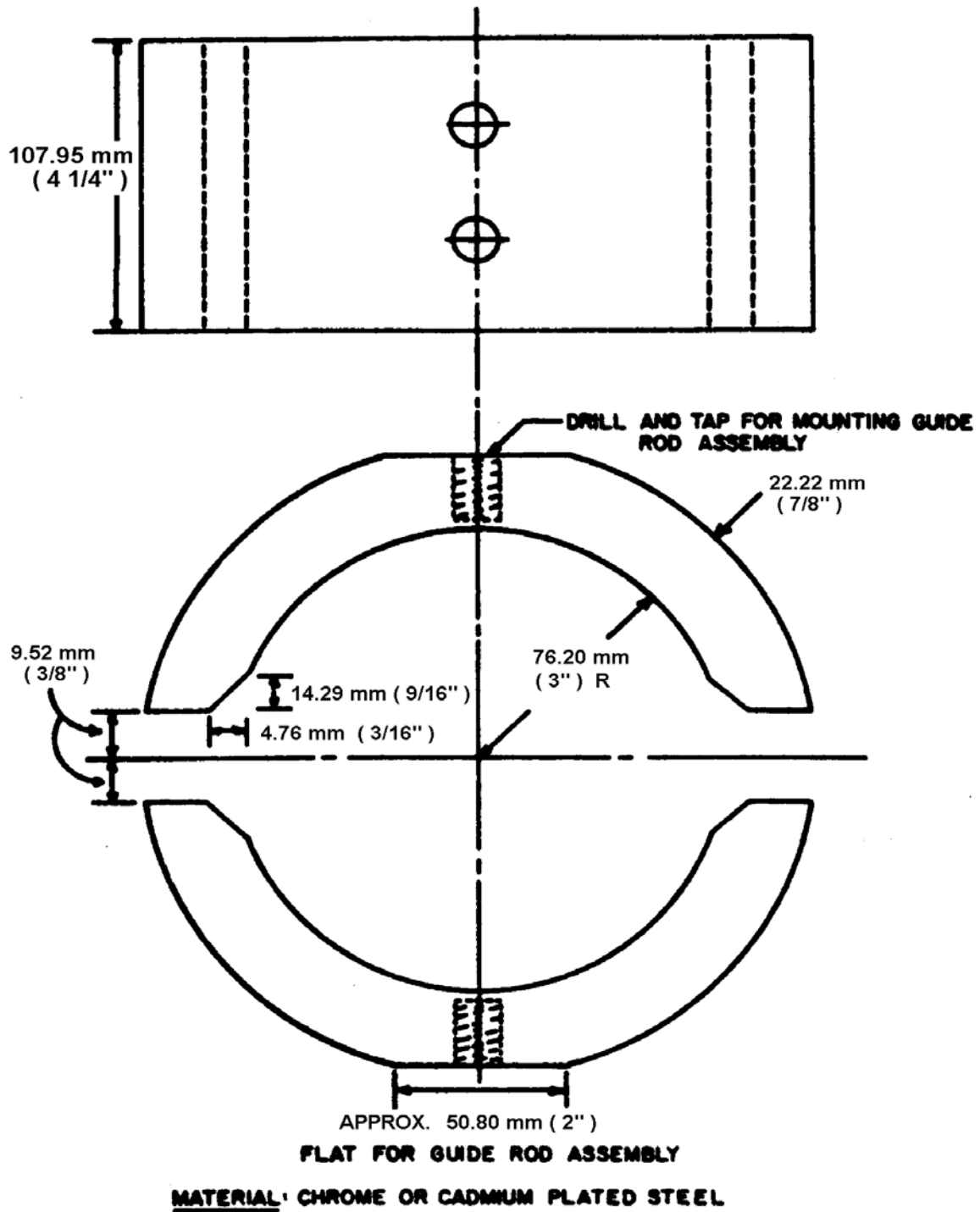
Figure 6 - 152.4 mm (6") Compression Ring

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF SPECIFIC GRAVITY OF SOLVENTS

1.   SCOPE

        1.1   This method of test is used to determine the specific gravity of a solvent.

2.   APPARATUS

        2.1   Bitumenometer- Any capacity

        2.2   Thermometer- ASTM 17 C (17 F) having a range of 19 to 27º C (66 to 80º F), graduated in 0.1º C (0.2º F) subdivisions

        2.3   Water Bath- Thermostatically controlled so as to maintain the bath temperature at 25 C ± 0.5º C (77.0 F ± 0.9º F)

        2.4   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2

3.   TEST SAMPLE

        3.1   A solvent intended for use in extraction of bituminous mixtures.

4.   PROCEDURE

        4.1   Fill a calibrated bitumenometer with solvent at a temperature of 15 to 25º C (60 to 77º F), insert a capillary tube, and immerse in a water bath (to about the 22 mm (7/8) mark of the bitumenometer) maintained at 25.0º C (77.0º F) for one hour. At the end of the one hour period, slightly raise the bitumenometer, check the temperature, and make certain that the stopper-capillary tube is filled to the top with solvent and that no air bubbles are present. Remove the excess solvent from the top of the tube and place the overflow cap on the stopper-capillary tube.

        4.2   Remove the bitumenometer from the water bath and wipe it dry with a dry absorbent cloth. Weigh the bitumenometer and solvent to the nearest 0.1 gram of a gram.

5.   CALCULATIONS

5.1   Calculate the specific gravity of the solvent as follows:

$$WS / Vbr = GS$$

Where:

Vbr = Volume in mL of the bitumenometer at 25.0 ℃ (77.0 ℉)

WS   = Mass in grams of solvent in the bitumenometer at 25.0 ℃ (77.0 ℉).
(Subtract the mass of the bitumenometer from the mass determined in Section 4.2)

GS   = Specific gravity of the solvent at 25.0 ℃ (77.0 ℉)

NOTE 1- The specific gravity of the solvent enters into many calculations, therefore, it is important that the specific gravity of the solvent be determined within 0.001.

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LABORATORY TESTING SECTION

Method of Test for

EFFECTIVE ASPHALT CONTENT OF BITUMINOUS PAVING MIXTURES

1.   SCOPE

        1.1   This method computes the effective asphalt content in a bituminous paving mixture. The effective asphalt content (P_{be}) of a paving mixture is the total asphalt content (P_b) minus the quantity of asphalt lost by absorption into the aggregate particles. It is the portion of the total asphalt content that remains as a coating on the outside of the aggregate particles in which the service performance of a paving mixture depends.

        1.2   The effective asphalt content (not the total asphalt content) is to be used to compute the VMA (voids in mineral aggregate) and the VFA (voids filled with asphalt) in Marshall specimens (PTM 705) and pavement cores.

2.   MATERIALS AND TESTS

        2.1   Coarse Aggregate(s)

                2.1.1   A representative sample of the coarse aggregate(s) shall be obtained in accordance with AASHTO T-248.

Nominal Maximum Size (inches)	Minimum Mass of Sample (kg)
12.5 mm (1/2 inch) or less, (1B) aggregate	2.5
25.0 mm (1 inch), (2B) aggregate	4.5

2.1.2   The bulk specific gravity (dry) of the coarse aggregate(s) shall be determined in accordance with AASHTO T-83 using the following formula (the value shall be reported to three decimal places):

$$\text{Bulk Sp. Gr.} = \frac{A}{B - C}$$

2.2   Fine Aggregate(s)

2.2.1   A representative sample of the fine aggregate(s) weighing at least 1.0 kg shall be obtained in accordance with AASHTO T-248.

2.2.2   The bulk specific gravity (dry) of the fine aggregate(s) shall be determined in accordance with AASHTO T-84 using the following formula (the test value shall be reported to three decimal places):

$$\text{Bulk Sp. Gr.} = \frac{A}{B + S - C}$$

2.3   Mineral Filler

2.3.1   If a mineral filler is added separately to the paving mixture, a representative sample weighing at least 200 g shall be obtained in a plastic lined bag.

2.3.2   The specific gravity of the mineral filler shall be determined in accordance with AASHT0 T-133 using kerosene as a wetting agent. The test value shall be reported to three decimal places.

2.4   Asphalt Cement

2.4.1   The specific gravity of the asphalt cement (G_b) shall be determined at 25 ^{o}C (77 ^{o}F) in accordance with AASHT0 T-228 and shall be reported to three decimal places. The value furnished by the asphalt supplier may be used.

2.5   Bituminous Paving Mixture

    2.5.1   The maximum specific gravity (G_{mm}) of the loose bituminous paving mixture containing a known asphalt content (P_b), by total mass of the mixture, shall be determined by AASHTO T-209.

    2.5.2   The effective specific gravity (G_{se}) of the combined aggregates in the same mixture shall be calculated as follows (Note 1):

$$G_{se} = \frac{G_{mm}(100 - P_b)}{100 - \dfrac{G_{mm}\, FUNCx\, P_b}{G_b}}$$

Where:

G_{se} = effective specific gravity of the aggregates

G_{mm} = maximum specific gravity of the loose paving mixture

P_b = asphalt content, percent by total weight of the mixture

G_b = specific gravity of the asphalt

NOTE 1- A worksheet to calculate the effective specific gravity(G_{se}) by the above formula is appended to this PTM.

3.   CALCULATIONS

3.1   Bulk specific gravity of the total aggregate (G_{sb})- When the total aggregate consists of separate fractions of coarse aggregate(s), fine aggregate(s), and mineral filler (if added separately), all having different specific gravities, the combined bulk specific gravity for the total aggregate is calculated as follows (assuming there are three aggregates):

$$G_{sb} = \frac{P_1 + P_2 + P_3}{\dfrac{P_1}{G_1} + \dfrac{P_2}{G_2} + \dfrac{P_3}{G_3}}$$

Where:

G_{sb} = bulk specific gravity of the total aggregate

P_1, P_2, P_3 = percentages by weight of aggregates l, 2 and 3 in the paving mixture

G_1, G_2, G_3 = bulk specific gravities of aggregates l, 2, and 3 (Sections 2.1, 2.2, and 2.3 of this PTM)

NOTE 2- A worksheet to calculate G_{sb} by the above formula is appended to this PTM.

3.2   Percent asphalt absorbed by the aggregate (P_{ba})- Absorption is expressed as a percentage by weight of aggregate rather than as a percentage by total weight of the mixture. It shall be calculated as follows:

$$P_{ba} = \frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}} \times G_b \times 100$$

Where:

P_{ba} = absorbed asphalt, percent by weight of aggregate

G_{se} = effective specific gravity of the aggregate

G_{sb} = bulk specific gravity of the aggregate

G_b = specific gravity of the asphalt

NOTE 3 - A worksheet to calculate P_{ba} by the above formula is appended to this PTM.

3.3   Effective asphalt content of the paving mixture- The effective asphalt content (P_{be}) of a paving mixture is the total asphalt content minus the quantity of asphalt lost by absorption into the aggregate particles.

Effective asphalt content (P_{be}) shall be calculated as follows:

$$P_{be} = P_b - \frac{P_{ba}}{100}(100 - P_b)$$

Where:

P_{be} = effective asphalt content, percent by total weight of the mixture

P_b = asphalt content, percent by total weight of the mixture

P_{ba} = absorbed asphalt, percent by weight of the aggregate

NOTE 4 - A worksheet to calculate P_{be} by the above formula is appended to this PTM.

4.   REPORT

4.1   Effective asphalt content (P_{be}) shall be reported to the nearest 0.1 percent.

4.2   Effective asphalt content (P_{be})is intended to be used to compute the VMA (voids in mineral aggregate) and the VFA (voids filled with asphalt) using the Marshall specimen worksheet (PTM 705).

5.   REFERENCES

The Asphalt Institute MS-2

AASHTO T-84, T-85, T-209, T-248, and PTM 705

APPENDIX TO PTM 709

EXAMPLE 1 (Using Formula)

Given:

Constituent Material	Value	Bulk Sp. Gr Test Method	Percent by Weight Total Mix
Coarse aggregate	2.604 (G_1)	AASHTO T-85	51.4 (P_1)
Fine aggregate #1	2.827 (G_2)	AASHTO T-84	18.7 (P_2)
Fine aggregate #2	2.619 (G_3)	AASHTO T-84	22.9 (P_3)
Asphalt cement	1.010 (G_b)	AASHTO T-228	7.0 (P_b)
		TOTAL:	100.0

Maximum Sp. Gr. of Mix (AASHTO T-209) = 2.439 (G_{mm})

Calculate the Effective Asphalt Content in the above mixture as follows:
   (a) Bulk Sp. Gr. of the Total Aggregate (G_{sb})

$$G_{sb} = \frac{P_1 + P_2 + P_3}{\dfrac{P_1}{G_1} + \dfrac{P_2}{G_2} + \dfrac{P_3}{G_3}}$$

$$= \frac{51.4 + 18.7 + 22.9}{\dfrac{51.4}{2.604} + \dfrac{18.7}{2.827} + \dfrac{22.9}{2.619}}$$

$$= \frac{93.0}{19.739 + 6.615 + 8.744}$$

$$= \frac{93.0}{35.098} = 2.650$$

(b)   Effective Sp. Gr. of the Total Aggregate (G_{se}):

$$G_{se} = \frac{G_{mm}\,(100 - P_b)}{100 - \dfrac{G_{mm}\ x\ P_b}{G_b}}$$

$$= \frac{2.439\,(100 - 7.0)}{100 - \dfrac{2.439\ x\ 7.0}{1.010}}$$

$$= \frac{226.827}{100 - 16.904}$$

$$= \frac{226.827}{83.096} = 2.730$$

(c)   Percent Asphalt Absorbed by the Aggregate (P_{ba}):

$$P_{ba} = \frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\ x\ G_b\ x\ 100$$

$$= \frac{2.730 - 2.650}{2.730\ x\ 2.650}\ x\ 1.010\ x\ 100$$

$$= \frac{0.080}{7.234}\ x\ 101.0 = 1.117$$

(d)   Effective Asphalt Content (P_{be}) in the Mixture:

$$P_{be} = P_b - \frac{P_{ba}}{100}(100 - P_b)$$

$$= 7.0 - \frac{1.117}{100}(100 - 7.0)$$

$$= 7.0 - 1.039$$

$$= 5.961 = 6.0 \text{ (rounded to one-tenth percent)}$$

WORK SHEET
DETERMINATION OF EFFECTIVE ASPHALT CONTENT

A. BULK SP. GR. OF TOTAL AGGREGATE (G_{sb})

Aggregate	Type (Coarse or Fine)	Percentage in Mix (P)	Bulk Sp. Gr. (G)	P/G
Aggregate #1	Coarse (1B)	51.4	2.604	19.739
Aggregate #2	Fine (Nat. Sand)	18.7	2.827	6.615
Aggregate #3	Fine (Screenings)	22.9	2.619	8.744
Aggregate #4	—	—	—	—
Mineral Filler	—	—	—	—
TOTALS	—	93.0	—	35.098

$$G_{sb} = \frac{\text{Summation of P}}{\text{Summation of P/G}} = \frac{93.0}{35.098} = 2.650$$

B. EFFECTIVE SP. GR. OF TOTAL AGGREGATE (G_{se})

Line		1	2	3
1	Max. Sp. Gr. Of Mix (G_{mm})	2.439		
2	% Total AC in Mix (P_b)	7.0		
3	Sp. Gr. Of AC (G_b)	1.010		
4	Line 2 ÷ Line 3 (cc of AC)	6.931		
5	100 - Line 2	93.0		
6	Line 1 x Line 5	226.827		
7	Line 1 x Line 4	16.905		
8	100 - Line 7	83.095		
9	Line 6 ÷ Line 8 (Effective Sp. Gr. Of Total Aggregate, (G_{se})	2.730		

Average Value of G_{se} =

C. PERCENT ASPHALT ABSORBED BY AGGREGATE (P_{ba})

Line

1	Effective Sp. Gr. Of Total Aggregate (G_{se})	2.730
2	Bulk. Sp. Gr. Of Total Aggregate (G_{sb})	2.650
3	Sp. Gr. Of Asphalt Cement (G_b)	1.010
4	Line 1 - Line 2	0.080
5	Line 1 x Line 2	7.2345
6	Line 4 ÷ Line 5	0.01106
7	Line 6 x Line 3	0.01117
8	Line 7 x 100 (Percent AC Absorbed by Aggregate, P_{ba})	1.117

D. EFFECTIVE ASPHALT CONTENT IN MIX (P_{be})

Line

1	% Total AC in Mix (P_b)	7.0
2	% AC Absorbed by Aggregate (P_{ba})	1.117
3	Line 2 - 100	0.01117
4	100 - Line 1	93.0
5	Line 3 x Line 4	1.0388
6	Line 1 - Line 5 (Effective Asphalt Content in Mix, P_{be})	5.9612 6.0 (rounded)

End of PTM 709

TR-4265 (9-77)
M (1/96)

Example

MARSHALL SPECIMEN WORK SHEET

SAMPLE NO.	1					
SPECIFICATION	ID-2W					
AGGREGATE	Gravel					
% ASPHALT (Total) P_b	7.0					
MASS SAMPLE + H_2O	1826.9					
− MASS S.S.D. SAMP.	1229.3					
= VOL WATER	597.6					
VOL VOLUMETER	1122.8					
− VOL WATER	597.6					
= VOL SAMPLE	525.2					
MASS SAMPLE	1228.8					
÷ VOL SAMPLE	2.439					
= SP GR SAMPLE	503.8					
MASS SAMPLE	1228.8					
÷ THEOR. SP GR (Gmm)	2.439					
= THEOR. VOL.	503.8					
VOL. SAMPLE	525.2					
− THEOR. VOL.	503.8					
= VOL. VOIDS	21.4					
÷ VOL. SAMPLE	525.2					
= % VOIDS	4.1					
MASS SAMPLE	1228.8					
x % ASPHALT (Effective) P_{be}	6.0					
= MASS ASPHALT	73.7					
÷ SP GR A.C.	1.010					
= VOL. A.C.	73.0					
+ VOL. VOIDS	21.4					
= VOL. V.M.A.	94.4					
÷ VOL. SAMPLE	525.2					
= % V.M.A.	18.0					
VOL. ASPHALT	73.0					
÷ VOL. V.M.A.	94.4					
= % V.F.A.	77.3					
MASS S.S.D. SAMP.						
− DRY MASS						
= MASS ABSORB.						
÷ VOL. SAMPLE						
= % ABSORB (VOL.)						
STABILITY						
FLOW						
AVG. SP. GR.						
AVG. % VOIDS						
AVG. % VMA						
AVG. % VFA						
AVG. STABILITY						
AVG. FLOW						

TR-4265 (9-77)
M (1/96)

MARSHALL SPECIMEN WORK SHEET

SAMPLE NO.						
SPECIFICATION						
AGGREGATE						
% ASPHALT						
MASS SAMPLE + H_2O						
− MASS S.S.D. SAMP.						
= VOL WATER						
VOL VOLUMETER						
− VOL WATER						
= VOL SAMPLE						
MASS SAMPLE						
÷ VOL SAMPLE						
= SP GR SAMPLE						
MASS SAMPLE						
÷ THEOR. SP GR						
= THEOR. VOL.						
VOL. SAMPLE						
− THEOR. VOL.						
= VOL. VOIDS						
÷ VOL. SAMPLE						
= % VOIDS						
MASS SAMPLE						
x % ASPHALT (Effective)						
= MASS ASPHALT						
÷ SP GR A.C.						
= VOL. A.C.						
+ VOL. VOIDS						
= VOL. V.M.A.						
÷ VOL. SAMPLE						
= % V.M.A.						
VOL. ASPHALT						
÷ VOL. V.M.A.						
= % V.F.A.						
MASS S.S.D. SAMP.						
− DRY MASS						
= MASS ABSORB.						
÷ VOL. SAMPLE						
= % ABSORB (VOL.)						
STABILITY						
FLOW						
AVG. SP. GR.						
AVG. % VOIDS						
AVG. % VMA						
AVG. % VFA						
AVG. STABILITY						
AVG. FLOW						

WORK SHEET FOR DETERMINATION OF
EFFECTIVE ASPHALT CONTENT

A. BULK SP. GR. OF THE TOTAL AGGREGATE (G_{sb})

Aggregate	Type (Coarse or Fine)	Percentage in Mix (P)	Bulk Sp. Gr. (G)	$\frac{P}{G}$
Aggregate #1				
Aggregate #2				
Aggregate #3				
Aggregate #4				
Mineral Filler				
TOTALS				

$$G_{sb} = \frac{\text{Summation of P}}{\text{Summation of P/G}} =$$

B. EFFECTIVE SP. GR. OF THE TOTAL AGGREGATE (G_{se})

		1	2	3
1	Max. Sp. Gr. of the Mix (G_{mm})			
2	% Total AC in the Mix (P_b)			
3	Sp. Gr. of the AC (G_b)			
4	Line 2 ÷ Line 3 (cc of AC)			
5	100 - Line 2			
6	Line 1 x Line 5			
7	Line 1 x Line 4			
8	100 - Line 7			
9	Line 6 ÷ Line 8 (Effective Sp. Gr. of the total aggregate, (G_{se})			

Average Value of G_{se} =

C.   PERCENT ASPHALT ABSORBED BY AGGREGATE (P_{ba})

Line

1	Effective Sp. Gr. of the total aggregate (G_{se})	
2	Bulk. Sp. Gr. of the total aggregate (G_{sb})	
3	Sp. Gr. of the Asphalt Cement (G_b)	
4	Line 1 - Line 2	
5	Line 1 x Line 2	
6	Line 4 ÷ Line 5	
7	Line 6 x Line 3	
8	Line 7 x 100 (Percent AC Absorbed by the aggregate, P_{ba})	

D.   EFFECTIVE ASPHALT CONTENT IN MIX (P_{be})

Line

1	% Total AC in the Mix (P_b)	
2	% AC Absorbed by the aggregate (P_{ba})	
3	Line 2 - 100	
4	100 - Line 1	
5	Line 3 x Line 4	
6	Line 1 - Line 5 (Effective Asphalt Content in the Mix, P_{be})	

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF BULK SPECIFIC GRAVITY OF
COMPACTED BITUMINOUS MIXTURES

1.   SCOPE

        1.1   This method of test is intended for determining the bulk specific gravity of
laboratory compacted bituminous mixtures or bituminous roadway samples, such as cores, small
sawed slabs, density ring samples, etc. This method shall not be used if the samples contain open
or interconnecting voids and/or absorb more than 3.0 percent water. For such samples, PTM No.
716 shall be used.

2.   TEST SPECIMEN

        2.1   Compacted specimens in accordance with PENNDOT Methods or obtained in
accordance with PENNDOT methods of sampling a compacted roadway.

        2.2   Size of specimens- It is recommended, (1) that the diameter of cylindrically
molded or cored specimens, or the length of the sides of the sawed specimens, be at least equal to
four times the nominal maximum size of the aggregate; and (2) that the thickness of the
specimens be at least 1.5 times the nominal maximum size of the aggregate.

        2.3   Specimens shall be free of foreign materials such as seal coat, tack coat,
foundation material, soil, paper, or foil.

        2.4   If desired, specimens may be separated from the other pavement layers by sawing
or other suitable means. Care shall be exercised to ensure sawing does not damage the
specimens.

METHOD A (VOLUMETER)

3. APPARATUS

     3.1   Weighing Device-A weighing device conforming to the requirements of AASHTO M-231, Class G2

     3.2   Water Bath- Thermostatically controlled so as to maintain the bath temperature at 25 ± 0.5°C (77 ± 0.9°F)

     3.3   Thermometer- ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions

     3.4   Volumeter[1] - Calibrated, 1.2 L or an appropriate capacity depending upon the size of the test sample

4. PROCEDURE

     4.1   Immerse the specimen in the water bath and let saturate for at least 10 minutes. At the end of the 10 minute period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F). Place the saturated specimen into the volumeter. Bring the temperature of the water in the volumeter to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter making certain that some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and contents to the nearest 0.1 of a gram.

     4.2   Remove the immersed and saturated specimen from the volumeter, quickly damp dry the saturated specimen with a damp towel, and as quickly as possible weigh the specimen. Any water that seeps from the specimen during the weighing operation is considered as a part of the saturated specimen. Dry the specimen to constant mass (NOTE 1). Weigh the dried specimen to the nearest 0.1 of a gram.

     NOTE 1- Constant mass shall be defined as the mass at which further drying at 52 ± 3°C (125 ± 5°F) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at 52 ± 3°C (125 ± 5°F), flipped top to bottom, then dried until a Minimum Standard Drying Time of 20 hours has elapsed. This Minimum Standard Drying Time shall be reestablished using the procedure in NOTE 1A if there are substantial changes in ovens, paving materials, or mix design methods from 2002 conditions. Laboratory compacted specimens and density ring samples need not be dried.

[1]Aluminum Volumeters of different sizes available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA. 16127 and Rainhart Co., 604 Williams St., Austin, TX, 78765 have been found suitable.

NOTE 1A- PROCEDURE FOR DETERMINING A MINIMUM STANDARD DRYING TIME: Assemble a random sample of cores representing the compacted asphalt mixtures typically tested. Saturate the cores with water, and place the saturated cores in the 52 ± 3ºC (125 ± 5ºF) oven overnight. At the start of the following workday flip the cores top to bottom. Continue to dry and weigh the cores at two-hour intervals until constant mass is attained. Document and use the time it took for all cores to reach constant weight as the Minimum Standard Drying Time.

NOTE 2- If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the dry mass of the specimen can be determined. Then the volumeter containing the saturated specimen and water can be weighed. The mass of the saturated specimen can be obtained last.

5.   CALCULATIONS

5.1   Calculate the bulk specific gravity (dry basis) of the samples as follows (report the value to three decimal places):

$$GSm = \frac{WSm}{(0.997 \text{ g/mL}) \text{ x } [VVo - (1.003 \text{ mL/g}) \text{ x } (WT - WSa - WVo)]}$$

Where:

GSm   = bulk specific gravity of the specimen at 25.0ºC (77ºF)

WSm   = mass in grams of the dry specimen

VVo   = volume in mL of the volumeter at 25.0ºC (77ºF) to the nearest tenth of a milliliter

WT   = total mass in grams of the volumeter, saturated specimen, and water in the volumeter at 25.0ºC (77ºF)

WSa   = mass in grams of the saturated specimen

WVo   = mass in grams of the volumeter

5.2   Calculate the percent water absorbed by the specimen as follows (report the value to one decimal place):

$$\text{Percent Water Absorbed} = \frac{WSa - WSm}{(0.997 \text{ g/mL}) \times [VVo - (1.003 \text{ mL/g}) \times (WT - WSa - WVo)]} \times 100$$

If the percent water absorbed is more than 3.0 percent, use PTM No. 716.

METHOD B (SUSPENSION IN WATER)

AASHTO T-166, Method A, except as follows:

> NOTE 1- replace with the following: Constant mass shall be defined as the mass at which further drying at 52 ± 3ºC (125 ± 5ºF) does not alter the mass by more than 0.05 percent. Samples saturated with water shall initially be dried overnight at 52 ± 3ºC (125 ± 5ºF), flipped top to bottom, then dried until a Minimum Standard Drying Time of 20 hours has elapsed. This Minimum Standard Drying Time shall be reestablished using the procedure in NOTE 1A if there are substantial changes in ovens, paving materials, or mix design methods from 2002 conditions. Laboratory compacted specimens and density ring samples need not be dried.

> Add: NOTE 4 – Referee Method- In case of discrepancies between the test results obtained by Method A and Method B, the referee test shall be Method A.

METHOD C (RAPID TEST)

AASHTO T-166, Method C

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF BULK SPECIFIC GRAVITY OF
COMPACTED BITUMINOUS MIXTURES THAT ABSORB MORE THAN 3.0 PERCENT
WATER BY VOLUME

1.   SCOPE

        1.1   This method of test is intended for determining the bulk specific gravity of laboratory compacted bituminous mixtures or bituminous roadway samples that contain open or interconnecting voids and/or absorb more than 3.0 percent of water by volume.

2.   TEST SPECIMEN

        2.1   Compacted specimens in accordance with PENNDOT Methods or obtained in accordance with PENNDOT Methods of sampling a compacted roadway.

METHOD A (VOLUMETER)

3.   APPARATUS

        3.1   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2

        3.2   Water Bath- A thermostatically controlled bath, capable of maintaining the bath temperature at 25 ± 0.5ºC (77 ± 0.9ºF)

        3.3   Thermometer- An ASTM 17 C (17 F), having a range of 19 to 27ºC (66 to 80ºF), graduated in 0.1ºC (0.2ºF) subdivisions

        3.4   Volumeter[1] – Calibrated, 1.2 L or an appropriate capacity depending on the size of the test sample

        [1]Aluminum Volumeters of different sizes available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA. 16127 and Rainhart Co., 604 Williams St., Austin. TX 78765 have been found suitable.

4.   PROCEDURE

4.1   Dry the specimen to constant mass (NOTE 1) and weigh the specimen to the nearest tenth (0.1) of a gram.

NOTE 1- Constant mass shall be defined as the mass at which further drying at 52 ± 3ºC (125 ± 5ºF) does not alter the mass by more than 0.05 percent of the test load.

4.2   Coat the specimen with melted paraffin sufficiently thick to seal all surface voids. Allow the specimen to cool in air at room temperature for 30 minutes, and then weigh to the nearest tenth (0.1) of a gram.

NOTE 2- Application of the paraffin may be accomplished by chilling the specimen in a refrigerating unit to a temperature of approximately 4.5ºC (40ºF) for 30 min. and then dipping the specimen in warm paraffin at 5.5ºC (10º F) above the melting point. It may be necessary to brush the surface of the specimen with added hot paraffin in order to fill any pinpoint holes.

4.3   Fill a calibrated volumeter with distilled water at 25ºC (77ºF). Place the coated specimen into the volumeter and cover the volumeter making certain that some water escapes through the capillary bore in the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and its contents to the nearest tenth (0.1) of a gram.

4.4   Determine the specific gravity of the paraffin at 25 ± 1ºC (77 F $\pm$ 2ºF), if unknown, using the bitumenometer method, as is used for determining the specific gravity of bitumen (AASHTO T-228).

5. CALCULATIONS

5.1 Calculate as follows:

$$GSm = \frac{WSm}{VVo - [(PWSm + WWa) - PWSm + \dfrac{(PWSm - WSm)}{GP}}$$

Where:

GSm = Specific gravity of the specimen at 25.0ºC (77ºF)

WSm= Mass in grams of the uncoated specimen in air at 25.0ºC (77ºF)

VVO = Volume in cc of the volumeter at 25.0 ºC (77ºF)

PWSm = Mass in grams of the paraffin coated specimen in air at 25.0 ºC (77ºF)

(PWSm + WWa) = Mass in grams of the paraffin coated specimen and
water in the volumeter at 25.0ºC (77ºF)

GP = Specific gravity of the paraffin at 25.0ºC (77ºF)

5.2 Report the bulk specific gravity value to three decimal places.

NOTE 3- The mass of the specimen and water in the above formula does not include the
mass of the volumeter. The use of a tare weight for the volumeter is recommended.

NOTE 4- If the bulk specific gravity value of the sample is to be converted to kg/m^3
(pounds per cubic foot), it shall be multiplied by 1000 (62.4) and the value rounded to the
nearest tenth.

METHOD B (SUSPENSION IN WATER)

6.   APPARATUS

6.1   Balance-Conforming to the requirements of AASHTO M- 231, Class G2. The balance shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan of the balance (NOTE 5).

NOTE 5- The holder should be immersed to a depth sufficient to cover it and the sample during weighing. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

6.2   Water Bath- For immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level. The water bath temperature shall be maintained at 25 ± 1ºC (77 ± 2ºF).

7.   PROCEDURE

7.1   Weigh the uncoated specimen after it has been dried to constant mass (NOTE 1). Designate this as mass A.

7.2   Coat the test specimen on all surfaces with melted paraffin sufficiently thick to seal all voids. Allow the specimen to cool in air at room temperature for 30 minutes, then weigh the specimen. Designate this as mass D (NOTE 2).

7.3   Weigh the coated specimen in the water bath at 25 ± 1ºC (77 ± 2ºF). Designate this as mass E.

7.4   Determine the specific gravity of the paraffin at 25ºC (77ºF), if unknown, and designate this as mass F.

8.   CALCULATION

   8.1   Calculate the bulk specific gravity of the specimen as follows (report to three
            decimal places):

$$\text{Bulk Specific Gravity} = \frac{A}{D - E - \dfrac{(D - A)}{F}}$$

Where:

A = mass of the dry specimen in air

D = mass of the dry specimen plus paraffin in air

E = mass of the coated specimen in water

F = specific gravity of the paraffin at 25ºC (77ºF)

9.   REFEREE METHOD

   9.1   In case of discrepancies between the test results obtained by Methods A and B.
The referee test shall be Method A.

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LABORATORY TESTING SECTION

Method of Test for

OPERATION OF AN AUTOMATIC MECHANICAL RECORDING TESTER (TYPE 1)
FOR USE IN THE PENNDOT DESIGN AND CONTROL METHODS

1.   SCOPE

1.1   This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on a lateral surface by means of the SATEC Automatic Bituminous Recording Tester.

2.   APPARATUS

2.1   Bituminous Tester- The bituminous tester shall be an Automatic Mechanical Recording Tester. The tester shall provide a uniform upward movement at a rate of 50.8 mm (2 in.) per minute and shall be capable of loading the specimen over the ranges of 0 to 11.12 kN (2500 pounds) and 0 to 22.24 kN (5000 pounds). (Later models are capable of 44.48 kN (10,000 pounds)).

2.2   Breaking Head- The breaking head shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm or 76.2 mm (2 or 3 in.) accurately machined, and conforming to the dimensions of Figures 3 and 6, respectively, of PTM 705. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves for the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.

2.3   Water Bath- The water bath shall be at least 150 mm (6 in.) deep and shall be thermostatically controlled so as to maintain the bath temperature at 60 ± 1.0ºC (140 ± 1.8º F). A motor driven propeller type agitator shall be provided to insure adequate mixing and circulation of the water. The tank shall have a perforated bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 in.) above the bottom of the bath.

2.4   Recorder Charts- Recorder charts having an ordinate scale of 0 to 11.12 kN (0 to 2500 pounds) and 0 to 22.24 kN (0 to 5000 pounds), and an abscissa scale for both charts of 0 to 35 flow units. These charts shall be provided for recording the stability and flow characteristics of the specimens.

2.5   Gloves- Long rubber gloves are required to protect the operator when inserting or removing specimens from the water bath.

3.   PROCEDURE

3.1   Heating of Specimens-The bituminous paving material specimens are prepared according to the PENNDOT Design and Control Methods. The specimens shall be placed in the water bath in such a position that they are submerged completely and that the specimens do not touch each other. The specimens shall be heated for not less than 45 or more than 60 minutes.

3.2   Recorder Chart- A recorder chart having an ordinate scale corresponding to the maximum load setting of the machine. This chart shall be placed on the platen so that the ordinate scale is horizontal and the point of the recorder pen is touching the corner of the chart at zero load and zero flow.

3.3   Load Setting- The load range of the machine is set by the position of a weight on a pendulum arm. This weight is accessible through a small door at the right rear of the unit. A large knurled hand screw locks the weight to the pendulum. Loosen the screw and raise the weight to the extreme upper position on the pendulum to set the load range for a maximum of 11.12 kN (2500 pounds). Secure the weight in this position by tightening the hand screw. Loosen the weight and carefully move it to the extreme lower position on the pendulum to set the load range for a maximum of 22.24 kN (5000 pounds). For 44.48 kN (10,000 pounds), remove the weight from the pendulum and replace with the required weight in the lower position. Tighten the hand screw when the weight is in position.

3.4   Testing- Check the spirit level on the machine and adjust the screw legs if the machine is not level. It is essential that the machine is level. Heat the testing head to 37.8 to 43.3ºC (100 to 110º F) prior to making the first test. Remove the heated breaking head from the water bath and place it in front of the machine. Separate the two portions of the head. Remove a specimen from the water bath and place it centrally on the lower segment. Place the upper segment in position over the guide rods and the specimen. Place the assembly on the lower platen of the machine against the location pins so that the breaking head is centered under the pressure sensor in the upper part of the machine. The testing machine may be operated under either automatic or manual control. To operate the testing machine automatically, set the master switch in the "AUTO" position and the "UP" button is pressed to start the machine. The test will continue until the platform has reached the uppermost position. When the tester has stopped, press the "DOWN" button. The platform will continue down until the normal position is reached. To reverse the direction of platform travel, press the red "STOP" button, wait until the motor has stopped, and then press the button for the desired direction. To operate the tester manually, set the master switch on "MANUAL". With the specimen in position and when the test is ready to

start, press the "UP" button and hold the button until the test is completed or until the upper limit switch stops the travel of the machine. To return the platform to the normal position, press the "DOWN" button and hold the button until the platform has completed its downward travel. In the manual position, the tester will operate only as long as the "UP" or "DOWN" buttons are held. Upon completion of the test, remove the breaking head from the tester and remove the tested specimen from the breaking head. Place the master switch in the "OFF" position upon completion of all tests.

4.   MAINTENANCE

4.1   Breaking Head- The inside surfaces of the breaking head must be kept clean by wiping with a rag containing a suitable solvent. The guide rods and bushings must be kept clean and shall be lubricated by wiping with an oiled rag.

4.2   Testing Machine- The cams, pivots, and rollers of the tester shall be lightly oiled approximately every three months. These areas can be reached by removing the covers and the chart platen from the tester. The drive chain is accessible when the front control panel is removed from the tester. This chain shall be lubricated every six months with a light machine oil. In order to oil the entire chain, it is necessary to operate the tester manually to move the chain through short distances.

WARNING- Since the front control panel must be removed to reach the drive chain, the contacts at the rear of this panel are exposed to the operator. These contacts are energized when the power plug is connected to the source of electricity. To avoid an electrical shock, it is essential that the power plug be disconnected immediately after advancing the chain and before attempting to oil the chain.

The weighted pendulum must be firmly secured before the machine is moved. If the pendulum is not secured, the tester can be damaged. Unlock the pendulum before making any tests.

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LABORATORY TESTING SECTION

Method of Test for

OPERATION OF AN AUTOMATIC MECHANICAL RECORDING TESTER (TYPE 2)
FOR USE IN THE PENNDOT DESIGN AND CONTROL METHODS

1.   SCOPE

        1.1   This method covers the measurement of resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on a lateral surface by means of the Pine Instrument Automatic Recording Tester.

2.   APPARATUS

        2.1   Bituminous Tester- The bituminous tester shall be an Electric Automatic Recording Test Apparatus. The tester shall provide a uniform upward movement at the rate of 50.8 mm (2 in.) per minute and shall be capable of loading the specimen over three ranges. 0 to 11.12 kN, 22.24 kN, and 44.48 kN (0 to 2500, 5000 and 10,000 Pounds).

        2.2   Breaking Head- The breaking head shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 or 76.2 mm (2 or 3 in.) accurately machined and conforming to the dimensions of Figures 3 and 6, respectively, of PTM 705. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves for the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.

         2.3   Water Bath- The water bath shall be at least 150 mm (6") deep and shall be thermostatically controlled to maintain the bath temperature at 60 ± 10 ℃ (140 F ± 18ºF). A motor driven propeller type agitator shall be provided to insure adequate mixing and circulation of the water. The tank shall have a perforated bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 inches) above the bottom of the bath.

        2.4   Recorder Charts- Recorder charts having an ordinate scale of 0 to 11.12 kN, 0 to 22.24 kN, and 0 to 44.48 kN (0 to 2500 pounds, 0 to 5000 pounds, and 0 to 10,000 pounds) and an abscissa scale of 0 to 35 flow units for each of the three charts. These charts shall be provided for recording the stability and flow characteristics of the specimens.

        2.5   Gloves- Long rubber gloves shall be provided to protect the operator when inserting or removing specimens from the water bath.

3.   PROCEDURE

  3.1 Heating of Specimens- The bituminous paving material specimens are prepared according to the PENNDOT Design and Control Methods. The specimens shall be placed in the water bath in such a position that they are completely submerged and that the specimens do not touch each other. The specimens shall be heated for not less than 45 or more than 60 minutes.

  3.2 Recorder Chart- The recorder chart is installed by laying a sheet of paper on the recording writing surface and sliding it under the two holding clips. The paper must be tight against the side and the bottom bars of the recorder writing surface.

  3.3 Recorder Pen- The recorder pen is a Paper Mate Piggy-Back refill, although other types of ball-point pen refills may be used. The pen is inserted into the holder as follows:

    3.3.1 Turn the instrument off.

    3.3.2 Move the pen carriage by hand to a convenient location.

    3.3.3 Move the pen raising lever all the way towards the back of the instrument. The pen raising lever is 1.6 mm (1/16 in.) in diameter and is located on the right side of the pen holder.

    3.3.4 Insert the pen into the holder so that it touches the chart paper and secure the pen by making the screw in the front of the pen holder finger tight.

  3.4 Load Range- The No. 750 Test Press has three ranges: 0 to 11.12 kN, 0 to 22.24 kN, and 0 to 44.48 kN (0 to 2500 pounds, 0 to 5000 pounds, and 0 to 10,000 pounds). The desired range is selected by using the RANGE knob on the front of the recorder.

  3.5 Zero Adjustment- Turn the tester on, select the desired range, and place the pen and recorder chart in the correct place. Adjust the recorder to read zero newtons (pounds) by turning the zero knob until the pen indicates zero newtons (pounds) on the paper. If the pen does not indicate zero flow units on the recorder chart, it will be necessary to relocate the chart paper to obtain this adjustment.

  3.6 Pen Check- To see if the ball point pen is working properly, gently move the pen carriage by hand across the bottom of the paper and back to zero again.

  3.7 Limit Switches- The platen of the test press is limited to about 9.5 mm (3/8 in.) of travel by limit switches. These limit switches are located below the right-hand end of the platen

and are actuated by the LIMIT SWITCH ROD on the end of the platen. The limit switch rod is factory set to make the tester work properly. If it is necessary to change the travel of the platen, loosen the set screws on the right-hand end of the platen, adjust the limit switch rod, and tighten the set screws.

3.8   Motor Control Relays- The press drive motor is controlled by a motor reversing relay. The relay, in turn, is controlled by the UP, DOWN, and STOP buttons. An overload limit switch in the recorder controls the platen travel.

NOTE 1- CAUTION. If the STOP and DOWN buttons are pushed in rapid succession when the platen is traveling up, or if the STOP and UP buttons are pushed in rapid succession when the platen is traveling down, this will cause the relay to reverse without the motor changing direction. In such a case the limit switches controlling the platen will not work as desired. Instead, the limit switches will deactivate both the UP and DOWN buttons and the tester will not operate.

To get the tester back in operation:

3.8.1   Lift the limit switch rod clear of the limit switches.

3.8.2   Press the UP or DOWN button to bring the platen into the proper position, 177.8 mm (7 in.) from the platen to load cell, and stop it there.

3.8.3   Replace the limit switch rod to its former position and tighten the set screws on the rod.

3.9   Overload Limit Switch- This switch is located on the recorder and is actuated when the pen carriage travels to the top of the chart paper. When the overload limit switch is operated, it turns off the pilot light on the recorder and shuts off the motor reversing relay. If the overload limit switch shuts off the tester, the pen carriage must be moved down by hand until the pilot light comes on. The DOWN button will then work to remove the overload from the load cell.

3.10   Testing- Heat the testing head to 37.8 to 43.3ºC (100 to 110 ºF) prior to making the first test. Remove the heated breaking head from the water bath and place it in front of the tester after separating the two portions of the head. Remove a specimen from the water bath and place it centrally on the lower segment. Place the upper segment in position over the guide rods and the specimen. Place the assembly on the lower platen of the tester and against the location pins so that the breaking head is centered under the load cell. Press the UP button to initiate the test. The limit switch will stop upward travel of the platen after 35 units of flow. When the motor has stopped, press the DOWN button to return the platen to its initial position. Upon completion of the test, remove the breaking head from the tester and remove the tested specimen from the breaking head. Place the master switch in the OFF position upon completion of all tests.

4.   MAINTENANCE

4.1   Breaking Head- The inside surfaces of the breaking head must be kept clean by wiping with a rag containing a suitable solvent. The guide rods and bushings must be kept clean and shall be lubricated by wiping with an oiled rag.

4.2   Testing Machine- The platen guide rods must be kept clean and shall be lightly lubricated by wiping with an oily rag.

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LABORATORY TESTING SECTION

Method of Test for

OPERATION OF AN AUTOMATIC MECHANICAL RECORDING TESTER (TYPE 3)
FOR USE IN THE PENNDOT DESIGN AND CONTROL METHODS

1.   SCOPE

        1.1   This method covers the measurement of the resistance to plastic flow of
cylindrical specimens of bituminous paving mixtures loaded on a lateral surface by means of the
Rainhart Series 760 Automatic Tester and Recorder.

2.   APPARATUS

        2.1   Bituminous Tester- The bituminous tester shall be an automatic mechanical tester
providing a uniform downward movement at the rate of 50.8 mm (2 in.) per minute and shall be
capable of loading the specimen over the following ranges: 0 to 11.12 kN (0 to 2500 pounds), 0
to 22.24 kN (0 to 5000 pounds), and 0 to 44.48 kN (0 to 10,000 pounds).

        2.2   Recorder- The recorder shall be an electronic strip chart servo-recorder type. The
width of the strip chart shall be graduated in 100 uniform divisions and will be printed with three
load scales corresponding to the range of the automatic tester. The length of the chart shall be
divided into uniform divisions that represent 0.25 mm (0.01 in.) of breaking head travel. The
chart speed shall be 1016 mm (40 in.) per minute to correspond to the closing speed of the
automatic tester.

        2.3   Water Bath- The water bath shall be at least 150 mm (6 in.) deep and shall be
thermostatically controlled so as to maintain the bath temperature at 60 ± 10 ºC (140 ± 18ºF). A
motor driven propeller type agitator shall be provided to insure adequate mixing and circulation
of the water. The tank shall have a perforated bottom or be equipped with a shelf for supporting
specimens 50.8 mm (2 in.) above the bottom of the bath.

        2.4   Gloves- Long rubber gloves are required to protect the operator when inserting or
removing specimens from the water bath.

        2.5   Breaking Head- The breaking head shall consist of upper and lower cylindrical
segments or test heads having an inside radius of curvature of 50.8 mm or 76.2 mm (2 or 3 in.),
accurately machined and conforming to the dimensions of Figures 3 and 6, respectively, of

PTM 705. The lower segment shall be mounted on a base having two perpendicular rods or posts extending upwards. Guide sleeves for the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.

3.   PROCEDURE

3.1   Heating of Specimens- The bituminous paving material specimens are prepared according to PENNDOT Design and Control Methods. The specimens shall be placed in the water bath in such a position that they are completely submerged and that the specimens do not touch each other. The specimens shall be heated for not less than 45 or more than 60 minutes.

3.2   Recorder Chart- Remove the cover plate on the recorder. Remove the chart spindle and place it through the core of the recorder chart roll. Place the roll and spindle in the recorder so that the chart feeds from the bottom of the roll. Pull the end of the chart forward and insert it under the guide plate so that the perforations engage the drive sprockets.

3.3   Recorder- Insert the five-pronged connector, which is attached to the recorder, into the receptacle on top of the switch box at the front of the tester. Insert the color-coded plugs that lead from the load cell into the same colored connectors on the top of the recorder. Turn the main switch ON and turn the Chart Drive switch on the recorder to STANDBY. Allow the recorder to warm up for 30 minutes. Insert the fountain pen or felt tip pen into the spring holder at the front of the recorder in such a position that the post just touches the paper. The pen may be raised from contact with the chart be means of the Pen Lift Knob on the left side of the recorder. Advance the chart manually with the knob on the left side of the recorder until the pen is zeroed at the start of the chart. After the unit has warmed up, the pen may be set to zero by turning the Chart Drive knob to SERVO and then turning the Zero knob to obtain the adjustment. If chatter or fluctuations appear in the pen, eliminate the chatter by adjustment of the damping control. The chart drive position of the controls is used only for rapid advancement of the chart. The wiring of the recorder has been changed so that the chart will be advanced automatically when the tester is started and the Chart Drive control is in the SERVO position. Return the control to STANDBY when the tester is not being used. The recorder can be set for maximum ranges of 11.12 kN (2500 pounds), 22.24 kN (5000 pounds), and 44.48 kN (10,000 pounds) by operation of the Range Control.

3.4   Automatic Tester- Heat the breaking head assembly to 37.8 to 43.3ºC (100 to 110 ºF) prior to making the first test. Remove the heated breaking head from the water bath and place it in front of the tester. Separate the heads. Remove a specimen from the water bath and place it centrally on the lower segment. Place the upper segment in position over the guide rods and the specimen. Place the assembly on the lower platen of the tester against the location pins so that the breaking head is centered under the load cell in the upper part of the tester. Move the motor

control lever downward until the handle is held by the decent. Release pressure on the handle. The tester will apply pressure to the specimen until the maximum amount of movement has been obtained and at this point the limit switch will stop the motor. When the motor has stopped, raise the motor control lever to the upper position until it has been held by the ascent. Release pressure on the handle. The tester will stop automatically when in the fully opened position. Remove the breaking head from the tester and remove the tested specimen from the breaking head. Advance of the chart paper will be stopped as soon as the tester completes the closing operation. The chart paper will not advance during the tester opening operation. Advance the chart manually to the TEAR position and remove the chart from the recorder.

NOTE l- The tester will not operate unless the 5-prong plug from the recorder is plugged into the main switch box and the plugs from the load cell are connected to the recorder.

NOTE 2- The travel of the loading head of the tester is controlled by the small collars positioned on the limit switch rod. These collars will have to be positioned by trial and error.

NOTE 3- The ring dynamometer furnished with the tester is used to check the calibration of the tester. When the dynamometer is positioned in the tester, various loads can be applied to the load cell by manually turning the drive pulley counter clockwise. The drive belt can be removed from the motor pulley as a safety measure.

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING ROADWAY BITUMINOUS CONCRETE

1.   SCOPE

1.1   This method covers the procedure for sampling of bituminous paving mixtures taken from the finished pavement for determination of the characteristics of the compacted mixture. Alternative methods of sampling may be found in AASHTO T- 230.

CORING OF BITUMINOUS CONCRETE

2.   EQUIPMENT

2.1   Powered core drill, water cooled, equipped to core cylindrical samples.

2.2   Diamond drill bit of six (6) inch size.

2.3   Incidental materials and equipment.

2.4   Hand-held core sample extraction tool capable of grasping and removing a drilled cylindrical pavement core sample from the pavement without damage to the core sample.

2.5   A rigid plate or a suitable container large enough to hold the sample without distortion after it is removed from the pavement.

2.6   Masking tape

2.7   A marking pencil or lumber crayon.

3.   SELECTION OF ACCEPTANCE SAMPLES

3.1   Density acceptance of the bituminous mixture from the roadway shall be on the basis of test results from consecutive probability samples for each Lot. One probability sample shall be taken from each Sublot. Samples are to be selected by means of a stratified random sampling plan. Refer to Illustrative Examples No. 1 & No. 2 in the Appendix of PTM No. 746 for examples of how to select samples using a stratified random sampling plan for pavement courses. Density acceptance samples must be cross referenced to a corresponding mixture acceptance sample on Form TR-447.

3.2 The testable sampling width is determined by taking the nominal paving width and subtracting one (1) foot from each edge (supported and/or unsupported edges). Refer to Illustrative Example No. 1 in the Appendix of this PTM.

3.3 Areas within one (1) foot from the edge of obstructions to normal paving such as manhole covers, inlets, and utility valve covers are considered non-testable areas for core sampling. When a sample location falls within a non-testable area, adjust the location of the core sample longitudinally in the direction of paving to a location at the edge of the non-testable area. Refer to Illustrative Example No. 2 in the Appendix of this PTM.

4. SELECTION OF LONGITUDINAL JOINT INCENTIVE/DISINCENTIVE SAMPLES

4.1 Incentive/Disincentive samples shall be taken on the basis of consecutive probability samples for each Lot. Lots shall be established as specified in Pub. 408, Section 405. One probability sample shall be taken from each Sublot. Samples are to be selected by means of a stratified random sampling plan. Refer to Illustrative Example No. 3 in the Appendix of this PTM for an example of how to select samples using a stratified random sampling plan. Each joint core will be comprised of portions of two lanes, with the potential for two different JMFs within each core. All cores within a lot having the same JMF combination shall be included on one TR-447 (except work stoppages of greater than five (5) days which will require the first portion of the lot to be included on one TR-447 with the remaining portion of the lot to be included on a second form when work continues). The theoretical maximum specific gravity value to place on Form TR-447 will be the overall average of each core's average value. Sublots with different JMF combinations or work stoppages of more than five (5) days will require a separate Form TR-447. Refer to Illustrative Example No. 4 in the Appendix of this PTM for an example of how to evaluate JMF combinations and arrive at the proper theoretical maximum specific gravity.

4.2 A core sample taken from a longitudinal vertical joint shall be centered on the line where the joint between the two adjacent lifts abut at the surface as illustrated on the next page. The center of all vertical joint cores shall be within one (1) inch of this joint line. A core sample taken from a longitudinal notched wedge joint shall be centered six (6) inches or one-half the width of the joint taper away from the joint line in the direction of the wedge as illustrated on the next page. When the two lanes forming the longitudinal joint have daily theoretical maximum specific gravity values differing by more than 0.050, examine each longitudinal joint core sample to ensure that approximately one-half of the longitudinal joint core sample is from each lane. If the materials in the longitudinal joint core are unbalanced, adjust the location of the core drill relative to the joint line to ensure approximately equal material. Take a replacement sample at a location within twelve (12) inches longitudinally of the original sample location.

Vertical Joint

Figure not to scale

Notched Wedge Joint

Figure not to scale
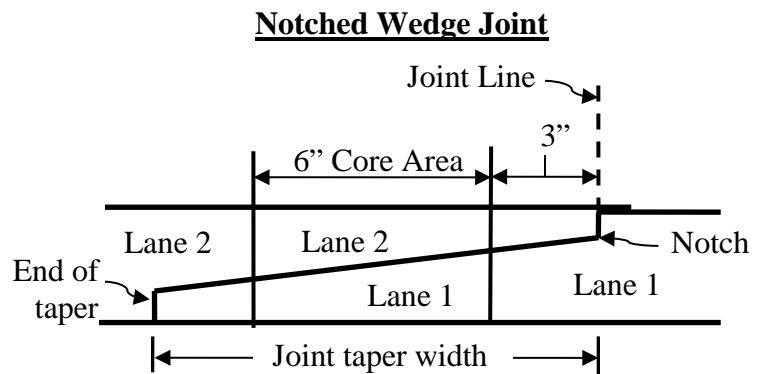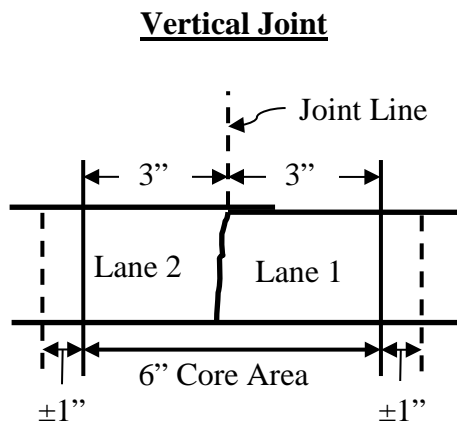
5.   PROCEDURE

        5.1   In the presence of the Department Representative, core and identify the density acceptance samples as specified in Pub. 408, Section 409.

                5.1.1   With the powered core drill, drill core samples to the specified diameter and to a depth sufficiently below the depth of the pavement course to be sampled. Ensure sufficient water is dispersed through the core drill during drilling to keep the drill bit and core sample cool enough to prevent damage to the bit and sample. Carefully and slowly lower the drill bit to the surface of the pavement course at the start of drilling to prevent the drill bit from moving and to obtain a smooth clean initial drill cut at the surface of the core sample. After drilling to a sufficient depth, carefully raise the core drill bit to prevent any damage to the core sample.

                5.1.2   Carefully dislodge or break the core sample away from the underlying pavement layer. Do not distort, bend, crack, damage or physically change the physical condition of the core sample during this operation.

                5.1.3   Using a hand-held core sample extraction tool, carefully grasp and remove the core sample from the pavement. Do not distort, bend, crack, damage or physically change the physical condition of the core sample during removal from the pavement.

                5.1.4   Immediately after removing the core sample from the pavement, wash off the core sample with water to remove the fine material generated from the drilling operation. Air dry or towel dry the core sample sufficiently to allow identification of the Lot and Sublot number on each core sample by using a marking pencil or lumber crayon.

5.1.5   If a core sample includes materials other than the material or pavement course to be tested, clearly show and mark with a marking pencil or lumber crayon the section(s) of each core sample to be discarded. Core samples suspected of including more than one material and not clearly showing the section to test, and the section(s) to discard, will be considered non-conforming samples and will not be tested by the Laboratory Testing Section (LTS) until the section to test is identified.

5.2   Once the core sample has been obtained and identified as outlined in Section 5.1, the Department Representative will take immediate possession of the core sample and store it in a proper environment while awaiting packaging and delivery. Overheating or impact can damage core samples and prevent accurate test results.

5.3   After the Lot is completed or has been terminated, the Department Representative will perform the following:

5.3.1   Complete a Form TR-447 for proper Lot identification. In the event that both 9.5 mm and 12.5 mm materials are incorporated in the same joint cores, use the 12.5mm mix to identify the material class.

5.3.2   Place the appropriate Bar Code Sticker from Form TR-447 on each core sample (Bar Code Sticker Axxxxxx-1 on the core sample for Sublot 1, etc.). For core samples identifying materials other than the material or pavement course to be tested as outlined in Section 5.1.5, place the appropriate Bar Code Sticker from Form TR-447 on the section of each core sample to be tested.

5.3.3   Package the pavement cores in a suitable container.

5.3.3.1 Plastic concrete cylinder molds have proven to be satisfactory and convenient containers for shipping core samples. Core samples placed in plastic concrete cylinder molds shall be cushioned /separated with crumpled newspaper. If other containers are used, such as, 6-inch diameter PVC plastic pipes, they shall not exceed 24 inches in length and shall not weigh more than 50 lbs. when packaged with core samples. Place an unused bar code sticker from Form TR-447 on the outside of all containers.

5.3.3.2 Secure the ends of the core sample containers with masking tape.

5.3.4   Deliver the core samples to a Department pick-up point within three (3) days for shipment to the LTS.

APPENDIX

Illustrative Example No. 1 – Adjustment for Edges

Using the parameters of Illustrative Example No. 2 in the Appendix of PTM No. 746, for a normal Lot of 2,500 tons with five (5) Sublots of 500 tons each, the following sampling plan was developed for density core samples. The Lot length is 22,727 ft. and the Sublot length is 4,545.4 ft. This example is for a 12 ft. lane width placed next to a previously placed lane. Therefore, there is one supported edge at the centerline longitudinal joint and one unsupported edge longitudinally at the shoulder joint.

A typical random plan would be similar to the following:

The testable sampling width would be:
    12 ft. - 1 ft. (supported Left edge) - 1 ft. (unsupported Right edge) = 10 ft.

RANDOM NUMBER			LENGTH	WIDTH OF PAVEMENT
	X	Y	X	Y
#17	.08	.70L	.08 x 4545.4 ft. = 364 ft.	.70 (10 ft.) = 7.00 ft. L
#18	.67	.68L	.67 x 4545.4 ft. = 3045 ft.	.68 (10 ft.) = 6.80 ft. L
#19	.83	.97R	.83 x 4545.4 ft. = 3773 ft.	.97 (10 ft.) = 9.70 ft. R
#20	.54	.58R	.54 x 4545.4 ft. = 2455 ft.	.58 (10 ft.) = 5.80 ft. R
#21	.82	.50R	.82 x 4545.4 ft. = 3727 ft.	.50 (10 ft.) = 5.00 ft. R

Note: The "X" value equals the station
         The "Y" value has been corrected for the non-testable edge conditions

The sampling for the Lot (22,727 ft. in length) would be:

Sta.   3+64   7.00 ft. from lt. edge + 1 ft. for supported edge = 8.00 ft. from lt. edge of lane
Sta. 75+90   6.80 ft. from lt. edge + 1 ft. for supported edge = 7.80 ft. from lt. edge of lane
Sta. 128+63   9.70 ft. from rt. edge + 1 ft. for unsupported edge = 10.70 ft. from rt. edge of lane
Sta. 160+90   5.80 ft. from rt. edge + 1 ft. for unsupported edge = 6.80 ft. from the rt. edge of lane
Sta. 219+07   5.00 ft. from rt. edge + 1 ft. for unsupported edge = 6.00 ft. from the rt. edge of lane

*Note: Refer to Illustrative Example No. 2 in the Appendix of PTM No. 746 for the beginning and ending stations of the Lot and each Sublot. Each density acceptance sample must have a corresponding mixture acceptance sample.

Illustrative Example No. 1: Adjustment for Edges (continued)

Centerline Longitudinal Joint (supported edge)

*Sta. 3+64	*Sta. 75+90	*Sta.128+63	*Sta.160+90	*Sta.219+07

1ft.

		3773 ft.		
8.0 ft.	7.80 ft.	O	2455 ft.	
10 ft. (width)			O	3727 ft.
O	O	10.70ft.	6.80ft.	O
364 ft.	3045 ft.			6.00 ft.
Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5

1ft.

Sta. 0+00	Sta. 45+45	Sta. 90+90	Sta. 136+35	Sta. 181+80
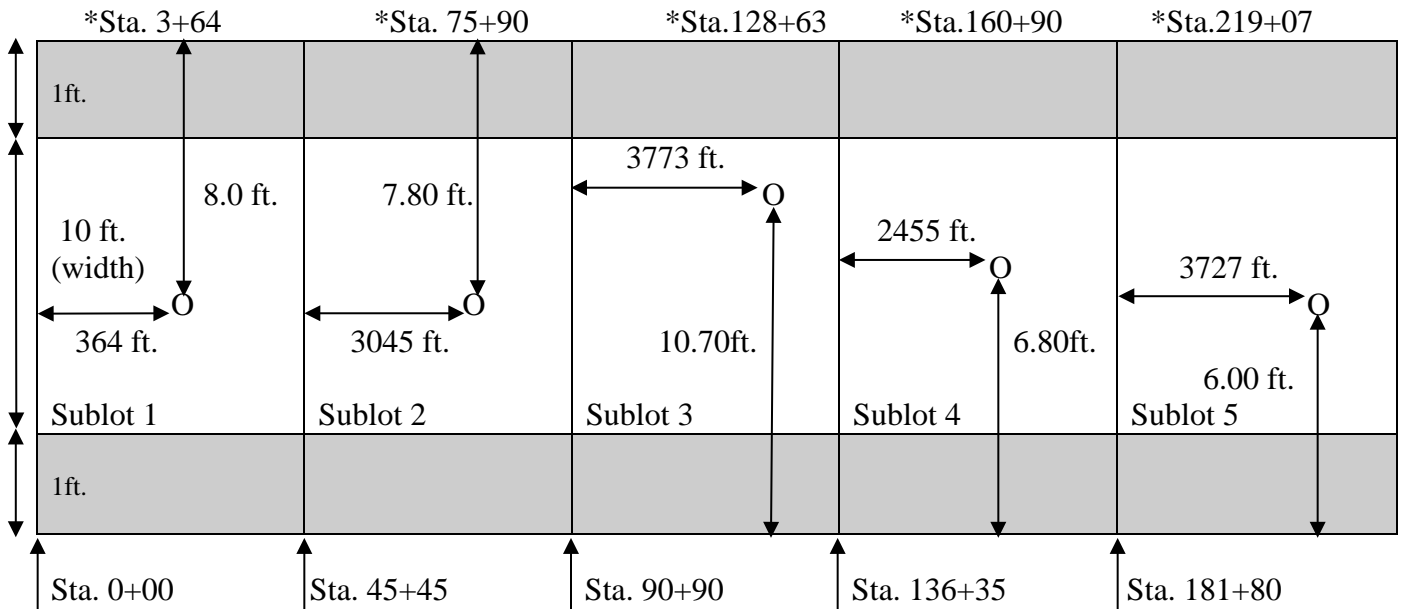
Shoulder Joint (unsupported edge)

DIRECTION OF PAVING $\longrightarrow$

Note: Drawing not to scale

Illustrative Example No. 2: Adjustments for Obstructions

Sublot 1

8.0 ft. from left edge

364 ft.

Sample location in a non-testable area
3 ft. diameter manhole cover

DIRECTION OF PAVING
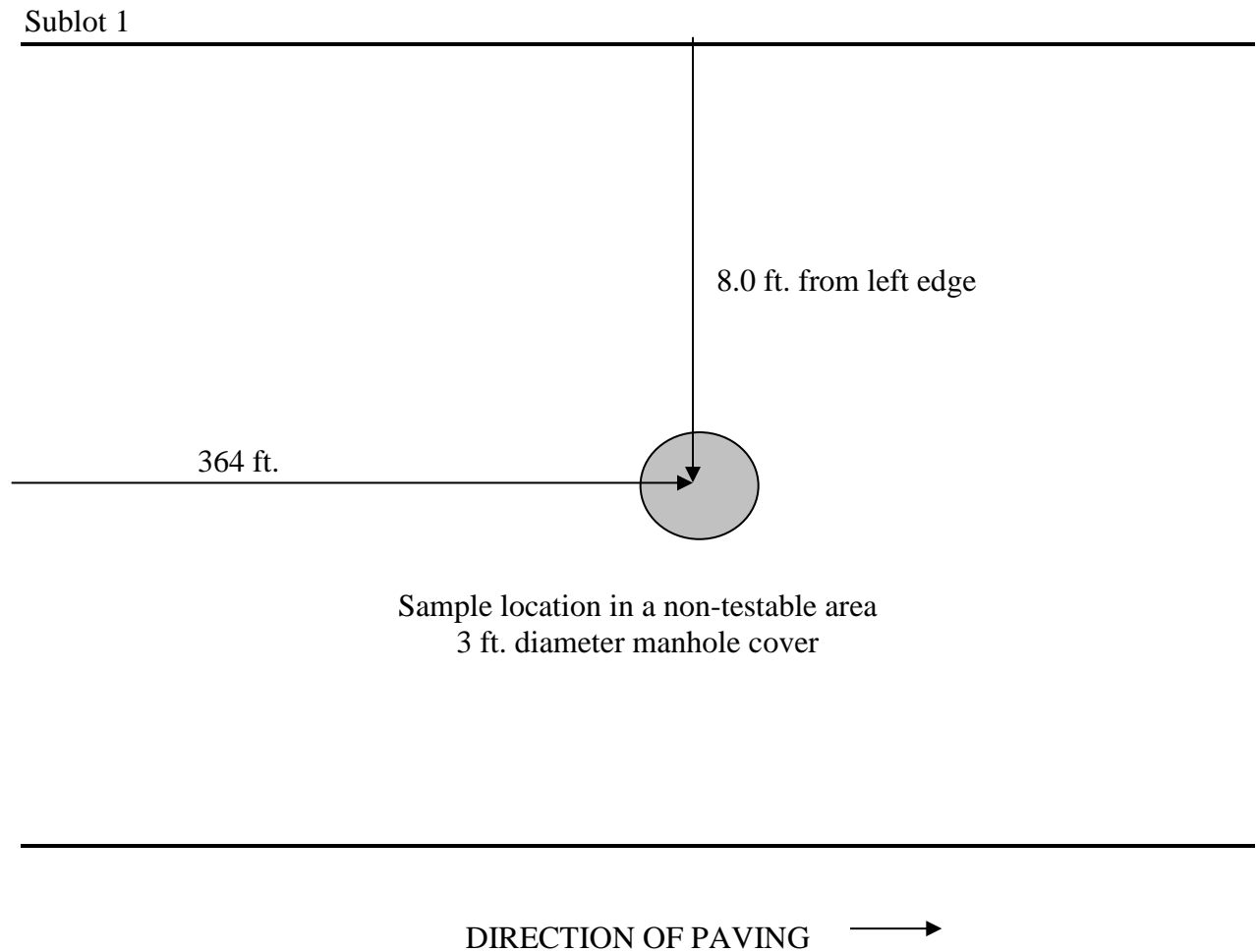
Illustrative Example No. 2: Adjustments for Obstructions (continued)

Sublot 1

Maintain the original sample offset
of 8.0 ft. from the Left edge

8.0 ft.

364 ft.

Sample location in a non-testable area
3 ft. diameter manhole cover
+ 1 ft. from the edge of obstruction

DIRECTION OF PAVING ⟶
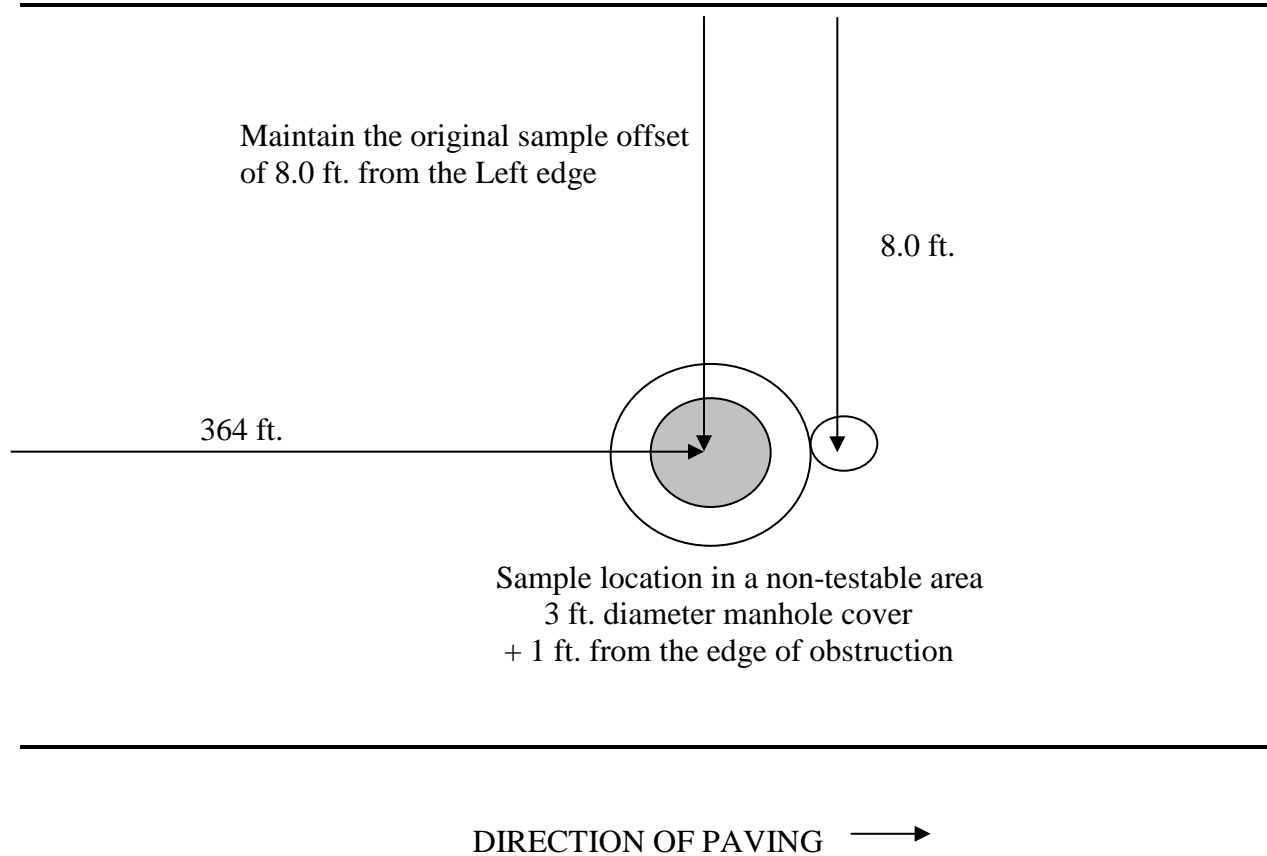
Note: Maintain the original transverse co-ordinate of the sample. In this illustration the transverse co-ordinate of 8.0 ft. from the Left edge is maintained. The longitudinal co-ordinate is adjusted in the direction of paving to a location just outside the non-testable area (refer to Section 3.3 for the definition of non-testable areas). If the adjusted location also falls into another non-testable area or outside the sublot, move the core back longitudinally to the other side of the obstruction.

Illustrative Example No. 3: Longitudinal Joint Samples

A paving project 21,000 feet in length for a two lane roadway consists of four paving lanes on the surface course (left and right shoulders, left and right travel lanes). The density for all four paving mats is being accepted via pavement cores. This results in three eligible longitudinal joints for joint pavement cores.

Example Pavement Project Information

Length of Project Paving	21,000	linear feet
Number of Eligible Joints	3	(2 shoulder joints, 1 centerline joint)
No. of Lots at 12,500 linear feet	5	(21,000 ft. x 3 joints /12,500 ft. per lot)
No. of Sublots in each Lot	5	(potentially 6 for the final lot)
Length of each Sublot	2,500	linear ft. (last sublot varies in length)

Lot and Sublot Determination

Lots are determined as paving progresses. Select at random a series of five (5) consecutive numbers from PTM No. 1, Table 1 for the first Lot. Multiply the length of each Sublot by the two place decimal value "X" to obtain the sample location within that Sublot.

RANDOM NUMBER			LINEAR FEET BY SUBLOT
	X	Y	
#47	.93	N/A	.93(2,500 ft.) = 2,325 ft.
#48	.43	N/A	.43(2,500 ft.) = 1,075 ft.
#49	.99	N/A	.99(2,500 ft.) = 2,475 ft.
#50	.61	N/A	.61(2,500 ft.) = 1,525 ft.
#51	.87	N/A	.87(2,500 ft.) = 2,175 ft.

The sampling sequence for the Lot (12,500 linear feet) shall be:

Sublot 1	2,325 = Sta.	23+25
Sublot 2	2,500 + 1,075 = Sta.	35+75
Sublot 3	5,000 + 2,475 = Sta.	74+75
Sublot 4	7,500 + 1,525 = Sta.	90+25
Sublot 5	10,000 + 2,175 = Sta.	121+75

1. Core samples shall be cut at the above stations to obtain the five (5) Sublot samples for calculating the incentive/disincentive value for Lot 1.

2. Repeat the same operation for Lots 2 through 5 using other randomly selected starting points for numbers under Column X.

Illustrative Example No. 3: Longitudinal Joint Samples (continued)

3. Calculate the sample for the final anticipated Sublot, use a length of 2,500 linear feet and multiply by the random number. If the resulting sample location falls beyond the actual length of joint, then the Sublot will not be counted and no sample will be taken. If the sample location falls within the actual length of joint, then the sample will be taken and the Sublot will be added to the final Lot.

Based on the sketch on the next page, since the centerline joint was the first joint paved, Lot 1 will come from the centerline joint. Each Lot will follow as paving progresses thereafter, consisting of 12,500 feet per Lot.

Final Lot Determinations:

1. The length of the final Lot shall be adjusted to ensure that the final Lot has between three and seven Sublots. In this example the final joint, Lot 5, shall be 13,000 linear feet as shown.

   21,000 LF x 3 joints = 63,000 LF total   63,000 LF – (4 x 12,500 LF) = 13,000 LF

2. Sublots 1 - 5 will be 2,500 LF, leaving 500 LF at the end. 13,000 LF - (5 x 2,500 LF) = 500 LF. Calculate the sample location for the final Sublot based on 2,500 LF.

3. The random number will determine if a sample will be taken in this 500 LF. Two scenarios are shown illustrating the two possibilities.

   3.1 Random No. ("X") = 0.12   2,500 LF x 0.12 = 300 LF, so a sample shall be obtained 300 LF into Sublot 6. The final Lot would have six (6) Sublots.

   3.2 Random No. ("X") = 0.67   2,500 LF x 0.67 = 1,675 LF, so since this is beyond the 500 LF available. No sample shall be obtained and the final Lot would have five (5) Sublots.

Entire Project Lots:

◄─────────────	21,000 ft ───────────────►

Sta. 40+00   **Shoulder 1 (Paved 3rd)**   Sta. 165+00

2nd portion   1st portion   Edge
Joint Lot 2   Joint Lot 3   Joint Lot 4   joint 1
◄─ 4,000 ft ─►◄───────── 12,500 ft ─────────►◄── 4,500 ft ──►

Lane 1 (Paved 1st)
Sta. 125+00

─── CL joint
Joint Lot 1   1st portion Joint Lot 2
◄──────── 12,500 ft ────────►◄──────── 8,500 ft ────────►

Lane 2 (Paved 2nd)

2nd portion   Sta. 80+00   Edge
Joint Lot 4   Joint Lot 5   joint 2
◄──── 8,000 ft ────►◄──────── 13,000 ft ────────►

Shoulder 2 (Paved 4th)
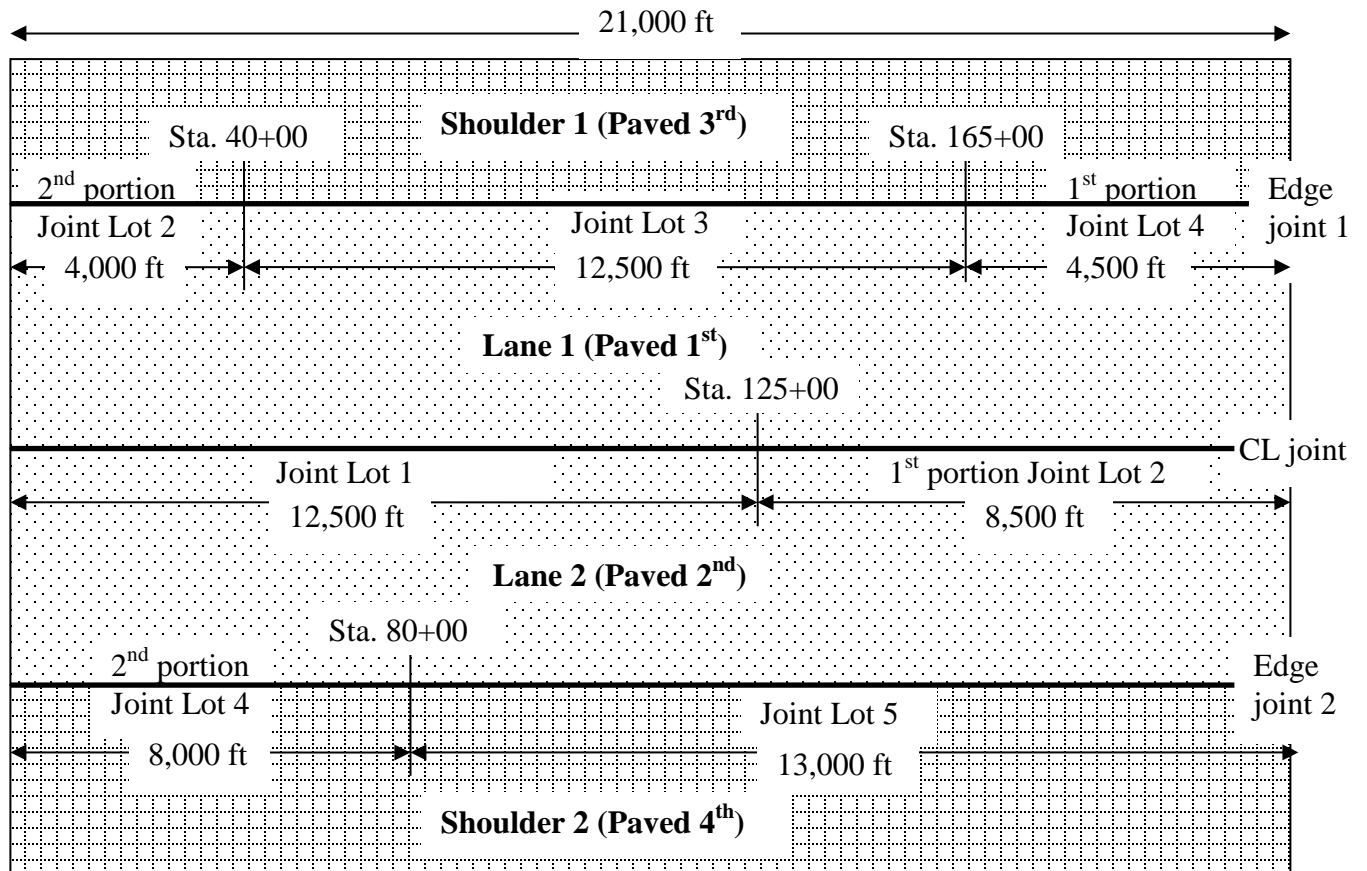
Illustrative Example No. 4: Longitudinal Joint Lot Submittal Calculations for Theoretical Maximum Specific Gravity (Gmm)

Joint Core 1-1 = comprised of JMF#1 (2.451 daily Gmm) and JMF#1 (2.447 daily Gmm), joint paved on day 1

Joint Core 1-2 = comprised of JMF#1 (2.451 daily Gmm) and JMF#1 (2.447 daily Gmm), joint paved on day 1

Joint Core 1-3 = comprised of JMF#1 (2.451 daily Gmm) and JMF#1 (2.447 daily Gmm), joint paved on day 2

Joint Core 1-4 = comprised of JMF#1 (2.447 daily Gmm) and JMF#1 (2.443 daily Gmm), joint paved on day 3

Joint Core 1-5 = comprised of JMF#1 (2.447 daily Gmm) and JMF#2 (2.483 daily Gmm), joint paved on day 5

Step 1 – Verify JMF combinations for each sublot and any time impacts

- No work stoppages exceeded five (5) days, so no required break in TR-447's due to time
- Sublots 1 through 4 are comprised of the same JMF combination (JMF#1 and JMF#1). Include sublots 1 through 4 on one Form TR-447 (in the remarks, list the other TR-447's that will comprise the remainder of the lot)
- Sublot 5 is comprised of a different JMF combination (JMF#1 and JMF#2). Sublot 5 must be placed on a separate Form TR-447 (in the remarks, list the other TR-447's that comprise the remainder of the lot)

Step 2 – Calculate theoretical maximum specific gravity values for each TR-447

- FIRST FORM TR-447
  Joint core 1-1: (2.451 + 2.447) / 2 = 2.449
  Joint core 1-2: (2.451 + 2.447) / 2 = 2.449
  Joint core 1-3: (2.451 + 2.447) / 2 = 2.449
  Joint core 1-4: (2.447 + 2.443) / 2 = 2.445
  Overall average of the 4 cores = (2.449 + 2.449 + 2.449 + 2.445) / 4 = 2.448
  Use 2.448 as the value for AASHTO T-209 on the first TR-447 form and to calculate the density for each sublots 1 through 4 when calculating Percent within Tolerance.

- SECOND FORM TR-447
  Joint core 1-5: (2.447 + 2.483) / 2 = 2.465

Use 2.465 as the value for AASHTO T-209 on the second TR-447 form and to calculate the density for sublot 5 when calculating Percent within Tolerance.

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LABORATORY TESTING SECTION

Method of Test for

MEASURING THE THICKNESS OF BITUMINOUS CONCRETE COURSES

1.   SCOPE

        1.1   This method covers the procedure for determining the thickness of bituminous concrete courses from the cores taken from bituminous concrete roadways.

2.   APPARATUS

        2.1   Ruler - Standard ruler with 1 mm (1/16") graduations

3.   TEST SPECIMENS

        3.1   Cores used as specimens for thickness measurement shall be representative of the pavement from which they are removed. The specimen shall be drilled with the axis normal to the surface of the pavement. The upper and lower surfaces shall be free from all conditions not typical of the surfaces of the pavement. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used.

4.   PROCEDURE

        4.1   Place the core horizontally on a smooth flat surface with the end that represents the upper surface facing left.

        4.2   Four measurements ninety degrees apart shall be made for each course (layer). Measurements shall be made from the top to bottom of each layer and recorded to the nearest 1 mm (1/16 inch) (Note 1).

        NOTE 1-When the bottom of a layer is uneven at least two additional diametrical measurements shall be made.

5.   CALCULATION

        5.1   The thickness of each course shall be determined from the average of all readings.

6.   REPORT

        6.1   The thickness of the desired course shall be reported to the nearest 3 mm (1/8 inch).

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LABORATORY TESTING SECTION

Method of Test for

SIEVE ANALYSIS OF EXTRACTED AGGREGATE

1.   SCOPE

        1.1   This method of test covers a procedure for the determination of the particle size distribution of aggregates extracted from bituminous mixtures using sieves with square openings. This method was developed for use with PTM 702, Method D.

2.   APPARATUS

        2.1   Balance- Conforming to the requirements of AASHTO M-231, Class G2.

        2.2   Sieves- Square openings and conforming to the requirements AASHTO M-92. All sizes shall be available as required by bituminous concrete specification.

        2.3   Timer- An electric timer accurate and variable in one-minute increments with a minimum range of 15 minutes.

        2.4   Mechanical Shaker- Capable of performing the sieving action as specified in Section 4.3.

3.   SAMPLE

        3.1   The sample shall consist of the entire aggregate sample from PTM 702.

        NOTE 1- When the extracted sample is too large in quantity to be sieved over one set of 203.2 mm (8") sieves, the sample may be split and sieved over more than one set of 203.2 mm (8") sieves. The weights on each sieve size are combined for calculation of the final percent passing. For sieves with openings of 4.75 mm (No.4) and larger, the mass retained in grams at the completion of the sieving operation shall not exceed the product of 2,500 x (sieve opening in mm) x (sieving surface area in m^2). For the 2.36 mm (No.8) sieve, the mass retained shall not exceed 9 kg/m^2 (6g/$in.^2$), or 300 g for the usual 8-inch diameter sieve. For sieves with openings smaller than 2.36 mm (No.8), the mass retained shall not exceed 6 kg/m^2 (4g/$in.^2$), or 200 g for the usual 8-inch diameter sieves.

        3.2   If the sample has remained at room temperature for more than one hour it shall be dried to constant mass.

4.   PROCEDURE

4.1   Record the mass of the extracted aggregate from PTM No. 702.

4.2   The sample shall be sieved over sieves of various sizes as required by the bituminous concrete specifications. The mass of material passing each sieve and retained on the next shall be recorded, starting with the pan mass (material passing the 75 μm (No. 200) mesh) and continuing up to and including the maximum sieve size.

4.3   The sieving operation shall be conducted by means of a circular motion of the sieve accompanied by a jarring action to keep the sample moving continuously over the surface of the sieve. In no case shall fragments in the sample be turned or manipulated through the sieve by hand. Mechanical sieving shall be controlled by a timer and shall continue for the pre-determined time. The pre-determined time is established when not more than one percent by mass of the residue passes the sieve during one minute of hand sieving. Hand sieving shall be used to evaluate the thoroughness of mechanical sieving.

> NOTE 2- When mechanical shakers and 8 inch sieves are used, 8 minutes has generally shown to be a suitable shaking time.

4.4   The mass of each size aggregate shall be obtained by weighing the pan material and accumulating the mass of each increasing sieve size (Column A, Table 1). All sieve masses shall be accurate to within 0.1 percent of the total sample mass.

4.5   Add the mass of fine aggregate in the extract liquid (Column B, Table 1) as determined in PTM 702, to the mass of aggregate passing each sieve used in the gradation, (Column A, Table 1), to obtain the total mass passing each sieve (Column C, Table 1).

> NOTE 3- The mass of fine aggregate in the extract liquid may be obtained with suitable accuracy by subtracting the total mass obtained on the maximum sieve size from the total mass of aggregate in the sample. The total mass of aggregate in the sample is obtained by subtracting the mass of the bitumen in the sample from the total mass of the sample. This calculation assumes that all mass loss on grading is passing the 75 μm (No. 200) mesh sieve. The mass loss on grading shall be limited to 0.4 percent of the total sample. All weights for the wash test are recorded to the nearest 0.1 g (0.004 ounce). All weights for the gradation testing are recorded to the nearest 1 g (0.04 ounce).

5.   CALCULATIONS

5.1   Divide the total mass of the extracted aggregate into the total mass passing each sieve (Column C, Table 1), and record in Column D, Table 1, as the percent of raw aggregate passing each sieve.

6.   REPORT

6.1   Percentages shall be reported to the nearest whole number except for the percentage passing the 75 μm (No. 200) sieve which shall be reported to the nearest 0.1 percent.

GRADATION WORK SHEET
Table 1

(All masses in grams)

Mass of Original Sample = 2173.8   Mass of Bitumen = 81.6
Mass of Extracted Sample = 2073.2   % Aggregate = 96.2
Mass of Aggregate in Extract = 19.0   % Bitumen = 3.8
Mass of Total Extracted Aggregate= 2092.2

Passing Sieve Size	Mass Passing each Sieve	+	Fines in Ext. Liq.	=	Total Mass Passing each Sieve	Raw Aggreg. % Passing
	A	+	B	=	C	D
37.5 mm (1½)	2073		19		2092	100
25 mm (1)	2018		19		2037	97
12.5 mm (1/2)	1035		19		1054	50
4.75 mm (No.4)	593		19		612	29
2.36 mm (No. 8)	435		19		454	22
1.18 mm (No. 16)	363		19		382	18
600 mm (No. 30)	156		19		175	8
300 mm (No. 50)	89		19		108	5
150 mm (No. 100)	56		19		75	4
75 mm (No. 200)	35		19		54	2.6

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LABORATORY TESTING SECTION

Method of Test for

BITUMEN CONTENT OF BITUMINOUS CONCRETE MIXTURES
(Pennsylvania Pycnometer Method)

1.   SCOPE

         1.1   This method of test covers a procedure for determining the bitumen content of bituminous concrete mixtures.

2.   APPARATUS

         2.1   Balance- A balance conforming to the requirements of AASHTO M-231, Class G2.

         2.2   Pennsylvania Pycnometer- A 4000 mL heavy wall glass pycnometer, fitted with a vacuum adapter, capillary stopper, and overflow cap. (Table 2 and Figure 1). The pycnometer shall be sufficiently strong to withstand a partial vacuum (air pressure less than 30 mm of mercury).

         2.3   A vacuum pump or water aspirator for evacuating air from the pycnometer

         2.4   Dial type vacuum gauge- 0 to 760 (0 to 30 inches) of mercury vacuum
                                          OR
                  Mercury filled absolute pressure manometer calibrated to at least 1 mm divisions

         2.5   Vacuum Trap- Consisting of a 600 mL filter flask fitted with a rubber stopper

         2.6   Tubing and connectors assembly as shown in Figure 2

         2.7   Water Bath- The bath temperature shall be maintained at a temperature of 25 ± 0.5 ^{o}C (77 ± 0.9ºF).

         2.8   Thermometers- Temperature range 19 to 27ºC (66 to 80ºF) and 20 to 47ºC (69 to 116ºF) as prescribed in ASTM Specification E-1.

3.   CALIBRATION OF PYCNOMETER

        3.1   Calibrate the pycnometer by accurately determining the mass of water at 25 ± 0.5 ºC (77 ± 0.9ºF) required to fill the pycnometer with the capillary stopper and overflow cap in place. Allow some water to overflow through the capillary tube while inserting the capillary stopper. Make sure 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 one hour. A vacuum shall be applied to remove the air bubbles, if necessary. Dry the outside of the pycnometer with an absorbent paper or cloth towel prior to weighing.

4.   TEST DATA- The following data must be obtained to calculate the bitumen content.

        4.1   Specific Gravity of bitumen (G_b) at 25ºC (77 ºF) (AASHTO T-228).

        4.2   Effective Specific Gravity of the combined aggregate (G_a)- This value is determined by testing samples having a known bitumen content. The procedure is explained in Section 8 of this PTM.

5.   TEST SAMPLES

        5.1   The sample shall be obtained in accordance with PENNDOT Methods of Sampling Bituminous Mixtures. Inspect the sample for coating deficiencies and note any problems found.

        5.2   The size of the sample of bituminous concrete shall be 1000 to 2000 g. In no case shall the selection of a sample of a pre-determined mass be attempted.

6.   PROCEDURE

        6.1   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 6.3 mm (1/4 inch). 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 handled.

        6.2   Place approximately 1000 mL of room temperature water in the pycnometer to prevent asphalt stains. Determine the mass of the pycnometer plus the added water. Record the mass on Line 2 of Work Sheet No. 1.

        6.3   Place the warm bituminous concrete sample (Note 2) in the pycnometer and

obtain the mass of the pycnometer, water, and sample. Record the mass on Line 1 of Work Sheet No. 1.

6.4   Remove the entrapped air from the pycnometer by subjecting the contents of the pycnometer to a partial vacuum, more than 635 mm (25 inches) mercury vacuum or less than 125 mm mercury absolute pressure, for 10 ± 2 minutes. Agitate the container and contents either continuously by using a mechanical device or manually by vigorously shaking at intervals of about 2 minutes.

   NOTE 1- The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT at a concentration of 0.01 percent, or 1 mL of 10 percent solution in 1000 mL of water.

6.5   Fill the flask with water. If filling the flask causes air bubbles, these air bubbles shall be removed by using a stirring rod or an additional vacuum, if necessary. Bring the contents of the flask to a temperature of between 20 ℃ (68 ℉) and 37.8 ℃ (100℉) (Note 2). Determine the mass of the pycnometer and contents (completely filled) and record on Line 9 of Work Sheet No. 1. 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. Immediately after weighing, measure the temperature of the water in the pycnometer and record on Line 5 within the parentheses.

   NOTE 2- For rapid determinations of maximum specific gravity at the bituminous concrete plant, the sample from the truck shall be spread in a shallow pan and allowed to cool so that the temperature of the contents in the pycnometer (mix & water) does not exceed 37.8℃ (100 ℉). For hot mixes, chilled water may be used to cool the mix to a temperature below 37.8℃ (100 ℉).

7.   CALCULATIONS

7.1   The maximum specific gravity of the voidless mix (G_m) is determined as follows:

$$\text{Maximum Specific Gravity } (G_m) = \frac{A}{A + D + E} \quad (1)$$

Where:

A = mass of the mix in air

D = mass of the pycnometer filled with water

E = mass of the pycnometer filled with water and mix
The equation above can be solved by operations in lines 1 through 12 of Work Sheet

No.1. Factors F1 and F2 for the corresponding test temperatures are given in Table 1. If the mixture contains porous aggregate not completely coated, follow the supplemental procedure given in Section 11 of AASHTO T-209.

7.2 The effective specific gravity of the aggregate (G_a) shall be determined as explained in AASHTO T-228. Given G_a, F, G_b, and G_m, the percent bitumen content can be determined over the range of temperatures from 20.0 to 37. 8 ℃ (68 to 100℉) by operations in lines 13 and 14 of Work Sheet No. 1, or by solving the following equation:

$$P = \frac{100\, G_b}{G_a - G_b} \left[\frac{G_a}{G_m} - 1 \right] (2)$$

7.3 Knowing the values G_a, G_b, and G_m, the bitumen content can also be determined by use of the attached nomograph which has been prepared to solve Equation (2) at 25℃ (77℉). This nomograph is not applicable at other temperatures. The maximum specific gravity of the mix (G_m) is connected using a straight line to (G_a). At the point where this line crosses the 1.02 Sp. Gr. of AC line, proceed horizontally to the line that is applicable to the specific gravity of the asphalt being used and read the percentage by weight of asphalt in the total mix.

8. EFFECTIVE SPECIFIC GRAVITY OF AGGREGATE (G_a)

8.1 The effective specific gravity of the aggregate is determined by testing a sample of the mix that has been prepared in the laboratory with a known asphalt content (P). In order to obtain accurate results, the gradation and asphalt content of the sample must match, as closely as possible, the gradation and asphalt content of the mix being produced at the plant. The sample shall be about the same size as the samples that are tested for bitumen content.

8.2 Transfer the prepared mix to the pycnometer and determine the maximum specific gravity of the mix (G_m) in accordance with Section 7.1 of this PTM. Knowing the bitumen content (P) and the specific gravity of the bitumen (G_b), the effective specific gravity of the aggregate (G_a) can be determined by using Equation (2) which has been rearranged algebraically as Equation (3) below:

$$G_a = \frac{G_m (100 - P)}{100 - \dfrac{G_m \times P}{G_b}} (3)$$

This equation can be conveniently solved by operations on lines 1 through 9 on

Worksheet No. 2.

8.3   At least 10 bituminous samples of known asphalt content shall be tested to establish the effective specific gravity of the aggregate (G_a) for an asphalt plant. Calculate the average of the 10 determinations and then determine the maximum (+) and minimum(-) variations from this average. If the values vary more than ± 0.010, discard these values and re-calculate the average and re-determine the variation. A minimum of 6 values shall be used to establish the final average.

8.4   Testing Frequency- The specific gravity of the aggregate may change during production. The effective specific gravity (G_a) should be re-determined if the type or source of any of the aggregates being used in the mix is changed, or if the gradation of the aggregate changes enough to require a change in the job-mix formula.

> NOTE 3-While transferring the mix from the mixing bowl to the pycnometer, some fine material and asphalt will stick to the bowl and spatula. This weight loss must be accounted for to determine the actual asphalt content (P) of the mix added to the pycnometer. To determine the mass of this material, determine the initial mass of the mixing bowl and the spatula, including the adhering fine material and asphalt. Wash the mixing bowl and the spatula with successive portions of solvent to dissolve the asphalt. Decant the supernatant liquid after each washing operation. When the supernatant liquid is a straw color, decant the last portion. Place the spatula and bowl in an oven to evaporate the remaining solvent. Determine the final mass of the dry bowl, spatula, and aggregate fines. The difference between the initial mass and final mass is the mass of asphalt lost during transfer to the pycnometer. Remove the spatula, weigh the bowl and aggregate. Wipe dry the aggregate in the bowl, and weigh the clean, empty bowl. The difference between these masses is the mass of the aggregate fines remaining in the bowl. The masses of asphalt and aggregate fines lost during transfer are subtracted from the original mix masses to determine the percent of asphalt in the mix added to the pycnometer.

9.   ACCURACY OF METHOD

9.1   The bitumen content of the bituminous mixture will vary by ±0.10 percent for the following variations in the measurements:

Mass of the specimen	± 1.0 g
Mass of displaced water	± 0.5 g
Maximum Sp. Gr. of the Mix (G_m)	± 0.003 units
Sp. Gr. of the Bitumen (G_b)	± 0.010 units

Effective Sp. Gr. of the Aggregate (G_a) $\pm$ 0.010 units

Table 1
CONVERSION FACTORS

Test Temp.-ºC(ºF)	F_1	F_2	Test Temp.-ºC(ºF)	F_1	F_2
20.0(68)	1.0012	1.0018	29.4(85)	0.9988	1.0042
20.6(69)	1.0010	1.0019	30.0(86)	0.9986	1.0044
			30.5(87)	0.9984	1.0045
21.1(70)	1.0009	1.0020	31.1(88)	0.9982	1.0047
21.7(71)	1.0008	1.0021	31.6(89)	0.9981	1.0049
22.2(72)	1.0007	1.0023			
22.8(73)	1.0005	1.0024	32.2(90)	0.9979	1.0050
23.3(74)	1.0004	1.0025	32.8(91)	0.9977	1.0052
			33.3(92)	0.9975	1.0054
23.9(75)	1.0003	1.0026	33.9(93)	0.9974	1.0056
24.4(76)	1.0001	1.0028	34.4(94)	0.9972	1.0058
25.0(77)	1.0000	1.0029			
25.6(78)	0.9999	1.0031	35.0(95)	0.9970	1.0060
26.1(79)	0.9997	1.0032	35.6(96)	0.9968	1.0062
			36.1(97)	0.9996	1.0064
26.7(80)	0.9996	1.0034	36.7(98)	0.9964	1.0066
27.8(81)	0.9994	1.0035	37.2(99)	0.9882	1.0068
27.8(82)	0.9992	1.0037			
28.3(83)	0.9991	1.0039	37.8(100)	0.9960	1.0070
28.9(84)	0.9989	1.0040			

Table 2

DETAILS OF THE PENNSYLVANIA PYCNOMETER

A.   Pennsylvania Pycnometer composed of:

(a)   A Heavy Wall Flask- 4000 mL, with a ⊤ 55/50 outer joint
(b)   A Vacuum Adapter with a ⊤ 55/50 inner joint
(c)   Special Overflow Cap- The main part is a ⊤ 65/50 inner joint with a small cap
        s 7/15 on top

B.   Accessories for the Pycnometer:

(a)   Vacuum Gauge- 0 to 762 mm (0 to 30 inches), 6.4 mm (1/4 inch) ips male
(b)   T-connectors- 6.4 mm (1/4 inch) Kimble or Nalgene polypropylene (2 Nos.)
(c)   Valve to tubing connector- Female, 6.4 mm (1/4 inch) ips threaded brass with a
        fiber washer
(d)   Rubber tubing- Neoprene vacuum 6.4 mm (1/4 inch) ID., 4.8 mm (3/16 inch) wall
        3 m (10 ft)
(e)   Filter Flask- Vacuum trap, 500 mL, heavy wall with side tabulation
(f)   Rubber stopper- One hole, Neoprene (fusiform safety bore)
(g)   Filter pump- Aspirator, 96.5 mm (3.8 inch) ips thread
(h)   Alternate for item g above:

Welch Dist-o-pump, Model 1399 B or equivalent, Vacuum obtainable 2 Pa (15 micron),
35 liters/min, 248.6 W (1/3 HP) , 750 RPM, 115 Volts AC, 60 cycles.

C.   Known Suppliers of Pennsylvania Pycnometer complete with accessories:

(a)   Scientific Glass Company
        735 Broad Street
        Bloomfield New Jersey 07003

(b)   Kontes Glass Company
        Vineland, New Jersey 08360

WORK SHEET NO. 1 (PTM No. 742)

Project No._____ Mix Type _____ Producer & Location _____ Type Aggregate

Line	Sample Identification							
1	Mass of Mix + Pyc. + Initial Water							
2	Mass of Pyc. + Initial Water							
3	Line 1 - Line 2 = Mass of the Mix (A)							
4	Mass of Water in the Pyc. at 25 °C (Calibration)							
5	Line 4 x Factor F_1 = Mass of Water in the Pyc. at Test Temperature [°C(°F)]							
6	Mass of the Dry Pycnometer							
7	Line 5+Line 6=Mass Pyc.+ Water at the Test Temperature							
8	Line 3 + Line 7							
9	Mass of Pyc. + Water + Mix (E)							
10	Line 8 - Line 9 = G_m of Displaced Water							
11	Line 10 x Factor F_2 = cc of Displaced Water							
12	Line 3 ÷ Line 11 = Max. Sp. Gr. Of the Mix (G_m)							
13	(G_a ÷ Line 12) - 1							
14	(J x Line 13) = % Bitumen							

G_a	Effective Sp.Gr.of the Agg. (Line 9, Sheet 2)	
G_b	Sp.Gr.of the Asphalt	Operator:
K	G_a - G_b	Date:
J	(100 x G_b) ÷ K	Laboratory:

WORK SHEET No. 2

EFFECTIVE SPECIFIC GRAVITY OF AGGREGATE (G_a)

Type Aggregate _____ Producer
Mix Type _____ Plant

LINE			Sample Identification						
1	Line 12(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	$(G_m xP)G_b$							
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
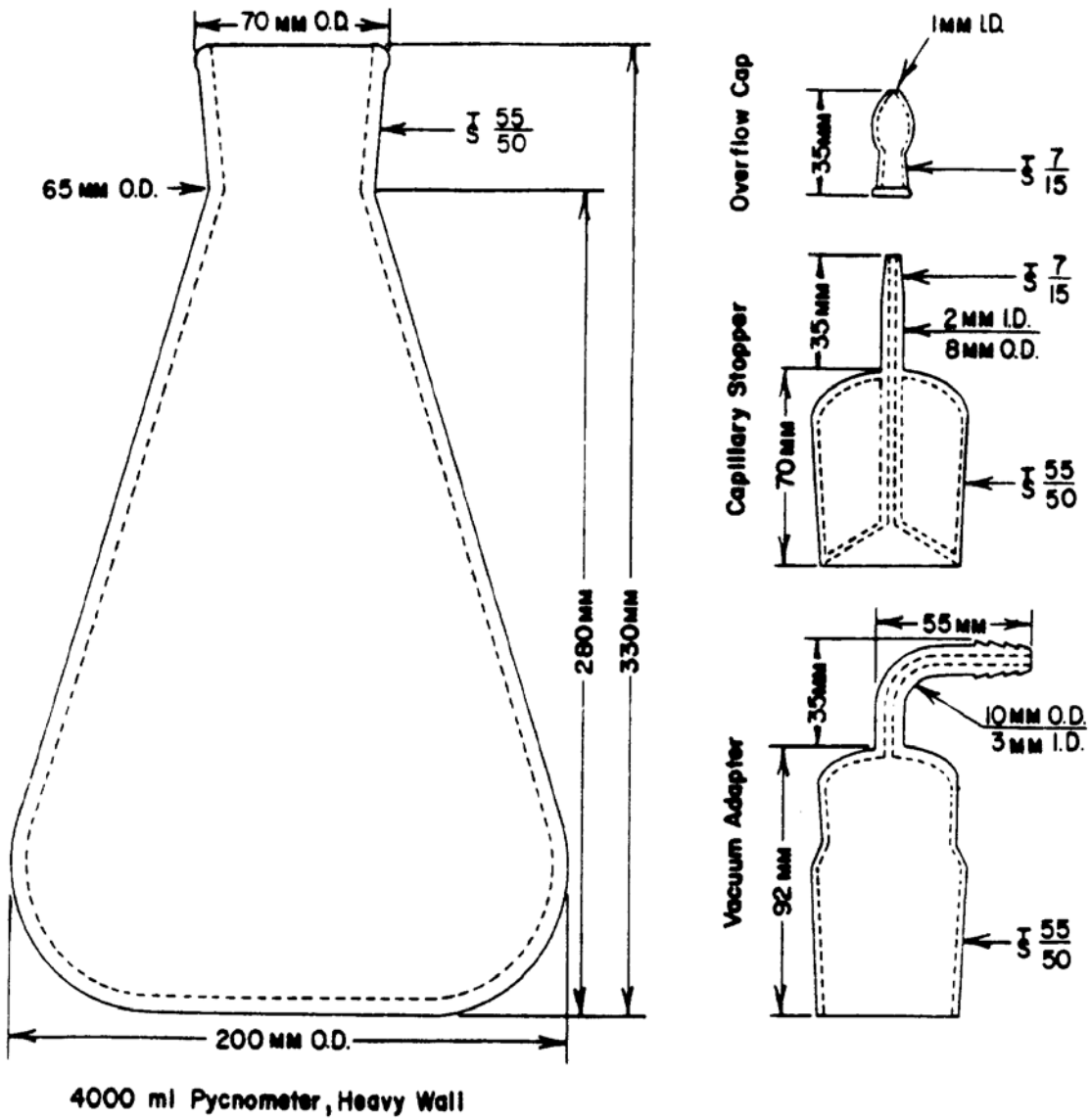
Fig. I   Pennsylvania Pycnometer-4000ml Capacity

Vacuum Gage 0~760 mm (30")
6.4 mm (1/4") I.P. Thread (Male or Female)

Tubing Connector
6.4 mm (1/4") I.P. Thread
(Male or Female)

6.4 mm (1/4")
T-Connectors

Water Faucet

Metal Aspirator

To Aspirator (Filter Pump)
or Vacuum Pump

6.4 mm (1/4") I.D Neoprene or
Rubber Vacuum Tubing

Rubber Stopper

Tubing Clamp

Air Bleed

Vacuum Adaptor $ 55/50

500ml
Filter Flask
(Vacuum Trap)

Overflow Cap

Capillary Stopper

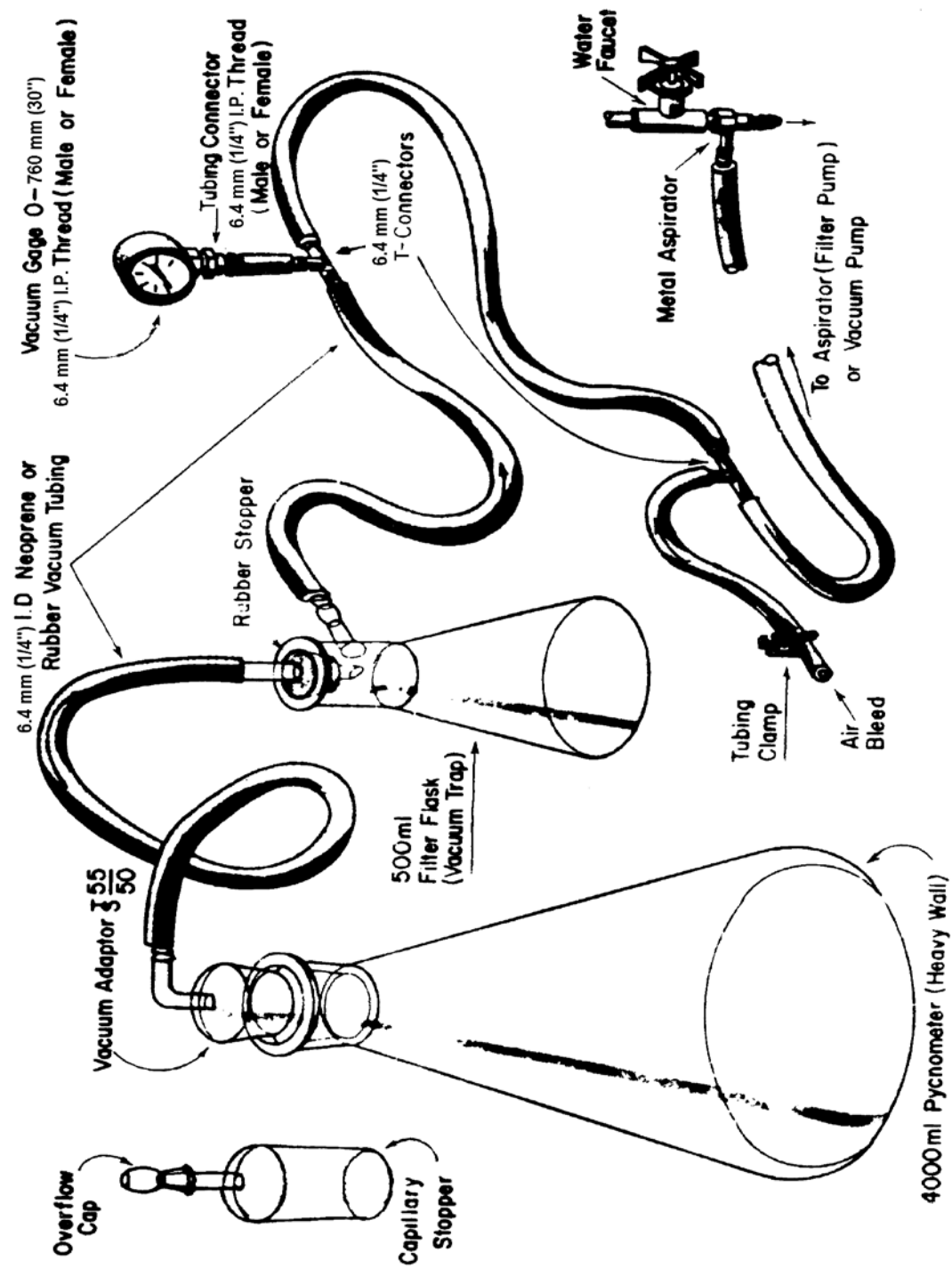4000ml Pycnometer (Heavy Wall)

Fig 2   Pennsylvania Pycnometer Assembly with Accessories

PTM No. 742, December 1973

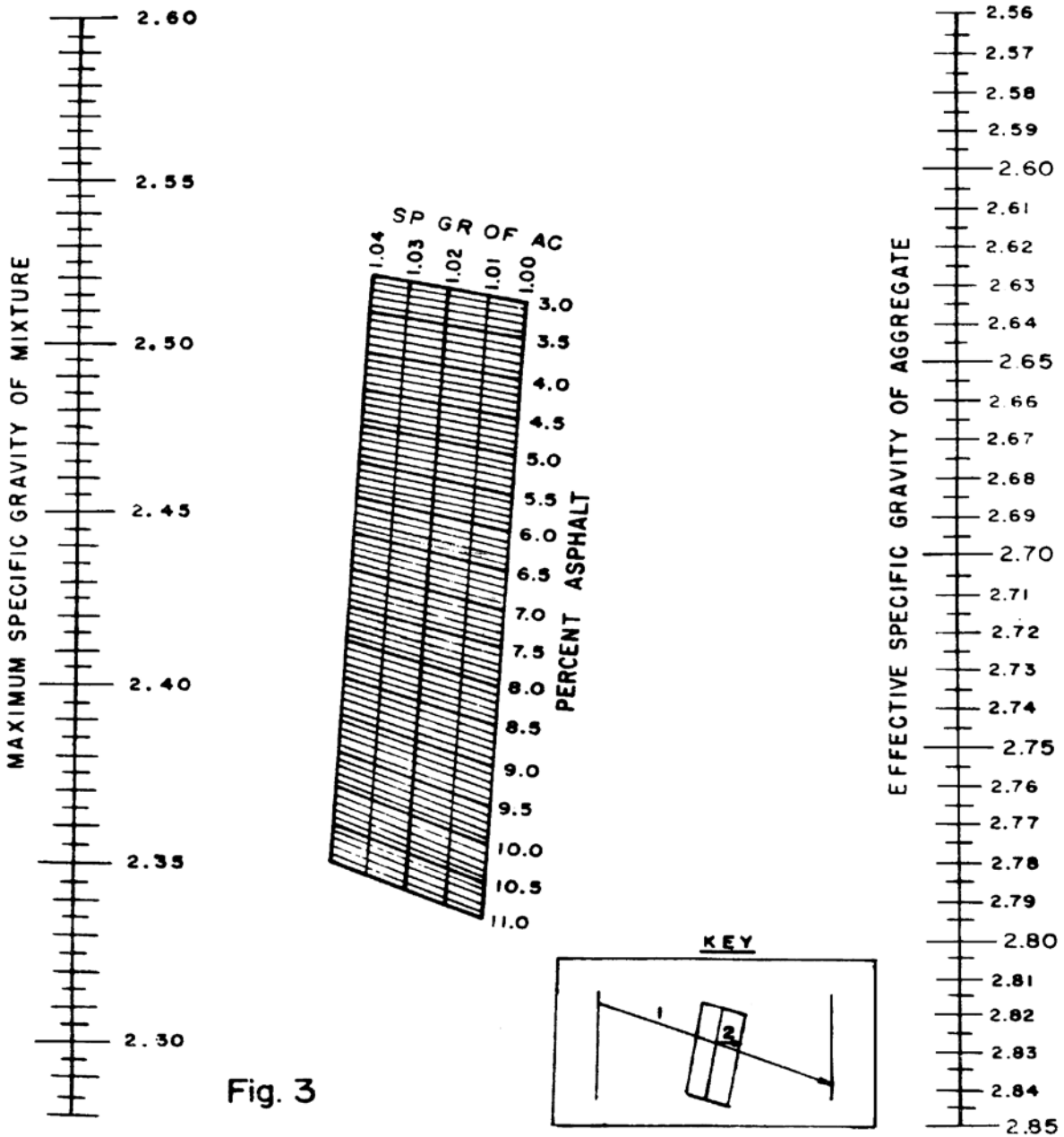## ASPHALT CONTENT

PENNSYLVANIA PYCNOMETER METHOD

Fig. 3

10

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF COMBINED GRADATION OF
AGGREGATES FROM HOT BINS

1.   SCOPE

    1.1   This method of test is intended for determining the gradation of aggregates in the bituminous mixture being produced, at an asphalt plant, by sampling from the hot bins.

2.   PURPOSE

    2.1   This method of test shall be used to analyze hot bin samples for quality control, and to check the uniformity of the bituminous concrete being produced to meet the approved job-mix formula.

    2.2   This method of test may be used in conjunction with PTM No. 742 in lieu of the extraction test for determining bitumen content and aggregate gradation.

3.   SAMPLING

    3.1   In the case of batch plants, the sample shall be obtained from the bin gates as the material falls into the weigh hopper. For continuous plants, the sample of aggregate shall be obtained from the feeder gates as the material is deposited on the elevator leading to the pugmill.

    3.2   It is essential that sampling facilities be constructed and located so that the samples obtained will be representative of the material in the bins. For material flowing over the plant screens, finer particles fall to the near side of the bins and coarser particles fall to the far side (Figure 1). When material is drawn from the bin by opening a gate at the bottom, the stream consists predominantly of fine material at one edge and coarse material at the other edge. This condition is critical in the No 1, or fine bin, since the material from this bin influences the asphalt demand heavily. Therefore, the relative position of the sampling device in the stream determines whether the sample will be composed of the fine portion, the coarse portion, or will be an accurate representation of the material in the bin.

    3.3   If the asphalt plant is equipped with devices for sampling hot aggregate from the bins, it would be necessary that these devices intercept the full width of the stream as shown in Figure 1. The sample device shown in Figure 2 shall be used, if the plant is not already equipped,

for obtaining samples from each hot bin.

4.   APPARATUS

    4.1   Balance- Conforming to the requirements of AASHTO M-231, Class G2.

    4.2   Sieves- Meeting the requirements of AASHTO M-92.

    4.3   Sampling device- As described in Section 3.3 of this test method.

    4.4   Mechanical Sieve Shaker- Capable of meeting the shaking efficiency requirements of PTM 608.

5.   SAMPLES

    5.1   Samples for sieve analysis shall be obtained by the use of a sample splitter or by use of the quartering method from the larger samples obtained from each hot bin. The sample for test shall be approximately the mass desired and shall be the end result of the sampling method. The selection of samples of an exact pre-determined mass shall not be attempted.

    5.2   Samples of fine aggregate for sieve analysis shall weigh approximately as follows:

        Material with at least 96 percent finer than the 2.36 mm (No.8) sieve...100 g

        Material with at least 90 percent finer than the 4.75 mm (No.4) sieve and more than 5 percent coarser than the 2.36 mm (No.8) sieve 500g

NOTE 1- In no case, however, shall the fraction retained on the sieve at the completion of the sieving operation weigh more than 200 g for the usual 203.2 mm (8 in.) diameter sieve. The amount of material retained on the critical sieve may be regulated by: (1) the introduction of a large sieve, immediately above the critical sieve or (2) by the selection of a sample of proper size.

5.3   Samples of coarse aggregate for sieve analysis shall weigh not less than the amount indicated in the following table:

Nominal Maximum Particle Size, mm (inch)	Minimum Mass of Sample, kg
9.5 mm (3/8)	1
12.5 mm (1/2)	2
19.0 mm (3/4)	5
25.0 mm (1)	10
37.5 mm (1½)	15
50.8 mm (2)	20

NOTE 2- For samples weighing 5 kg or more, it is recommended that sieves mounted in frames 406.4 mm (16 in.) in diameter or larger be used.

6.   PROCEDURE

6.1   The sample from each hot bin shall be separated into a series of sizes using such sieves as are necessary to determine compliance with the specifications for the material under test. The sieving operation shall be conducted by means of a lateral and vertical motion of the sieve, accompanied by a jarring action so as to keep the sample moving continuously over the surface of the sieve. In no case shall fragments of the sample be turned or manipulated through the sieve by hand. Sieving shall be continued until not more than 1 percent by mass of the residue passes any sieve during 1 minute of sieving.

6.2   The mass of each size shall be determined on a scale or balance conforming to the requirements specified in Section 4.1. If difficulty is experienced in determining the accurate amount of minus 75 µm (No.200) material in any of the hot bins, this determination can be made by using PTM No.100. This PTM may not necessarily need to be conducted daily once a correction factor based on a series of such tests is established for an asphalt plant using the same type of aggregate. This correction factor can then be applied to the results of the dry sieve analysis with respect to minus 75 µm (No.200) material.

6.3   If the accumulated mass after sieving differs from the original sample mass by more than 0.5 percent, the results will be deemed unreliable and another sample will be tested.

7.   CALCULATIONS

        7.1   The percentage passing the given sieves shall be calculated by dividing the accumulated weights of each sieve by the total weight of the sample. These gradation results shall be recorded to the nearest 0.1 percent in columns A, D, G and J of the Aggregate Blend Form appended in this PTM.

        7.2   The combined gradation of the aggregate from all the hot bins shall then be calculated on the Aggregate Blend Form according to the weight proportioning (decimal fraction of each bin in the blend) for use in the bituminous mix. This calculated combined gradation shall be checked against the gradation in the Job-Mix Formulas.

8.   REFERENCES

        PTM 100
        PTM 616
        PTM 742
        AASHTO M- 92
        AASHTO T-11
        AASHTO T-27
        The Asphalt Institute Manual Series No. 3

GRADATION OF HOT-BIN AGGREGATE BLEND

SIEVE	BIN NO. 1			BIN NO. 2			BIN NO. 3			BIN NO. 4			TOTAL % PASS	
	A	xB	=C	D	xE	=F	G	xH	=I	J	xK	=L	Calc.	Design
50 mm(2")														
37.5 mm(1-1/2")														
25.0 mm (1")														
19.0 mm (3/4")														
12.5 mm (1/2")														
9.5 mm (3/8")														
4.75 mm (No.4)														
2.36 mm (No.8)														
1.18 mm (No.16)														
600 µm (No.30)														
300 µm (No.50)														
150 µm (No.100)														
75 µm (No.200)														

A, D, G & J = Percent Pass Each bin. B,E,H & K = Decimal Fraction of each bin in the blend. C,F,I & L = Percent contribution of each bin to the final blend.   Type Bit. Con .

Calc. = Percent passing in final blend = C+F+I+L   Produce
Design = Percent passing in the approved design   Operator _____ Date
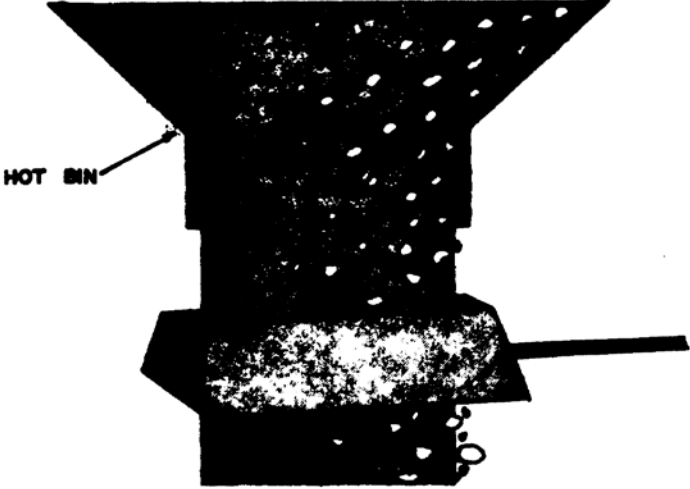
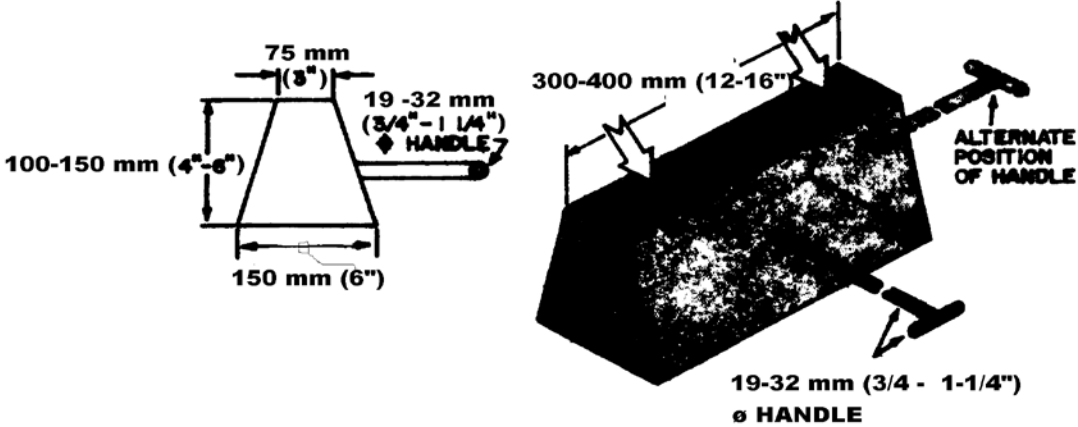FIGURE 1 CORRECT USE OF SAMPLING DEVICE

FIGURE 2 ASPHALT PLANT AGGREGATE SAMPLING DEVICE

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LABORATORY TESTING SECTION

Method of Test for

CHEMICAL ANALYSIS OF ASPHALT
(MODIFIED ROSTLER METHOD)

1.   SCOPE

1.1   This method of test is intended to cover the determination of the five subgroups comprising asphalt as defined by the method developed by Rostler and White. This method is applicable to all asphalts.

2.   SUMMARY OF METHOD

2.1   A one gram sample of asphalt is divided into 5 subgroups by selective solubility in n-Pentane and Sulfonizations with increasing strengths of Sulfuric Acid.

2.2   The five groups are:

2.2.1   Asphaltenes -The part insoluble in n-Pentane

2.2.2   N-Bases -The part that reacts with $85 \pm 0.1\%$ H_2SO_4

2.2.3   1st Acidaffins -The part that reacts with $95 \pm 0.1\%$ H_2SO_4

2.2.4   2nd Acidaffins -The part that reacts with 130% H_2SO_4

2.2.5   Paraffins - The part that does not react with the acids and consists of oils and waxes.

3.   APPARATUS

3.1   Reaction Assembly

3.1.1   Boiling Flasks- round bottom, 300 mL short neck with hooks on the neck, ground glass inner Joint ℑ 24/40, Pyrex or Kimex

3.1.2   Penny head stoppers- ground glass, outer Joint ℑ 24/40, Pyrex or Kimex

3.1.3   Beakers- 800 mL, Pyrex or Kimex

3.1.4   Graduated Cylinders- One 10 mL, one 50 mL, Pyrex or Kimex

3.1.5   Springs- nickel-chrome, spiral, 31.8 mm (1-1/4 inch), A. H. Thomas Cat. # 6098-P, 1972

3.1.6   Shaker- Burell wrist action, Multi-unit with a 60 minute timer, Burell Cat. # 75-765-16, Model BT, 1965

3.2   Filtering Assembly (Figure 1)

3.2.1   Boiling Flasks- round bottom, 300 mL, short neck with hooks on the neck, ground glass inner joint ℑ 24/40, Pyrex or Kimex

3.2.2   Filters- sintered glass, ultra- fine, ℑ 24/40 outer joint, jacketed with a vacuum outlet on the neck, 100 mL, Pyrex No. 36060, Lab Glass Cat. # LG-7120-s

3.2.3   Clamps- hosecock, screw type, A.H. Thomas Cat. # 3270-c, 1972

3.2.4   Manifold- six inlets, one outlet, 559 mm (22 inches) long, 13 mm (1/2 inch) diameter. The outlet is attached to a water jet vacuum. The inlet and outlet are to be 6 mm (1/4 in.) o.d. copper tubing.

3.2.5   Heating tape- 25 mm (one inch) wide by 1.5 m (six feet) long, A. H. Thomas Cat. # 6148-A, 1972

3.2.6   Variable transformer- 60 cycle, 120 volts, Fisher type 3PN116

3.2.7   Rubber tubing- Neoprene, vacuum, thick wall, 6mm (1/4 inch) I. D.

3.3   Distilling Assembly (Figure 2)

3.3.1   Boiling Flask- round bottom, 500 mL, short neck with hooks on the neck, ground glass inner joint ℑ 24/140, Pyrex or Kimex

3.3.2   Condenser- water jacketed, 250-300 mm long with a ℑ 25/18 inner joint at the inlet and an outer joint at the exit

3.3.3   Connecting tube- 105 degrees, ℑ 25/18 inner joint at the inlet, ℑ 21/40

outer joint at the exit, glass jacketed, with a vacuum outlet tube

        3.3.4   Electric heating mantles- 300 mL, 140 watts, 115 volts

        3.3.5   Distilling head- As shown in Figure 2 (made to order by SGA, 1962)

        3.3.6   Vacuum pump- 425 liters /minute displacement of free air at 1×10^{-4} mm mercury pressure (McLeod), with a 746 watt (one horse power) motor

        3.3.7   Manometer- Thomas-Bennet, 240 mm range, one mm divisions, with aluminum support, A. H. Thomas Cat. # 6395-B10, 1972

4.   REAGENTS

     4.1   Distilled n-Pentane- Simple distillation of technical grade n-Pentane. The first 75 mL and the last 100 mL of a 2000 mL charge are discarded, and the central fraction retained as distilled n-Pentane (Technical grade available from Phillips Petroleum, Special Products Div., Bartlesville, Okla. 74004).

     4.2   Sulfuric Acid, $85 \pm 0.1\%$

     4.3   Sulfuric Acid, $95 \pm 0.1\%$

     4.4   Sulfuric Acid, 130% fuming

5.   SAMPLE

     5.1   The sample shall consist of approximately a one gram sample of asphalt either poured from a heated and stirred sample of asphalt or cut from a sample of cold asphalt with a knife. (NOTES 1 and 2).

    NOTE 1- All weighing's are to be made to the fourth decimal place. An analytical balance must be used.

    NOTE 2- If cut with a knife, be sure to scrape off the upper 6 mm (1/4 inch) surface of the asphalt sample before cutting out the one gram sample.

6.	PROCEDURE

6.1	Asphaltene

6.1.1	Weigh a clean dry 300 mL flask. Add approximately a one gram sample of asphalt. Reweigh the flask and sample and subtract the mass of the flask to obtain the sample mass.

6.1.2	Add 50 mL of distilled n-Pentane (per gram of sample) to the flask and sample. Place a penny head stopper in the flask to insure that the stopper is held down tightly by the use of the spiral springs. Place the flask on the Burrell Wrist Action shaker for one hour at a maximum shaking speed. Keep the flask on the shaker overnight. Shake the flask for 15 minutes the following morning.

6.1.3	Remove the sample from the shaker and filter the contents through an ultra-fine sintered glass filter into a clean, dry, and weighed 300 mL boiling flask. Use a water jet vacuum to aid the filtering. Wash the flask and precipitate retained on the filter five times with 25 mL of distilled n-Pentane. Heating tape is place under the receiver flask so that heat can be used to evaporate and reduce the volume of n-Pentane received due to the washings.

6.1.4	Remove the 300 mL flask containing the filtrate and place it in the distilling apparatus (Figure 2). Distill off the excess n-Pentane until the last few drops remain. Slowly apply a vacuum, making sure the rate of the vacuum applied is slow enough to prevent explosive boiling of the last few drops of n-Pentane. Hold the system under full vacuum for 30 minutes. Turn off the vacuum pump and admit a small amount of air so that the system returns to atmospheric pressure very slowly (approximately one hour). Purge the system with CO_2. Stopper the flask upon removal of the vacuum and place in a desiccator over night. The next morning remove the flask, blow out the CO_2 with clean dry air, and weigh the flask and residue.

6.1.5	Record the mass of the flask and residue (Section 6.1.4). Subtract the mass of the flask from the recorded mass of the flask and residue and record the difference as R_1. Subtracting R_1 from the original sample mass will give the mass of the Asphaltene group.

6.2	N-Bases

6.2.1	To the residue R_1 add 50 mL of n-Pentane and dissolve the residue. Add 2-1/2 mL of $85 \pm 0.1\%$ H_2SO_4 to the dissolved residue. Stopper the flask and fasten the stopper down with wire springs. Place the flask on a Burrell shaker and agitate for three minutes.

6.2.2	Remove the flask from the shaker and decant the supernatant of unreacted

sample and n-Pentane into an ultra-fine sintered glass filter that has a 13 mm (1/2 inch) layer of

Na_2CO_3 on the filter. Apply a water jet vacuum to aid in filtering. Wash the reacted residue and oily mass in the flask with 50 mL of n-Pentane by shaking on a Burrell shaker for 15 minutes. Decant the supernatant washings through the filter. Continue washing until the supernatant is clear and has no yellow color.

6.2.3　After washing the reaction flask and residue, wash the glass filter five times with approximately 15 mL of n-Pentane. Proceed as stated in Section 6.1.4.

6.2.4　Record the mass of the flask and residue. Subtract the mass of the flask from the recorded mass of the flask and residue and record the difference as R_2. Subtracting R_2 from R_1 will give the mass of the N-Base group.

6.3　1st Acidaffins

6.3.1　To the residue R_2 add 50 mL of n-Pentane and dissolve the residue. Add 22 mL of $95 \pm 0.1\%$ H_2SO_4 to the dissolved residue. Stopper the flask and fasten the stopper down with wire springs. Place the flask on the Burrell shaker and agitate for three minutes.

6.3.2　Proceed as stated in Section 6.2.2

6.3.3　Proceed as stated in Section 6.2.3

6.3.4　Record the mass of the flask and residue. Subtract the mass of the flask from the recorded mass of the flask and residue and record the difference as R_3. Subtracting R_3 from R_2 will give the mass of the 1st Acidaffin group.

6.4　2nd Acidaffins and Paraffins

6.4.1　To the residue R_3 add 30 mL of n-Pentane and dissolve the residue. Place the 300 mL flask and sample in an 800 mL beaker containing a mixture of ice and water. Permit the sample to cool for 1/2 hour (NOTES 3 and 4). Cool a bottle of 130 % fuming H_2SO_4 in a bath containing a mixture of ice and water.

NOTE 3- An operator shall be wearing protective goggles, acid gloves, and an acid apron while handling 130% fuming H_2SO_4.

NOTE 4- The test shall be performed under a hood which has a safety shield.

6.4.2　Add 10 mL of the cooled 130% fuming H_2SO_4, slowly and carefully, to the

cooled sample. Stopper the flask and fasten down the stopper with wire springs. Shake the flask by hand for three minutes. Return the flask to the ice bath for ten minutes. Release the pressure

that has built up due to the chemical reaction by raising the stopper slightly <u>WITH THE SPRING STILL ATTACHED!</u> Return the flask to the ice bath and let the sample stand in the bath overnight under a hood. The flask temperature will slowly return to room temperature.

     6.4.3   The following day decant the unreacted sample, which is dissolved in the n-Pentane, through a fine sintered glass filter which has been added to a bed of 25 mm (one inch) thick silica gel and 13 mm (l/2 inch) thick Na_2CO_3. After decanting, wash the stopper, flask, and filter with 25 mL volumes of n-Pentane a minimum of five times. When decanting the solution make sure the acid residue remains in the reaction flask.

     6.4.4   After washing the flask, stopper, and filter proceed as stated in Section 6.1.4.

     6.4.5   Record the mass of the flask and residue. Subtract the mass of the flask from the recorded mass of the flask and residue and record the difference as R_5. This is the mass of the Paraffin group.

     6.4.6   Subtract R_5 from R_3. Record this difference as R_4. This is the mass of the 2nd Acidaffin group.

7.   CALCULATIONS

     7.1   To find the percentages of the groups, make ratios of the original sample mass (O.S.W.) to the residue fraction weights: R_1, R_2, R_3, R_4, and R_5, respectively, and multiply by 100 as shown in the following example (NOTE 5).

     NOTE 5- Round off the results for the 2nd Acidaffin group. The total of the groups is exactly equal to 100% since the 2nd Acidaffins were found by this difference.

$$\frac{R_1}{O.S.W.} \times 100 = \% \text{ Asphaltene}$$

     7.2   To find the Rostler Coefficient use the following equation:

$$\text{Rostler Coefficient} = \frac{\%\ \text{N-Base} + \%\ 1\text{st Acidaffin}}{\%\ 2\text{nd Acidaffin} + \text{Paraffin}}$$

7.3   To find Penn State University Coefficient use the following equation:

$$\text{Penn State U. Coef.} = \frac{\%\ \text{N-Base} + \%\ 1\text{st Acidaffin} + \%\ 2\text{nd Acidaffin}}{\%\ \text{Asphaltene} + \%\ \text{Paraffin}}$$

8.   REFERENCES

8.1   ASTM D 2006-65T, Part 16.

8.2   Rostler, F. S. and R. 0 White, "Influence of Chemical Composition of Asphalts on Performance Particularly Durability" in Symposium on Road and Paring Materials " 1959 ASTM Special Technical Publication No. 277, American Society for Testing Materials, Philadelphia, 1960, pp. 64-88.
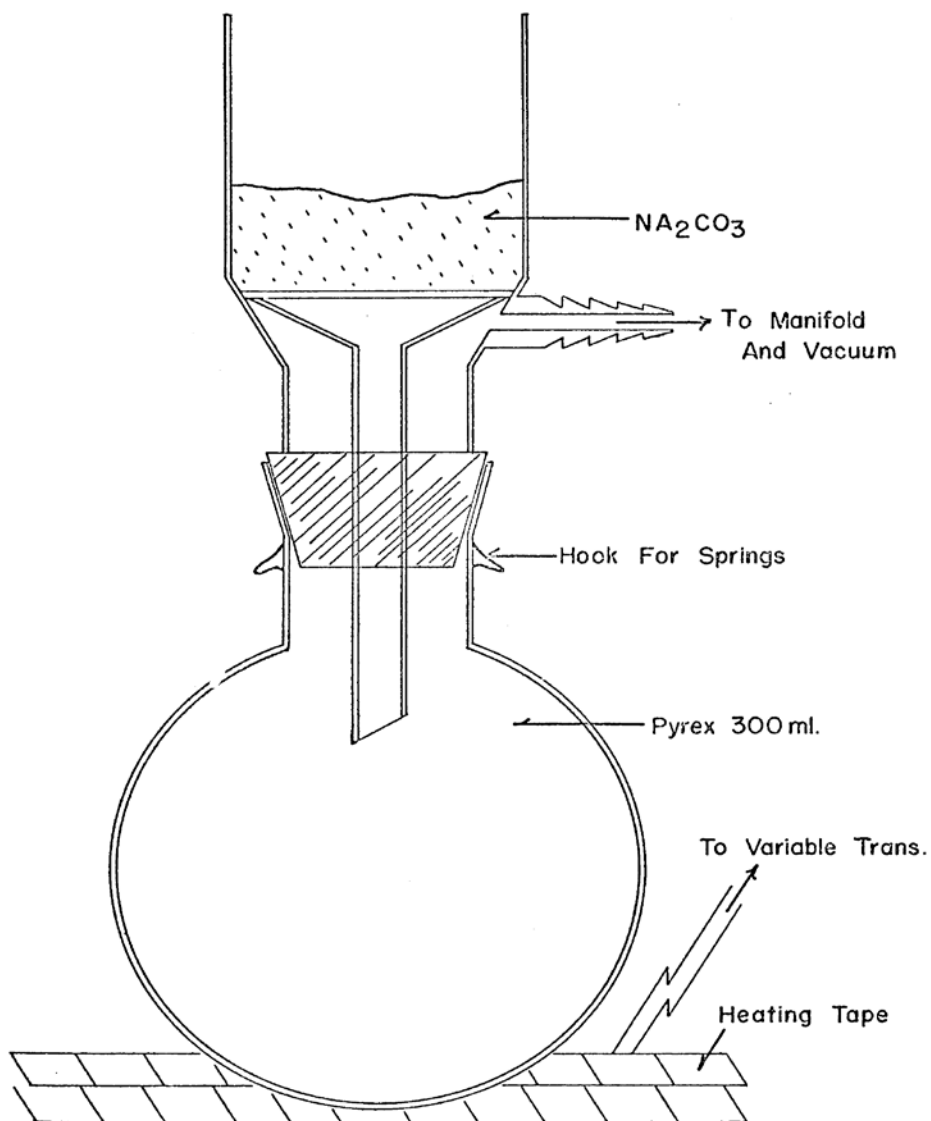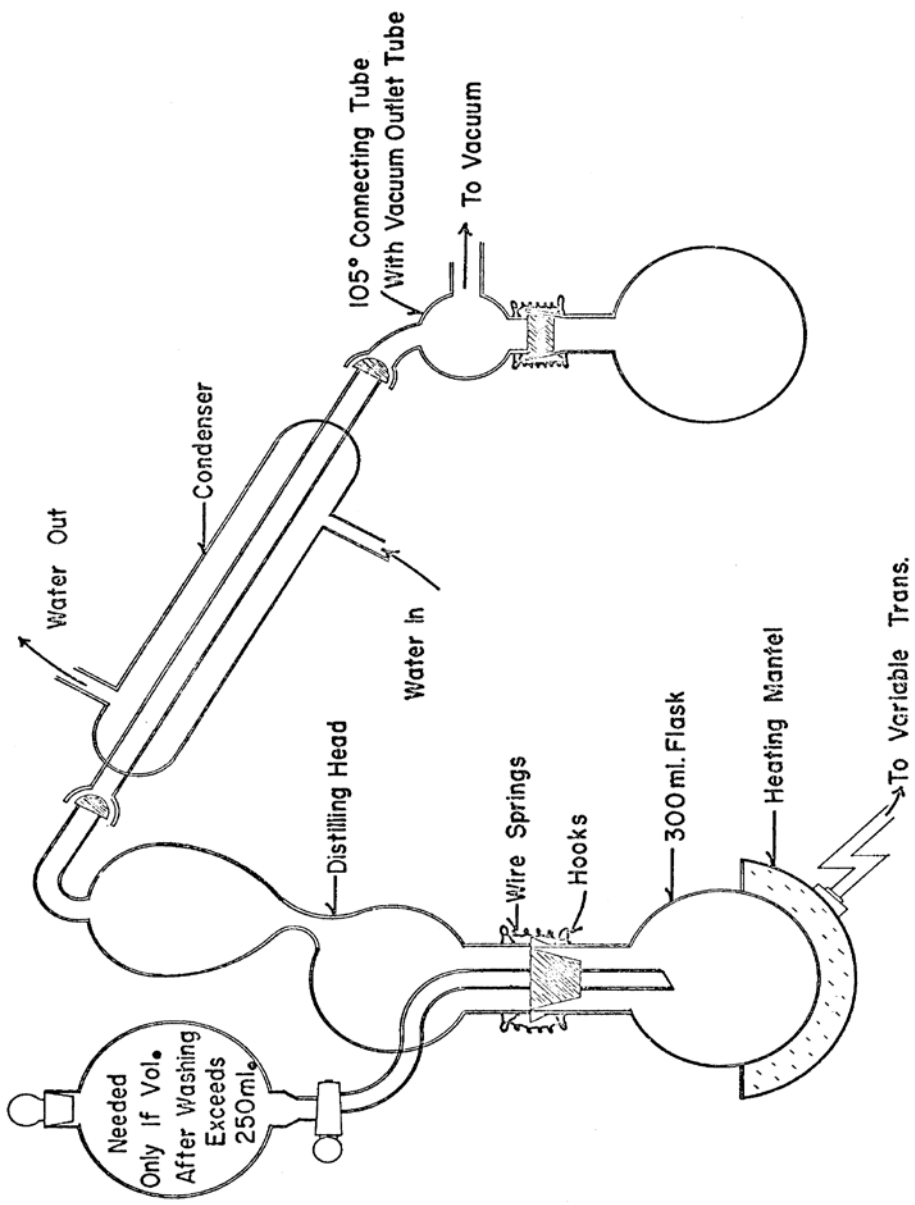
Figure 1

Figure 2

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LABORATORY TESTING SECTION

Method of Test for

SAMPLING BITUMINOUS PAVING MIXTURES

1.   SCOPE

        1.1   Loose Mixture Samples (Box Samples) - These methods cover the procedures for sampling mixtures of bituminous materials with mineral aggregate as prepared for use in paving. The samples shall be used for either of two purposes:

                1.1.1   To represent an average bituminous mixture for acceptance purposes.

                1.1.2   To ascertain the periodic variations in characteristics of the mixture for the purpose of quality control.

2.   EQUIPMENT

        2.1   A flat-bottom, high sided scoop.

        2.2   Sample Containers-

                2.2.1   For 3/4" (19 mm) and smaller Nominal Maximum Aggregate Size (NMAS) mixtures, use cardboard boxes dimensioned approximately 3 3/4 inches x 4 3/4 inches x 9 1/2 inches.

                2.2.2   For 1" (25 mm) and larger NMAS mixtures, use cardboard boxes dimensioned approximately 5 inches x 5 1/2 inches x 9 inches.

        2.3   Putty knife for scraping the **INSIDE** of the scoop.

        2.4   Incidental materials and equipment.

        2.5   Permanent marker

        2.6   Masking tape

3.   SELECTION OF SAMPLES

   3.1   Sampling on the Roadway

        3.1.1 Acceptance of the bituminous mixture from the roadway shall be on the basis of test results from consecutive probability samples for each Lot. One probability sample shall be taken from each Sublot. Samples are to be selected by means of a stratified random sampling plan. Refer to Illustrative Examples No. 1 & No. 2 in the Appendix of this PTM for examples of how to select samples using a stratified random sampling plan. If density acceptance is by pavement cores, mixture acceptance samples must be cross referenced to the corresponding density acceptance samples on Form TR-447.

        3.1.2   Bituminous mixture samples shall be taken directly from the un-compacted mixture placed by the paving equipment using a procedure described in Section 5 of this PTM.

        3.1.3   Areas within the handwork required at the edge of obstructions to normal paving such as manhole covers, inlets and utility valve covers are considered non-testable areas for obtaining bituminous mixture samples. When a sample location falls within a non-testable area, adjust the location of the sample longitudinally in the direction of paving to a location at the edge of the non-testable area.

   3.2   Sampling at a Bituminous Producer

        3.2.1   Sampling shall be on a random basis in accordance with an approved quality control program.

        3.2.2   Plant samples of the mixture shall be taken after the mixture has been discharged in hauling units using the procedure described in Section 6 of this PTM.

        3.2.3   An integral part of each quality control program shall require that samples be selected using a random number selection procedure such that all hauling units have an equal chance of being sampled by means of a stratified random sampling plan. Random numbers from PTM No. 1, Table 1, Column "X" shall be used to select the random tons to be sampled. These tons shall be obtained by multiplying the random numbers by the number of tons. The hauling units containing these random tons shall be sampled. Refer to Illustrative Example No. 1 in the Appendix of this PTM for an example of a typical stratified random sampling plan based on tonnage.

3.3   Quality Assurance (QA) Sampling

3.3.1   QA Sampling at a Bituminous Producer- Three (3) samples of bituminous mixture shall normally be obtained from each day's production from hauling units using the procedure stated in Section 6 of this PTM. The producer may obtain a companion sample with each of the three (3) QA samples for quality control purposes. Samples are to be selected by means of a stratified random sampling plan to distribute the sampling over a given period of time using the following procedure:

3.3.1(a)   Divide the anticipated time of the plant operation review into three (3) approximately equal time intervals.

3.3.1(b)   Select, at random, a series of three (3) consecutive numbers from PTM No. 1, Table 1.

3.3.1(c)   Determine the first sampling time by multiplying the first two place decimal value "X" by the number of minutes in the first time interval and add the product to the clock time at the beginning of the review. The load of mixture to be sampled is the first load (hauling unit) that leaves the plant following the computed sampling time.

3.3.1(d)   Repeat the operation, using the other two random numbers in the same order they appear in PTM No. 1, Table 1 to determine the sampling times for the two remaining time intervals. In each case, the product of the random number and the number of minutes in the particular interval is added to the clock time at the beginning of the interval to determine the sampling time. Refer to Illustrative Example No. 3 in the Appendix of this PTM for an example of a typical stratified random sampling plan based on time.

3.3.2   QA Sampling on the Roadway- Quality Assurance samples of the bituminous mixture are to be obtained directly from the un-compacted mixture placed by the paving equipment using a procedure described in Section 5 of this PTM.

3.3.2(a) Divide the anticipated period of the paving operation review into three (3) approximately equal time intervals.

3.3.2(b) Select, at random, a series of three (3) consecutive numbers from PTM No. 1, Table 1.

3.3.2(c) Determine the first sampling time by multiplying the first two place decimal value "X" by the number of minutes in the first time interval and add the product to the clock time at the beginning of the review. The load of mixture to be sampled is the first load (hauling unit) placed by the paving equipment following the computed sampling time. Multiply the pavement width by the two place decimal value "Y" to obtain the offset location for the sample.

3.3.2(d) Repeat the operation, using the other two random numbers in the same order they appear in PTM No. 1, Table 1 to determine the sampling times for the two remaining time intervals. In each case, the product of the random number and the number of minutes in the particular interval is added to the clock time at the beginning of the interval to determine the sampling time. Refer to Illustrative Example No.3 in the Appendix of this PTM for an example of a typical stratified random sampling plan based on time.

4.   SIZE OF SAMPLES

4.1   The size of the bituminous mixture samples shall be enough material to fill the appropriate sample container selected for the NMAS of the mixture as outlined in Section 2.2.

5.   PROCEDURE FOR SAMPLING BEHIND PAVING EQUIPMENT ON THE ROADWAY

5.1   In the presence of the Department Representative, bituminous mixture samples shall be lifted at pre-determined random locations, directly from the un-compacted mixture placed by the paving equipment, with a flat bottom, high-sided scoop. The scoop shall pass completely through the entire depth of the lift of material being sampled. When transferring the mixture into a clean cardboard sample box, any fines sticking to the INSIDE of the scoop shall be scraped and included with the sample.

5.1.1   For 3/4" (19 mm) and larger NMAS mixtures, a sample larger than is required in Section 4.1 may be obtained and placed on a mixing board, thoroughly mixed, formed into a flat pile and carefully quartered to provide a representative sample of the required size. Scrape the INSIDE of the scoop at each transfer point to incorporate any fines sticking to the inside of the scoop.

6.   PROCEDURE FOR SAMPLING FROM A HAULING UNIT

6.1   In the presence of the Department Representative, use a flat-bottom, high-sided scoop to obtain a bituminous mixture sample. Starting low on the pile and extending upward, sample the mixture by creating an approximately two (2) foot long and three (3) inches to four (4) inches deep vertical furrow. If the mixture is sampled from at least two places in the truck, place the material removed in this manner on a mixing board, thoroughly mix, form into a flat pile and carefully quarter to provide a representative sample of the required size. Scrape the INSIDE of the scoop at each transfer point to incorporate any fines sticking to the inside of the scoop.

7.   IDENTIFICATION AND DELIVERY OF SAMPLES

        7.1   Identify, using a permanent marker, package and immediately deliver bituminous mixture acceptance samples to the Department Representative as specified in Pub. 408, Section 409.

        7.2   Bituminous mixture acceptance samples shall be stored in a proper environment until the Lot is completed or has been terminated.

        7.3   After the Lot is completed or has been terminated, the Department Representative shall do the following:

        7.3.1   Complete a Form TR-447 for proper Lot identification.

        7.3.2   Using a permanent marker, write the TR-447 Sample Reference Number (A######) on the outside of each sample box and place the appropriate Bar Code Sticker from Form TR-447 on the outside of each sample box (Bar Code Sticker A######-1 on the sample box for Sublot # 1, etc.).

        7.3.3   Secure all the samples for the Lot together.

        7.3.4   Deliver the mixture acceptance samples to a Department pick-up point within three days for shipment to LTS.

8.   REFERENCES

        AASHTO T-168
        PTM No. 1

APPENDIX

Illustrative Example No. 1: Sampling Based on Tonnage

Total tonnage of Wearing Course

Normal Lot size	2500 tons
Number of Sublots in each Lot	5
Number of tons per Sublot	500 tons
Number of samples per Sublot	1

Select at random a series of five (5) consecutive numbers from PTM No. 1, Table 1 for the first Lot. Multiply the number of tons in a Sublot by the two place decimal value "X" to obtain the sample location within that Sublot. Multiply the pavement width by the two place decimal value "Y" to obtain the offset location for the sample. A typical stratified random sampling plan shall be similar to the following:

RANDOM NUMBER			NUMBER OF TONS/SUBLOT	WIDTH OF PAVEMENT
	X	Y		
#41	.27	.52L	.27(500 tons) = 135 tons	.52(12 ft) = 6.24 ft. L
#42	.39	.91R	.39(500 tons) = 195 tons	.91(12 ft) = 10.92 ft. R
#43	.57	.10L	.57(500 tons) = 285 tons	.10(12 ft) = 1.20 ft. L
#44	.82	.12L	.82(500 tons) = 410 tons	.12(12 ft) = 1.44 ft. L
#45	.14	.94L	.14(500 tons) = 70 tons	.94(12 ft) = 11.28 ft. L

The sampling sequence for a Lot of 2500 tons shall be as follows:

Sublot 1 = 135 tons; Sublot 2 = 500 + 195 = 695 tons; Sublot 3 = 1000 + 285 = 1285 tons; Sublot 4 = 1500 + 410 = 1910 tons; Sublot 5 = 2000 + 70 = 2070 tons

Looking at the information above this would mean the following: Hauling units containing the 135th ton would be sampled 6.24 ft. from the left edge of the paved lane; the 695th ton would be sampled 10.92 ft. from the right edge of the paved lane; the 1285th ton would be sampled 1.20 ft. from the left edge of the paved lane; the 1910th ton would be sampled 1.44 ft. from the left edge of the paved lane; the 2070th ton would be sampled 11.28 ft. from the left edge of the paved lane.

Note: When collecting samples from the roadway a Material Transfer Vehicle (MTV) is used in the paving train. Determine the amount of material carried in the paver hopper and the MTV. When the hauling unit carrying the sample tonnage empties into the MTV, allow the amount of material carried by the MTV and hopper to be placed prior to obtaining the sample from the roadway.

Illustrative Example No. 2: Sampling Based on Square Yards

Computing Theoretical Yield of Bituminous Pavement (from POM C/4/6)

Lift Depth (inch)	×	Compacted Conversion Factor (0.75 ft³/yd²·in)	=	Cubic Feet Per Square Yard (ft³/yd²)
½		0.75		0.3750
¾		0.75		0.5625
1		0.75		0.7500
1¼		0.75		0.9375
1½		0.75		1.1250
1¾		0.75		1.3125
2		0.75		1.5000
2¼		0.75		1.6875
2½		0.75		1.8750
2¾		0.75		2.0625
3		0.75		2.2500

Example:

Starting Station of Paving = 0 +00
Pavement Design depth = 1½ inches
Paving Width = 12ft.
Mix Design Laboratory (MDL) Specific Gravity (N_{des} Density G_{mb} from Mix Design) = 2.352

Normal Lot size	2500 tons
Number of Sublots in each Lot	5
Number of tons per Sublot	500 tons
Number of samples per Sublot	1

1. Calculate the theoretical yield to determine the weight of a square yard of pavement at the given depth:

   (*Cubic Feet Per Square Yard ft³/yd²) x (MDL Specific Gravity) x (62.4 lbs/ft³) = lbs/yd²

   (1.1250 ft³/yd²) x (2.352) x (62.4 lbs./ft³) = 165 lbs./yd²

   *From the chart above for the compacted lift depth being placed (1½ inches for this example)

Illustrative Example No. 2: Sampling Based on Square Yards (continued)

2. Find the length of the Lot in feet:

$(2,500 \text{ tons}) \times (2,000 \text{ lbs./ton}) \div (165 \text{ lbs./yd}^2) = 30,303 \text{ yd}^2$

$(30,303 \text{ yd}^2) \times (9 \text{ ft}^2/\text{yd}^2) \div (12 \text{ ft. lane width}) = 22,727 \text{ ft./Lot}$

$22,727 \text{ ft./Lot} \div 5 \text{ Sublots/Lot} = 4545.4 \text{ ft./Sublot}$

3. Determine sample locations:

Select at random a series of five (5) consecutive numbers from PTM No.1, Table 1 for the first Lot. Multiply the length of each Sublot by the two place decimal value "X" to obtain the sample locations within each Sublot. Multiply the pavement width by the two place decimal value "Y" to obtain the offset location for the sample. A typical stratified random sampling plan shall be similar to the following:

RANDOM NUMBER			LENGTH	WIDTH OF PAVEMENT
	X	Y	X	Y
#41	.27	.52L	.27 x 4,545.4 ft. = 1227 ft.	.52 x (12 ft.) = 6.24 ft. L
#42	.39	.91R	.39 x 4,545.4 ft. = 1773 ft.	.91 x (12 ft.) = 10.92 ft. R
#43	.57	.10L	.57 x 4,545.4 ft. = 2591 ft.	.10 x (12 ft.) = 1.20 ft. L
#44	.82	.12L	.82 x 4,545.4 ft. = 3727 ft.	.12 x (12 ft.) = 1.44 ft. L
#45	.14	.94L	.14 x 4,545.4 ft. = 636 ft.	.94 x (12 ft) = 11.28 ft. L

Note: The "X" value equals station along the pavement centerline.
The "Y" value equals the distance from the left or right edge of the paving lane.

Illustrative Example No. 2: Sampling Based on Square Yards (continued)

In summary the sampling for the Lot (22,727 ft.) shall be:

	Stations	X	Sample Location	Offset
Sublot 1	0+00 to 45+45	1227 ft.	12+27	6.24 ft. from L edge
Sublot 2	45+45 to 90+90	1773 ft.	63+18	10.92 ft. from R edge
Sublot 3	90+90 to 136+35	2591 ft.	116+81	1.20 ft. from L edge
Sublot 4	136+35 to 181+80	3727 ft.	173+62	1.44 ft. from L edge
Sublot 5	181+80 to 227+27	636 ft.	188+16	11.28 ft. from L edge

DIRECTION OF PAVING →
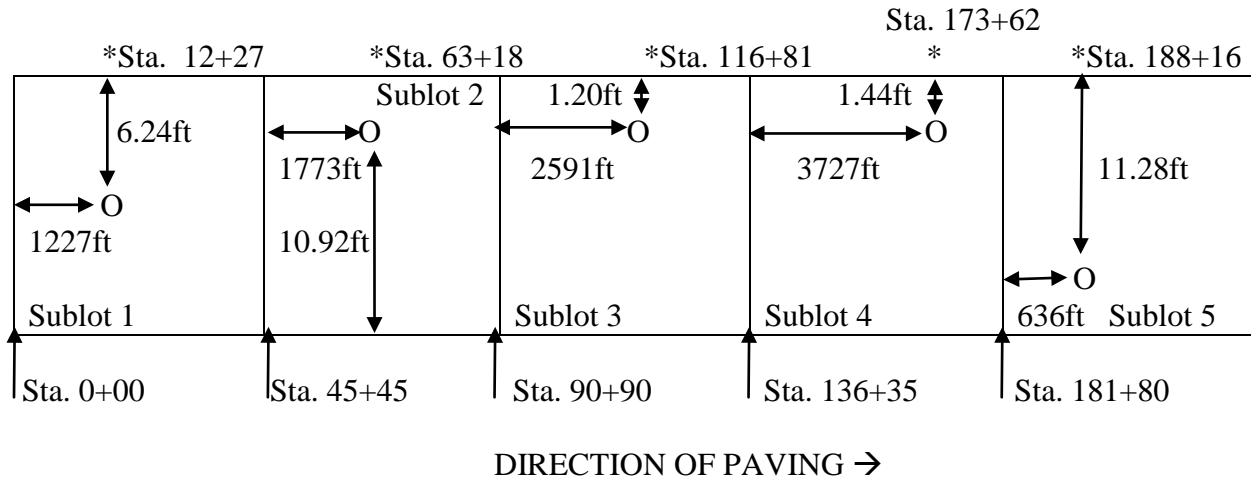
Illustrative Example No. 3: Quality Assurance Samples Based on Time

Assume the plant or project will be paving continuously throughout the day. Estimate the time needed for the plant/operation review. Divide this time into three (3) equal time intervals. For this example assume three (3) hours.

Each time interval will be one hour duration.

Select at random a series of three (3) consecutive numbers from PTM No. 1, Table 1. A typical stratified random sampling plan shall be similar to the following:

RANDOM NUMBER			TIME	WIDTH OF PAVEMENT
	X	Y	X	Y
#41	.27	.52L	.27 x 60 min. = 16 min.	.52 x (12 ft.) = 6.24 ft. L
#42	.39	.91R	.39 x 60 min. = 23 min.	.91 x (12 ft.) = 10.92 ft. R
#43	.57	.10L	.57 x 60 min. = 34 min.	.10 x (12 ft.) = 1.20 ft. L

The sampling times are indicated below:

8:00 am		9:00 am		10:00 am		11:00 am

x	x	x
8:16 am	9:23 am	10:34 am

For plant samples ignore the "Y" value. For roadway samples, determine the sample location on the mat using the "Y" value as indicated in the previous examples.

When it is not possible to obtain scheduled samples because of breakdown, weather, schedule, or other causes, it is still necessary to obtain a total of three samples wherever possible. Adjust the remaining intervals according to the situation and apply the originally selected random numbers as discussed above.

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF DISTRIBUTOR APPLICATION RATE IN THE FIELD

1.   SCOPE

1.l   This test method covers the procedure for determining the application rate in liters per square meter (gallons per square yard) of an approved pressure distributor (Note 1).

NOTE 1- Prior to the test, the pressure distributor shall be calibrated and any necessary adjustments made to give the desired rate of application. The height of the spray bar above the pavement surface shall be adjusted to assure uniformity of spread of the bituminous material without causing any streaking.

2.   EQUIPMENT

2.1   Carpenter's level- 1.2 m (48 inches) long

2.2   Manufacturer's certificate of calibration for the tank (Note 2)

2.3   A dipstick for the tank

NOTE 2- Most dipsticks furnished by manufacturers are calibrated in 95 to 189 liters (25 to 50 gallon) increments, depending upon tank size, however, it is necessary to check the contents of the tank more closely. Therefore, a calibration curve shall be prepared from the measurements on the dipstick so that the tank contents can be measured to the nearest 20 or 40 liters (five or ten gallons).

3.   SIGNIFICANCE

3.1   It is essential that the tank be level at the time of gauging.

3.2   The field application rate of the bituminous material at higher temperatures shall be determined by correcting for temperature using a Bulletin 25 conversion chart (Design Application Rate).

4.   PROCEDURE

4.1   Place a level on top of the tank. Raise or lower the front wheels of the truck until the tank is level (Note 3). The tank shall be level both lengthwise and width wise.

NOTE 3- The truck may be leveled by driving the front wheels into a gutter or up a slight incline.

4.2   Using a dipstick, measure the level of bituminous material in the tank. Calculate the contents of the tank in liters (gallons) (Q_1) from the calibration table (Section 2.2). Interpolate the quantities, if necessary (Note 4).

NOTE 4- For maximum accuracy in gauging, the tank should either be nearly full or nearly empty.

4.3   Select a test strip of a suitable length according to Table l and apply the bituminous material at the temperature corrected application rate.

TABLE l. LENGTH OF THE TEST STRIP

Application Rate L/m^2(gal/sq yd)	Length of the Test Strip, m(ft.)
Less than or equal to 0.45 (0.1)	300 (1000)
More than 0.45 (0.1)	150 (500)

4.4   Level the tank again and determine the level of bituminous material in the tank using the dipstick. Calculate the remaining contents of the tank in liters (gallons) (Q_2) from the calibration table. Interpolate the quantities, if necessary.

5.   CALCULATIONS

5.1   Calculate the application rate (G) in L/m^2 (gal/yd^2) as follows:

$$G = \frac{Q_1 - Q_2}{LW}$$

METRIC EQUATION

Where:

G = application rate in liters/m^2

Q_1 = quantity of bituminous material in liters in the tank before application

Q_2 = quantity of bituminous material in liters in the tank after application

L = length of the test strip in meters

W = width of the test strip in meters

$$G = \frac{9\,(Q_1 - Q_2)}{LW}$$

ENGLISH EQUATION

Where:

G = application rate in gallons/sq yd.

Q_1 = quantity of bituminous material in gallons in the tank before application

Q_2 = quantity of bituminous material in gallons in the tank after application

L = length of the test strip in feet

W = width of the test strip in feet

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LABORATORY TESTING SECTION

Method of Test for

APPARENT MOISTURE IN BITUMINOUS PAVING MIXTURES

1.   SCOPE

        This method describes the procedure to be used in determining the apparent moisture content of bituminous paving mixtures at the point of manufacture.

2.   APPARATUS

        2.1   A balance conforming to the requirements of AASHTO M-231, Class G2.

        2.2   A thermostatically controlled oven capable of maintaining the oven temperature at 163 ± 5ºC (325 ± 9º F).

        2.3   A drying pan of sufficient size for the moisture sample to be spread out to a maximum depth of 38 mm (1-1/2 inches) (Aluminum cake Pan 280 mm x 175 mm x 40 mm (11" x 7"x l-1/2")).

3.   PROCEDURE

        3.1   The material shall be sampled in a manner conforming to PTM 746 (Section 5). The size of the sample shall be approximately 1200 grams. In no case should the selection of a sample of pre-determined mass be attempted.

        NOTE 1- It is recommended that the sample for this test be obtained from the larger sample obtained from the routine extraction test.

        3.2   Determine the tare mass of the pan. Spread a sample of the mixture in a pan to a uniform depth.

        3.3   Immediately determine the mass of the pan and mixture (NOTE 2).

        NOTE 2- This mass must be taken as soon as possible but no longer than ten (10) minutes after the sample is obtained from the truck.

        3.4   Place the pan in the oven. After 20 minutes, weigh the pan and mixture and return

the pan and mixture to the oven for an additional 10 minutes. Again weigh the pan and mixture to check to see if constant mass has been achieved (NOTE 3). If the mixture has not achieved constant mass, continue the 10 minute heating and weighing cycles until constant mass has been obtained.

> NOTE 3- Constant mass shall be defined as the mass at which further drying at 163 ± 5 ºC ($325 \pm 9º$ F) does not alter the mass by more than 0.05 percent of the test load.

4.   CALCULATION

   4.1   Calculate the percent apparent moisture in the bituminous paving mixture as follows:

$$\% \text{ Apparent Moisture} = \frac{A - B}{B} \text{ x } 100$$

Where:

A = Original mass of the sample

B = Constant mass of the sample

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF OPTIMUM EMULSION CONTENT
FOR OPEN-GRADED EMULSION MIXTURES
(PENNSYLVANIA RUNOFF METHOD)

1.   SCOPE

1.1   This method covers procedures for preparing trial mixtures of open graded emulsion mixtures (such as, FB-1 and Moto-paver mixtures) using the job aggregate and a compatible emulsified asphalt for establishing an optimum emulsion content based upon the Pennsylvania Runoff Method.

2.   SUMMARY OF METHOD

2.1   Mixtures are made with varying emulsion contents in one percent increments and are subjected to the Pennsylvania Runoff method to determine the asphalt residue runoff. The emulsion content that gives an asphalt residue runoff of 10 grams is recommended as the optimum emulsion content.

3.   APPARATUS

3.1   Balance- Conforming to the requirements of AASHTO M-231, Class G2

3.2   Round, stainless steel mixing bowls

3.3   Serving spoon, long-handled

3.4   A 2.36 mm (No. 8) standard sieve, 203.2 mm (8 inches) in diameter, 50.8 mm (2 inches) high

3.5   Standard pan- 203.2 mm (8 inch) diameter, capable of an easy sliding fit with the 2.36 mm (No. 8) sieve placed over it

4.   PREPARATION OF MIXTURES

      4.1   Obtain a representative sample of dry job aggregate to be used.

      4.2   Obtain a representative sample of the emulsified asphalt to be used. It is assumed that the emulsified asphalt is compatible with the job aggregate.

      4.3   Pre-weigh a sufficient number of 2000 gram batch samples of the dry aggregate using the average stockpile gradation.

      4.4   Using stainless steel bowls; mix the aggregate with 40 grams of water (2%) until all the aggregate is damp. Cover the bowl with a clean cloth for 15 minutes.

      4.5   Add the appropriate amount of preheated 60 ℃ (140℉) emulsified asphalt to the dampened aggregate and prepare the mix by hand mixing for 2 minutes using a long-handled serving spoon. Observe and record the workability of the mix such as, stiff, O.K., and sloppy.

      NOTE 1- Use emulsion contents in 1.0% increments by mass of the dry aggregate. Start out with a 6% emulsion content for FB-1 wearing mixes and a 4.0% emulsion content for FB-1 binder mixes.

5.   TESTING PROCEDURE

      5.1   Immediately pour or spoon the whole batch of mix onto the 2.36 mm (No. 8) sieve, which is placed with a sliding fit above the tared standard pan. Prior to placing the mix, the 2.36 mm (No. 8) sieve shall be dampened with water.

      5.2   Allow the mix to drain into the standard pan for 30 minutes at ambient temperature.

      5.3   Lift off the 2.36 mm (No. 8) sieve containing the drained-off mix from the standard pan. Record the mass of the standard pan containing runoff as (W_1).

      5.4   Spread the mix from the 2.36 mm (No. 8) sieve onto a paper tray. Surface dry the mix with a fan and evaluate the percent coating.

      5.5   Place the standard pan containing runoff into a 110 ± 5℃ (230 ± 9℉) oven and dry to a constant mass. Determine and record the final mass (W_2).

6.   COMPUTATIONS

6.1   Calculate the total runoff as follows:

Total Runoff, grams = W_1 - Tared Weight of the Standard Pan

6.2   Calculate the asphalt residue runoff as follows:

Asphalt Residue Runoff, grams = W_2 - Tared Weight of the Standard Pan

7.   OPTIMUM EMULSION CONTENT DETERMINATION

7.1   Plot the Emulsion Content versus Asphalt Residue Runoff (grams) data on a graph and draw a smooth curve (Figure 1).

7.2   Draw a horizontal line at the 10 gram level on the Y-axis to intersect with the curve. Read the corresponding emulsion content on the X-axis. Report this emulsion content (to the nearest 0.1 percent) as the optimum emulsion content.

8.   REPORT

8.1   Report the following results:

    1.   Optimum Emulsion Content, percent

    2.   Mix Workability (Stiff, satisfactory or sloppy)

    3.   Mix Coating, percent

NOTE 2- At the optimum emulsion content the mix must have satisfactory workability and at least 90% coating for acceptance.
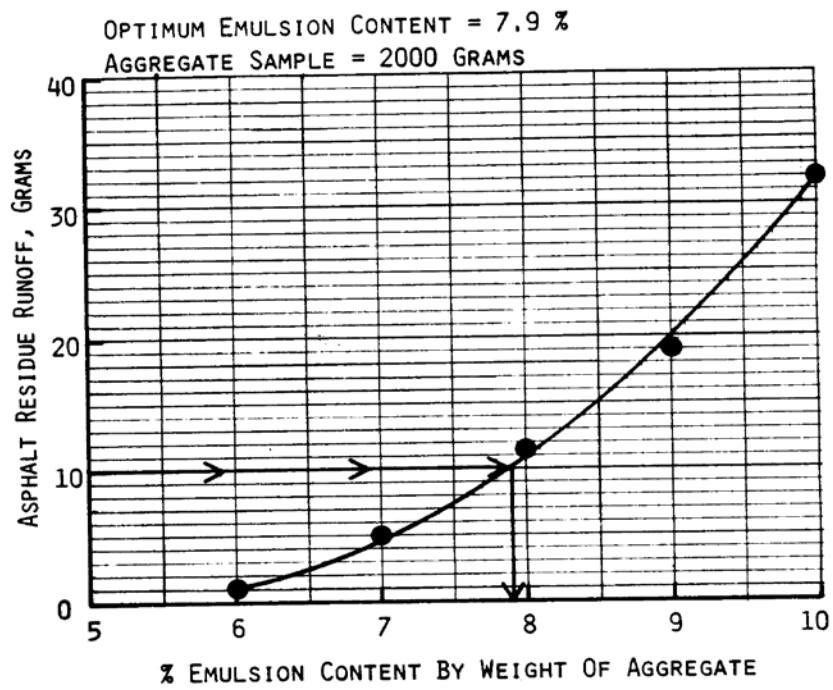
FIGURE 1

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LABORATORY TESTING SECTION

Method of Test for

MEASURING SURFACE MACROTEXTURE DEPTH
USING A VOLUMETRIC TECHNIQUE
AND DETERMINING PATTERN SEGREGATION

1.   SCOPE

1.1   This method of test, which is a modification of ASTM E965, outlines the procedure for determining the average depth of a pavement surface macrotexture by careful application of a known volume of material on the pavement surface and subsequent measurement of the total area covered. This technique is designed to provide an average depth value of only the pavement macrotexture and is considered insensitive to pavement microtexture characteristics. This method of test is also used to determine pattern segregation in bituminous concrete pavements.

NOTE 1- Pavement macrotexture is defined as the deviations of a pavement surface from a true planar surface. Average texture depth is the average depth between the bottom of the pavement surface voids and the tops of the surface aggregate particles. This test method is considered insensitive to distinguishing between (+) and (-) deviations of a pavement surface from a true planar surface.

NOTE 2- The pavement surface to be measured using this test method must be dry and free of any construction residue, surface debris, and loose aggregate particles that would be displaced or removed during normal environmental and traffic conditions.

2.   APPARATUS AND MATERIAL

2.1   Scale- A standard 300-millimeter (12-inch) scale having 2.0 millimeter (0.1 inch) divisions.

2.2   Sample Container- A cylindrical plastic or metal container with an internal volume of approximately 20,000 cubic millimeters (1.2 cubic inches) used to determine the volume of material to be spread on the pavement surface. An 18 mL polyethylene vial with a friction fit snap closure (Fisher Cat. #03-388-E) is suitable and is the standard container used to develop Table 1 in Section 4.

2.3   Spreader Tool- A #14 solid rubber stopper (Fisher Cat. #14-130V) or an ice hockey puck is suitable.

2.4   Brushes- Any size of paint brush with a soft bristle is suitable for cleaning loose debris and aggregate particles away from the test locations.

NOTE 3- If it is necessary to test locations that are contaminated with dried mud or other tightly adhering foreign material, a stiff wire brush shall be used to thoroughly clean the area prior to testing.

2.5   Material Storage Container- A one (1) liter (1-quart) plastic sample bottle with a lid is suitable for storing, transporting, and maintaining dry testing material. The container shall be kept sealed except for filling sample containers and recharging.

2.6   Material- Either of the following dry, clean materials is suitable.

NOTE 4- Use the same material for testing each area when conducting pattern segregation tests.

2.6.1   Solid glass beads- Tested by ASTM Test Method D1155 (70% roundness). The beads shall be graded such that 100% of the sample passes a 1.18 mm (No. 16) sieve, and no more than 5% of the sample passes the 150 µm (No. 100) sieve.

2.6.2   Standard graded sand- Meeting the requirements of ASTM Specification C778, Table 1.

2.7   Wind Screen- Any suitable method may be used to prevent turbulence from disturbing the material during the test. A 330 millimeter (13-inch) tubeless tire is the minimum sized tire that is suitable to be used as a shield. This tire is to be placed on the pavement surface around the test site when sufficiently windy conditions prevail or turbulence is created by traffic such that the test procedure is disturbed without the shield.

3.   PROCEDURE

3.1   Test Surface- Inspect the pavement surface to be measured and select a dry, homogeneous area that contains no unique, localized features such as cracks or joints. Thoroughly clean the pavement surface using a soft bristle brush to remove any residue, debris, or loosely bonded aggregate particles that are on the surface (See NOTES 2 and 3). Position the portable windscreen around the surface test area, if necessary.

3.2   Material Sample Preparation- Fill the sample container with dry material and gently tap the base of the cylinder three times on a rigid surface. Add more material to fill the cylinder to the top, and level the cylinder with a straight-edge.

3.3   Test Measurement- Pour the measured volume of material onto a clean test surface within the area protected by the windscreen. Carefully spread the material in a circular

patch with the spreader tool, filling the surface voids flush with the aggregate particle tips. Measure and record the diameter of the circular area covered by the material using the scale. Perform a minimum of three readings on the circular patch. Determine the radius by dividing the average diameter reading by 2. Record the measurements to the nearest 2.5 millimeters (0.1 inch).

Example of circular patch measurements:
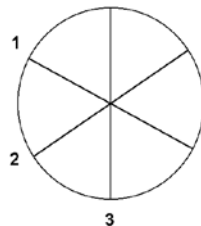
> NOTE 5- For very smooth pavement surfaces where test patch diameters exceed 203 millimeters (8-inches), it is recommended that the pavement be re-tested using a smaller sample container. (A 12 mL polyethylene vial, Fisher Cat. #03-388C, with an actual volume of 14 000 mm^3 is suitable for such cases).

> NOTE 6- For coarse open pavements, it may be necessary to use two or more 18 mL polyethylene vials.

3.4   Number of Test Measurements for Determining Surface Macrotexture when Used to Evaluate Surface Frictional Characteristics- The same operator shall perform at least 5 randomly selected measurements, utilizing PTM No. 1, per lane kilometer (mile) of a given test pavement surface type. Measurements shall be determined in either the right or left wheel path for each longitudinal offset calculated.

3.5   Number of Test Measurements for Determining Pattern Segregation- Perform a minimum of three tests in the suspected segregated area. Perform an equal number of tests in an acceptable area using PTM No. 1. Calculate the average radius for each area, suspected and acceptable. Determine the average texture depth for each area in accordance with Section 4. Calculate the difference between the average texture depths of suspected and acceptable areas to determine pattern segregation.

Example:

4. CALCULATION

    4.1   When using a standard sample container (18 mL Fisher vial), refer to the Table 1 Conversion Table, and convert each radius measurement to an average Texture Depth (T.D). Calculate and record an Average Surface Macrotexture Depth (ASMD) to 0.0254 mm (0.001 in.), and a Standard Deviation (S) for the measurements for each pavement surface type. Use Table 2 for the two 18 mL polyethylene vials. When more than two 18 mL polyethylene vials are used, follow the calculation procedure listed in Section 4.2.

        4.1.1   Calculate the ASMD by:

$$\text{ASMD} = \frac{\text{Sum of T.D. Measurements}}{\text{Number of Measurements}}$$

        4.1.2   Calculate the S by:

$$S = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}$$

    Where:

S= Standard deviation   n = Number of measurements

$\overline{X}$ = ASMD X_i= Individual T.D. measurement

$\sum_{i=1}^{n}$ = Sum of the squares of the deviation from ASMD

4.2   When using a container other than the standard sample container, use the following procedure:

        4.2.1   Cylinder Volume- Calculate the internal volume of the sample cylinder as follows:

$$V = \frac{\pi\, d^2\, h}{4}$$

Where:

V = Internal cylinder volume, mm^3 (in^3)

d = Internal cylinder diameter, mm(in.)

h = Cylinder height, mm (in.)

        4.2.2   Average Texture Depth - Calculate the average Texture Depth (T.D.) using the following equation:

$$T.D. = \frac{V}{\pi\, R^2}$$

Where:

T.D. = average texture depth, mm (in.)

V   = sample volume, mm^3 (in^3)(calculated in Section 4.2.1)

R   = average radius of the area covered by the material, mm (in.)

Calculate and record an Average Surface Macrotexture Depth (ASMD) to 0.025 mm (0.001 in.) and a Standard Deviation (S) as shown in Sections 4.1.1 and 4.1.2 for each pavement surface type.

5.   REPORT

    5.1   The report for each pavement test surface type shall contain the following items:

        5.1.1   Date of Testing

        5.1.2   Identify the roadway (Co., SR, Seg.) and pavement surface type (seal coat, etc.)

        5.1.3   Record each test location (Seg. offset, L or R wheel path) with an average texture depth (T.D.) determined for each location.

        5.1.4   For each pavement surface type report the following: Average Surface Macrotexture Depth (ASMD), Range (R) of measurements, and the Standard Deviation (S).

6.   REFERENCES

    ASTM E965
    British Standards - Sand Patch Method

TABLE 1- STANDARD MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius		Texture Depth		Radius		Texture Depth	
mm	(in)	mm	(in)	mm	(in)	mm	(in)
50.8	2.0	2.47	0.097	129.5	5.1	0.380	0.015
53.3	2.1	2.24	0.088	132.1	5.2	0.365	0.014
55.9	2.2	2.04	0.080	134.6	5.3	0.352	0.014
58.4	2.3	1.87	0.073	137.2	5.4	0.338	0.013
61.0	2.4	1.71	0.067	139.7	5.5	0.326	0.013
63.5	2.5	1.58	0.062	142.2	5.6	0.315	0.012
66.0	2.6	1.46	0.057	144.8	5.7	0.304	0.012
68.6	2.7	1.35	0.053	147.3	5.8	0.294	0.012
71.1	2.8	1.26	0.050	149.9	5.9	0.283	0.011
73.7	2.9	1.17	0.046	152.4	6.0	0.274	0.011
76.2	3.0	1.10	0.043	154.9	6.1	0.265	0.010
78.7	3.1	1.03	0.040	157.5	6.2	0.257	0.010
81.3	3.2	0.964	0.038	160.0	6.3	0.249	0.010
83.8	3.3	0.907	0.036	162.6	6.4	0.241	0.009
86.4	3.4	0.853	0.034	165.1	6.5	0.234	0.009
88.9	3.5	0.806	0.032	167.6	6.6	0.227	0.009
91.4	3.6	0.762	0.030	170.2	6.7	0.220	0.009
94.0	3.7	0.721	0.028	172.7	6.8	0.214	0.008
96.5	3.8	0.684	0.027	175.3	6.9	0.207	0.008
99.1	3.9	0.649	0.026	177.8	7.0	0.201	0.008
101.6	4.0	0.617	0.024	180.3	7.1	0.196	0.008
104.1	4.1	0.588	0.023	182.9	7.2	0.190	0.007
106.7	4.2	0.559	0.022	185.4	7.3	0.185	0.007
109.2	4.3	0.534	0.021	188.0	7.4	0.180	0.007
111.8	4.4	0.510	0.020	190.5	7.5	0.176	0.007
114.3	4.5	0.488	0.019	193.0	7.6	0.171	0.007
116.8	4.6	0.467	0.018	195.6	7.7	0.166	0.007
119.4	4.7	0.447	0.018	198.1	7.8	0.162	0.006
121.9	4.8	0.429	0.017	200.7	7.9	0.158	0.006
124.5	4.9	0.411	0.016	203.2	8.0	0.154	0.006
127.0	5.0	0.395	0.016				

* Valid only when using <u>ONE</u> standard container as specified in Section 2.2 (18 ml vial, Fisher Cat. # 03-388-E, with an actual volume of 20,000 mm^3) or an equivalent container with a measured volume of 20,000 mm^3 (1.2204 in^3).

TABLE 2 - COARSE MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius		Texture Depth		Radius		Texture Depth	
mm	(in)	mm	(in)	mm	(in)	mm	(in)
50.8	2.0	4.94	0.194	129.5	5.1	0.760	0.030
53.3	2.1	4.48	0.176	132.1	5.2	0.730	0.029
55.9	2.2	4.08	0.161	134.6	5.3	0.703	0.028
58.4	2.3	3.74	0.147	137.2	5.4	0.677	0.027
61.0	2.4	3.42	0.135	139.7	5.5	0.653	0.026
63.5	2.5	3.16	0.124	142.2	5.6	0.630	0.025
66.0	2.6	2.92	0.115	144.8	5.7	0.608	0.024
68.6	2.7	2.71	0.107	147.3	5.8	0.587	0.023
71.1	2.8	2.52	0.099	149.9	5.9	0.567	0.022
73.7	2.9	2.35	0.092	152.4	6.0	0.548	0.022
76.2	3.0	2.19	0.086	154.9	6.1	0.531	0.021
78.7	3.1	2.06	0.081	157.5	6.2	0.514	0.020
81.3	3.2	1.927	0.076	160.0	6.3	0.498	0.020
83.8	3.3	1.814	0.071	162.6	6.4	0.482	0.019
86.4	3.4	1.706	0.067	165.1	6.5	0.467	0.018
88.9	3.5	1.612	0.063	167.6	6.6	0.454	0.018
91.4	3.6	1.525	0.060	170.2	6.7	0.440	0.017
94.0	3.7	1.442	0.057	172.7	6.8	0.427	0.017
96.5	3.8	1.368	0.054	175.3	6.9	0.415	0.016
99.1	3.9	1.297	0.051	177.8	7.0	0.403	0.016
101.6	4.0	1.234	0.049	180.3	7.1	0.392	0.015
104.1	4.1	1.176	0.046	182.9	7.2	0.381	0.015
106.7	4.2	1.119	0.044	185.4	7.3	0.371	0.015
109.2	4.3	1.068	0.042	188.0	7.4	0.360	0.014
111.8	4.4	1.019	0.040	190.5	7.5	0.351	0.014
114.3	4.5	0.975	0.038	193.0	7.6	0.342	0.013
116.8	4.6	0.934	0.037	195.6	7.7	0.333	0.013
119.4	4.7	0.894	0.035	198.1	7.8	0.325	0.013
121.9	4.8	0.857	0.034	200.7	7.9	0.316	0.012
124.5	4.9	0.822	0.032	203.2	8.0	0.309	0.012
127.0	5.0	0.790	0.031				

* Valid only when using <u>TWO</u> standard containers as specified in Section 2.2 (Two 18 mL vials Fisher Cat. #03-388-E with an actual total volume of 40 000 mm^3) or an equivalent container with a measured volume of 40 000 mm^3 (2.4408 in^3).

TABLE 3 - VERY SMOOTH MIXES
AVERAGE TEXTURE DEPTH*
CONVERSION FROM RADIUS

Radius		Texture Depth		Radius		Texture Depth	
mm	(in)	mm	(in)	mm	(in)	mm	(in)
50.8	2.0	1.73	0.068	129.5	5.1	0.266	0.010
53.3	2.1	1.57	0.062	132.1	5.2	0.256	0.010
55.9	2.2	1.43	0.056	134.6	5.3	0.246	0.010
58.4	2.3	1.31	0.051	137.2	5.4	0.237	0.009
61.0	2.4	1.20	0.047	139.7	5.5	0.228	0.009
63.5	2.5	1.11	0.044	142.2	5.6	0.220	0.009
66.0	2.6	1.02	0.040	144.8	5.7	0.213	0.008
68.6	2.7	0.95	0.037	147.3	5.8	0.205	0.008
71.1	2.8	0.88	0.035	149.9	5.9	0.198	0.008
73.7	2.9	0.82	0.032	152.4	6.0	0.192	0.008
76.2	3.0	0.77	0.030	154.9	6.1	0.186	0.007
78.7	3.1	0.72	0.028	157.5	6.2	0.180	0.007
81.3	3.2	0.675	0.027	160.0	6.3	0.174	0.007
83.8	3.3	0.635	0.025	162.6	6.4	0.169	0.007
86.4	3.4	0.597	0.024	165.1	6.5	0.164	0.006
88.9	3.5	0.564	0.022	167.6	6.6	0.159	0.006
91.4	3.6	0.534	0.021	170.2	6.7	0.154	0.006
94.0	3.7	0.505	0.020	172.7	6.8	0.149	0.006
96.5	3.8	0.479	0.019	175.3	6.9	0.145	0.006
99.1	3.9	0.454	0.018	177.8	7.0	0.141	0.006
101.6	4.0	0.432	0.017	180.3	7.1	0.137	0.005
104.1	4.1	0.411	0.016	182.9	7.2	0.133	0.005
106.7	4.2	0.392	0.015	185.4	7.3	0.130	0.005
109.2	4.3	0.374	0.015	188.0	7.4	0.126	0.005
111.8	4.4	0.357	0.014	190.5	7.5	0.123	0.005
114.3	4.5	0.341	0.013	193.0	7.6	0.120	0.005
116.8	4.6	0.327	0.013	195.6	7.7	0.117	0.005
119.4	4.7	0.313	0.012	198.1	7.8	0.114	0.004
121.9	4.8	0.300	0.012	200.7	7.9	0.111	0.004
124.5	4.9	0.288	0.011	203.2	8.0	0.108	0.004
127.0	5.0	0.276	0.011				

* Valid only when using <u>ONE</u> standard container as specified in Section 3.3 (12 mL vial Fisher Cat. #03-388-C with an actual volume 0f 14 000 mm^3) or an equivalent container with a measured volume of 14 000 mm^3 (0.8543 in^3).

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LABORATORY TESTING SECTION

Method of Test for

DETERMINATION OF ASPHALT CONTENT AND GRADATION OF
BITUMINOUS MIXTURES BY THE IGNITION METHOD

1.   SCOPE

1.1   This test method covers the determination of asphalt content of bituminous mixtures by the ignition of the asphalt binder at 538 ± 5°C (1000 ± 9°F) in a furnace, and is a modification of AASHTO T-308. The aggregate remaining after burning can be used for the sieve analysis using AASHTO T-30 as modified herein.

1.2   The values in metric units are to be regarded as the standard.

1.3   This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2.   SUMMARY OF TEST METHODS

2.1   The asphalt binder in the bituminous mixture is ignited using the furnace equipment applicable to the particular method. The asphalt content is calculated as the difference between the initial mass of the bituminous mixture and the mass of the residual aggregate, any calibration factor(s) and moisture content. The asphalt content is expressed as a mass percent of the moisture-free mixture.

3.   SIGNIFICANCE AND USE

3.1   This method can be used for quantitative determinations of asphalt binder content and gradation in bituminous paving and patching mixtures and pavement samples for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to AASHTO T-30 as modified herein.

4.   SAMPLING

    4.1   Obtain samples of aggregate in accordance with AASHTO T-2.

       4.1.1   The test specimen shall be the end result of quartering a larger sample taken in accordance with AASHTO T-248.

    4.2   Obtain samples of asphalt binder in accordance with AASHTO T-40.

    4.3   Obtain samples of freshly produced bituminous mixture in accordance with PTM 746, or samples of compacted roadway in accordance with PTM 729, or prepared mixture samples composed of the design aggregate structure and design asphalt content as directed in Section 5.2 for mix calibration.

       4.3.1   The size of the test sample shall be the result of quartering from a larger sample, according to PTM 746 and shall conform to the mass requirement in Table 1. Specimen size shall not be more than 200 grams greater than the minimum recommended specimen size.

Table 1

Bituminous Mixture	Minimum Mass of Specimen, g
SP9.5, SP12.5, FJ's, ID2W, ID2WHD, FB1W, FB2W, FB3Mod, Micro-Surfacing, Ultra-Thin Friction Course, Cold Patch	1200
SP19, ID3W, ID2B, ATPBC, FB1B, FB2B, FBMod, SMA	1500
SP25, SP37.5, BCBC, ID2BHD	2000

5.   CALIBRATION

    5.1   Apparatus Calibration and Certification

       5.1.1   Items requiring periodic verification by calibration include ignition furnaces and balances. Calibration is performed annually using standards traceable to nationally or internationally recognized standards. Calibration services may be performed by the original manufacturer or by other outside certified agencies.

       5.1.2   Ignition Furnaces and their internal balances shall be calibrated using the manufacturer's procedure and tolerances for temperature and mass determination. Each furnace or balance is given a calibration status, which indicates the most recent calibration date.

        5.1.3   Balances used to weigh pans, baskets, or graded aggregate shall be calibrated to conform to the tolerances outlined in the most recent edition of AASHTO M-231 (Standard Specification for Weighing Devices Used in the Testing of Materials) for the type and class of balance being used.

        5.2   Mix Calibration

        5.2.1   This method may be affected by the type of aggregate in the mixture. The results may also be affected by the presence of additives and modifiers. Accordingly, to optimize accuracy, a Calibration factor (Cf) shall be established by testing a set of calibration samples for each mix type. This procedure must be performed before any acceptance testing is completed.

        5.2.2   The calibration shall be repeated each time if there is a change in the mix ingredients or design.

        5.2.3   According to the requirements of Section 4, prepare two calibration samples at the design asphalt content and aggregate structure, which shall also include additives and modifiers, if any. Prior to mixing, prepare a butter mix at the design asphalt content. The purpose of the butter mix is to condition the mixing bowl to provide a coating of asphalt and fines in the bowl. Mix and discard the butter mix prior to mixing any of the calibration specimens to ensure accurate asphalt content. Aggregate used for the calibration specimens shall be sampled from stockpiled material produced in the current production season and designated for use on the candidate project. Any method may be used to combine the aggregates, however, an additional "blank" specimen shall be batched and tested for the aggregate gradation according to AASHTO T-30. The washed gradation shall fall within the mix design tolerances.

        5.2.4   The freshly mixed specimens may be placed directly in the sample baskets except for mixtures containing cutbacks or emulsions as directed in Section 7.2. If allowed to cool, the samples must be preheated in a $163 \pm 5°C$ ($325 \pm 9°F$) oven for 25 minutes. Do not preheat the sample baskets.

        5.2.5   Test the specimens in accordance with Sections 8 and 9 (Test Method A) or Sections 10 and 11 (Test Method B).

        5.2.6   Once all of the calibration specimens have been burned, determine the measured asphalt content for each sample by calculation or from the furnace printout.

        5.2.7   If the difference between the measured asphalt contents of the two samples exceeds 0.15 percent, repeat the two tests, and from the four tests, discard the high and low result. Determine the Cf from the two remaining results. Calculate the difference between the measured and actual asphalt content for each sample. The Cf is the average of the differences expressed in percent by weight of the asphalt mixture, (measured-actual). Sign convention (+/-) is important and must be maintained.

5.2.8   It will be necessary to determine a separate Cf for the material passing the 75µm (No. 200) sieve. Perform a gradation analysis on the residual aggregate as indicated in Section 12. Compare this gradation, to the gradation of the unburned, "blank" specimen in Section 5.2.3, to evaluate the amount of aggregate breakdown. The No. 200 sieve Cf shall be the average percent passing the 75 µm (No. 200) sieve of the burnt samples minus the percent passing the 75 µm (No. 200) sieve of the blank sample.

5.3   RAP Calibration Factor Determination

5.3.1   Test a minimum of four 100% RAP samples. The sample size shall conform to Table 1. Test each sample according to Method A or Method B (60 minute burn time) to determine the AC content of each.

5.3.2   Determine the average total loss of the four samples. Subtract 0.5% from the average total percent loss (NOTE 1). This is the corrected percent of AC of the RAP (Pbr).

> NOTE 1- Since it is difficult and time consuming to determine the actual Cf for 100% RAP without a blank (virgin) aggregate specimen, 0.5% will be the standard Cf for 100% RAP. Only if prior testing experience with a specific RAP source indicates inadequate accuracy when compared to alternate methods, such as solvent extraction, should this standard factor (0.5%) not be used.

5.3.3   The value determined in Section 5.3.2 will be considered the corrected percent of asphalt in the RAP (Pbr).

5.3.4   Perform a sieve analysis (Washed) on three of the incinerated RAP samples as per Section 12. The average of the three samples will be considered the gradation for the 100% RAP. The fourth incinerated (unwashed) sample will be used to make the blank sample in Section 5.3.5.

5.3.5   Batch and test two calibration samples (plus a butter mix) according to Section 5.2.3, and according to the proportions of RAP and virgin materials established in the JMF. Also batch a blank sample (aggregate only) meeting the JMF of the RAP/virgin aggregate combination, using material from the unwashed RAP sample of Section 5.3.4. The actual asphalt content used to calculate the Cf shall be a combination of the Pbr and the virgin asphalt added. The No.200 sieve Cf shall be the average percent passing the 75 µm (No. 200) sieve of the burnt samples minus the percent passing the 75 µm (No. 200) sieve of the blank sample.

5.3.6   Calculations for Cf for mixtures with RAP:

Actual asphalt % = [(%RAP/100) x Pbr] + % Virgin Asphalt Added

Pbr = Corrected Percent Asphalt in 100% RAP

% Virgin Asphalt Added = % of new asphalt by total mix weight

EXAMPLE: If THE JMF INDICATES 20% RAP Material:

6.2% Avg. Total Loss

Pbr = 6.2% - 0.5% = 5.7%

4.3% new asphalt added

THEN: Actual Asphalt % = [(20/100) x 5.7] + 4.3%
             Actual Asphalt % = 1.14% + 4.3% = 5.44%

$$Cf = \frac{[(D1 - P1) + (D2 - P2)]}{2}$$

Where: D1, D2 = Total sample loss in percent for Calibration samples 1 and 2.
             P1, P2 = Actual asphalt % for Calibration samples 1 and 2.

IF: D1 = 5.52%
             D2 = 5.61%
             P1 and P2 = 5.44%

THEN: Cf = 0.13%

6.   MOISTURE CONTENT

6.1   Determine the moisture content of a representative portion of the mixture according to PTM 749 Apparent Moisture In Bituminous Paving Mixtures.

NOTE 2- The Moisture Content Test is conducted only when water is known or suspected to be present.

7.   SAMPLE PREPARATION

7.1   If the mixture is not sufficiently soft to separate with a spatula, scoop, or trowel, place 2000 to 5000 grams in an oven at 163 ± 5°C (325 ± 9°F) for a maximum of two hours or on a hot plate over low heat, until the mixture can be handled. Use care not to fracture the mineral particles. Thoroughly mix and form into a flat pile and quarter to the required size.

7.2   Mixtures containing liquid bituminous materials such as cutbacks and emulsified asphalt shall be cured before testing.

7.2.1   All bituminous mixtures containing emulsified asphalt and cutback asphalt shall be spread uniformly on a tray of sufficient size to hold the total sample. Place the sample in an oven maintained at 163 ± 5°C (325 ± 9°F) for approximately 15 minutes, remove and weigh. Place the sample back in the oven and remove at approximately 15 minute intervals, mixing occasionally, until the sample has reached constant mass.

NOTE 3- Constant mass will be defined as the mass at which further drying at 163 ± 5°C (325 ± 9°F) does not alter the mass by more than 0.6 grams.

TEST METHOD A

8.   APPARATUS

8.1   Ignition furnace- A forced air ignition furnace, capable of maintaining the temperature at 578 ± 5°C (1072 ± 9°F), with an internal balance thermally isolated from the furnace chamber accurate to 0.1 g. The balance shall be capable of weighing a 3500 gram sample in addition to the sample baskets. A data collection system shall be included so that the weight can be automatically determined and displayed during the test. The furnace shall have a built in computer program to calculate the change in mass of the sample and provide for the input of a correction factor for determining the aggregate loss. The furnace shall produce a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt content (%), test time, and test temperature. The furnace chamber dimensions shall be adequate to accommodate a sample size of 3500 grams. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the

total sample mass for three consecutive minutes. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method of reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside. When set up properly the furnace shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with the capability of pulling air through the furnace to expedite the test, and to reduce the escape of smoke into the laboratory.

8.2   Sample basket(s)- Of an appropriate size that allows the samples to be thinly spread, and allows airflow through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh or a perforated stainless steel plate, or other suitable material.

NOTE 4- Screen mesh or other suitable materials with maximum and minimum openings of 2.36 mm (No. 8) and 600 μm (No. 30), respectively, have been found to perform well.

8.3   Catch Pan- Of sufficient size to hold the sample basket(s) so that aggregate particles and melted asphalt binder falling through the screen mesh are caught.

8.4   Oven- Capable of maintaining 163 ± 5ºC (325 ± 9ºF)

8.5   Balance- External balance used to weigh pans, baskets, bituminous samples, or graded aggregate, conforming to AASHTO M-231 Class G2.

8.6   Safety Equipment - Safety glasses or a face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding 650ºC (1202ºF), and a protective cage capable of surrounding the sample and baskets during the cooling period

8.7   Miscellaneous Equipment - A pan larger than the sample basket(s) for transferring the sample after ignition, spatulas, scoops, bowls, and wire brushes

9.   TEST PROCEDURES

9.1   Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F). Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record it automatically.

9.2   The Cf value shall be entered into the ignition furnace for the specific mix to be tested as determined in Section 5.2 or 5.3.

9.3   Weigh and record the mass of the sample basket(s) and catch pan (with guards in place).

9.4   Prepare the sample as described in Section 7. Evenly distribute the required

amount of sample in the sample basket(s) that have been placed in the catch pan, taking care to keep the material away from the edges of the basket. While transferring the mix into the baskets, any fine mix sticking to the inside of the spatula shall be scraped and included in the sample. Use a spatula or trowel to level the specimen. The required sample sizes are listed in Section 4, Table 1.

9.5   Weigh and record the total mass of the sample, basket(s), catch pan, and basket guards. Calculate and record the initial mass of the specimen (total mass - the mass of the specimen basket assembly).

9.6   Input the initial mass of the specimen, in whole grams, into the ignition furnace controller. Press the enter key. Verify that the correct mass has been entered.

9.7   Open the chamber door and place the sample baskets in the furnace. Close the chamber door and verify that the sample mass (including the basket(s)) displayed on the furnace scale equals the total mass recorded in Section 9.5 within ± 5 g. Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall. Initiate the test by pressing the start/stop button. This will lock the sample chamber and start the combustion blower.

NOTE 5- The furnace temperature will drop below the set point when the door is opened, but will recover with the door closed and when ignition occurs. Sample ignition typically increases the temperature well above the set point, depending on sample size and asphalt content.

9.8   Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01 percent for three consecutive minutes). Press the start/stop button. This will unlock the sample chamber and cause the printer to print out the test results.

9.9   Open the chamber door, remove the sample basket(s) and allow the baskets to cool to room temperature (approximately 30 minutes).

9.10   Use the corrected asphalt content (%) from the furnace printout. If a moisture content has been determined, subtract the moisture content from the printed ticket corrected asphalt content and report the difference as the corrected asphalt content.

NOTE 6- In the event of a suspect result, it is recommended that the burnt aggregate be weighed after the aggregate has cooled (Never weigh the baskets hot, see Section 9.9) and calculate the asphalt content manually (see the formula in Section 11.15).

TEST METHOD B

10.   APPARATUS

10.1   Ignition Furnace- A forced air furnace, capable of maintaining the temperature at 578 ± 5°C (1072 ± 9°F). The furnace chamber dimensions shall be adequate to accommodate a sample size of 3500 grams. The furnace door shall be equipped so that the door cannot be opened during the ignition test. A method of reducing furnace emissions shall be provided. The furnace shall be vented into a hood or to the outside. When set up properly the furnace shall have no noticeable odors escaping into the laboratory. The furnace shall have a fan with the capability of pulling air through the furnace to expedite the test, and to reduce the escape of smoke into the laboratory.

10.2   Sample basket(s)- Of an appropriate size that allows the samples to be thinly spread out and allows airflow through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh or a perforated stainless steel plate or other suitable material.

NOTE 7- Screen mesh or other suitable materials with maximum and minimum openings of 2.36 mm (No. 8) and 600 μm (No. 30), respectively, have been found to perform well.

10.3   Catch Pan- Of sufficient size to hold the sample basket(s) so that aggregate particles and melted asphalt binder falling through the screen mesh are caught.

10.4   Oven- capable of maintaining 163 ± 5°C (325 ± 9°F)

10.5   Balance- Of sufficient capacity and conforming to the requirements of AASHTO M-231, Class G2 for weighing the specimen and basket(s).

10.6   Safety Equipment- Safety glasses or a face shield, high temperature gloves, long sleeve jacket, a heat resistant surface capable of withstanding 650°C (1202°F), and a protective cage capable of surrounding the sample and baskets during the cooling period

10.7   Miscellaneous Equipment- A pan larger than the sample basket(s) for transferring the sample after ignition, spatulas, scoops, bowls, and wire brushes

11.   TEST PROCEDURES

11.1   Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F).

11.2   Enter the Cf value into the ignition furnace for the specific mix to be tested as determined in Section 5.2 or 5.3.

11.2 Weigh and record the mass of the sample basket(s) and each pan (with guards in

place).

11.4   Prepare the sample as described in Section 7. Place the sample baskets in the catch pan. Evenly distribute the sample in the basket(s) taking care to keep the material away from the edge.

11.5   Weigh and record the total mass of the sample, basket(s), catch pan, and basket guards. Calculate and record the initial mass of the specimen (total mass - the mass of the specimen basket assembly).

11.6   Burn the sample in the furnace for at least 45 minutes.

NOTE 8- The appropriate time for the initial burn of a sample is dependent on the sample size. For large samples, the time could be significantly longer than 45 minutes. See the manufacturer's manual for guidelines.

11.7   Remove the sample from the furnace after ignition and allow the sample to cool to approximately room temperature (at least 30 minutes).

11.8   Weigh and record the mass (W_a) of the sample after ignition to the nearest 0.1 gram.

11.9   Return the sample to the furnace.

11.10   After the furnace reaches the set temperature, burn the sample for at least 15 minutes.

11.11   Remove the sample from the furnace and allow it to cool to approximately room temperature (at least 30 minutes).

11.12   Weigh and record the mass (W_a) of the sample after ignition.

11.13   Repeat these steps until the change in measured mass (W_a) of the sample after ignition does not exceed 0.01 percent of the initial sample mass (W_s).

11.14   Record the last value obtained for (W_a) as the mass (W_a) of the sample after ignition.

NOTE 9- Steps 11.9 through 11.14 may not be necessary if it can be demonstrated from the mix calibration data that constant mass can be achieved by heating the sample for the same time as the calibration samples. The type and mass of the sample being tested shall be reasonably close (within 200 grams) to those of the calibration sample.

11.15   Calculate the asphalt content of the sample as follows:

$$AC\% = \frac{W_s - W_a}{W_s} \text{ x } 100 - Cf$$

Where:

AC%   = the measured (corrected) asphalt content percent by weight of the sample
W_a = the total weight of the aggregate remaining after ignition
W_s = the total weight of the sample prior to ignition
Cf   =calibration factor, percent by weight of the sample

12.   GRADATION, METHODS A & B

12.1   Allow the specimen to cool to approximately room temperature in the sample baskets.

12.2   Empty the contents of the baskets into a flat pan. Use a small wire sieve brush to ensure that any residual fines are removed from the baskets.

12.3   Perform the gradation analysis according to AASHTO T-30 with the exception of NOTES 10 and 11.

NOTE 10- All gradations are to be washed. To expedite drying samples to a constant weight after washing, samples may be dried at 191 ± 5°C (375 ± 9°F).

NOTE 11- The permissible limit for mass retained on the 2.36 mm (No. 8) sieve shall be 9 kg/m^2 (6 g/in.^{2}), or 300 g for the usual 8-inch diameter sieve.

12.4   A gradation worksheet example is attached.

13.   REPORT, METHODS A & B

13.1   Always report the test method (A or B), corrected asphalt content, Cf for asphalt content, Cf for the percent passing the 75μm (No. 200) sieve, temperature compensation factor (if applicable), total percent loss, sample mass, moisture content (if determined), and test temperature. For units with internal balances attach a copy of the furnace printout to the report.

14.   REFERENCES

14.1   AASHTO M-231   Weighing Devices Used in the Testing of Material.
AASHTO T-2   Sampling Aggregates
AASHTO T-30   Mechanical Analysis of Extracted Aggregate
AASHTO T-40   Sampling Bituminous Materials
AASHTO T-248   Reducing Field Samples of Aggregate to Testing Size
PTM 729   Sampling Roadway Bituminous Concrete
PTM 746   Sampling Bituminous Paving Mixtures

14.2   Manufacturer's instruction manual.

Worksheet EXAMPLE

A Mass of Aggregate before wash	=	1143.0
B Mass of Aggregate after wash	=	1085.4
C Mass Loss on wash	=	57.6
D No. 200 Calibration factor (200Cf)	=	0.5

Passing Sieve Size	Mass Passing each sieve E		Mass loss on wash F		Total Mass Passing each sieve G=(E+F)	Raw Agg. % passing H=(G/A)	Corrected No. 200 I=(H-D)
12.5 mm (1/2")	1085	+	57.6	=	1142.6	100	
9.5 mm (3/8")	1048	+	57.6	=	1105.6	97	
4.75 mm (No. 4)	674	+	57.6	=	731.6	64	
2.36 mm (No. 8)	478	+	57.6	=	535.6	47	
1.18 mm (No. 16)	233	+	57.6	=	290.6	25	
600μm (No. 30)	126	+	57.6	=	183.6	16	
300μm (No. 50)	61	+	57.6	=	118.6	10	
150μm (No. 100)	23	+	57.6	=	80.6	7	
75μm (No. 200)	**1.3**	**+**	**57.6**	**=**	**58.9**	**5.2**	**- 0.5 = 4.7**

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LABORATORY TESTING SECTION

Method of Test for

OPEN DISTILLATION OF EMULSIFIED ASPHALTS

1. SCOPE

1.1   This test method covers procedures for a rapid determination of the percentage of residue in asphalt emulsions composed principally of a semi solid or liquid asphaltic base, water, and an emulsifying agent.

2. REFERENCED DOCUMENTS

2.1   AASHTO T59- Testing Emulsified Asphalts

2.2   ASTM D 244- Standard Test Methods and Practices for Emulsified Asphalts

2.3   ASTM D 6997- Standard Test Method for Distillation of Emulsified Asphalts

3. SIGNIFICANCE AND USE

3.1   This test method can be used for the rapid determination of residue in asphalt emulsions. This test method can also be used to obtain residue for further testing. This method is intended as a screening method only, and shall not be used to fail or reject material. If material fails refer to AASHTO T59, ASTM D 244 or ASTM D 6997.

4. APPARATUS

4.1   Balance- A weighing device conforming to the requirements of AASHTO M-231, Class G 2.

4.2   Metal Beaker of approximately 1100 milliliters capacity, measuring approximately 4.25 inches in diameter and 5.75 inches high.

4.3   Thermometer- ASTM 7F (or 7C) having a range of 30ºF (-2ºC) to 580ºF (300ºC).

4.4   Metal Stirring Rod- Approximately the same length as the thermometer and about 1/4 inch thick.

4.5   A stand with a heavy base and two circular rings, 5.25 inches in diameter, clamped to the stand.

4.6   Steel mesh to cover the lower ring to support the can, thermometer, steel rod and sample, and to allow the flame to heat the can.

4.7   Bunsen Burner- An adjustable-flame burner.

4.8   Heat Shield on Balance Tray- to prevent the hot sample from distorting the balance tray and give an incorrect reading.

5. TEST SPECIMEN

5.1   Test specimens shall be obtained from samples submitted in wide mouth, two liter (two quart) jars or bottles made of plastic as required in Bulletin 25.

6. SAMPLE PREPARATION

6.1   Stir the emulsion to ensure that the asphalt is evenly distributed and is completely homogeneous. Take care to check that there are no lumps of asphalt or hard residue in the container.

7. PROCEDURE

7.1   Assemble the stand, rings, and mesh so that the lower ring with the mesh is approximately two inches above the Bunsen burner. The second ring shall be clamped to the stand approximately three inches above the lower ring to support the sides of the beaker and to keep the beaker centered over the burner, preventing the beaker from falling off the lower ring. Place the burner on the steel base below the lower ring. Place the heat shield on the scale.

7.2   Obtain the tare weight of the beaker, thermometer, and stirring rod to the nearest 0.1 g. Record the weight on a lab worksheet.

7.3   Weigh 200 g +/- 0.1 g of a representative sample of the emulsion into the beaker.

7.4 Place the thermometer and stirring rod into the beaker and place the beaker on the ring stand over the burner. Heat and continue stirring the emulsion until the temperature reaches 177°C (350F) for polymer modified samples and 260°C (500F) for standard (un-modified) emulsion samples.

7.5 Upon reaching the specified temperature, immediately remove the beaker from the ring stand (leaving the thermometer and stirring rod in the beaker) and place the beaker on the heat shield on the balance. Record the total weight of the apparatus and the remaining asphalt residue to the nearest 0.1 g.

7.6 Immediately pour the residue into the required molds or containers for further testing as required.

8. CALCULATIONS

8.1 Calculate the percent asphalt using the following formula (report the value to one decimal place):

$$F - T / 200 * 100 = P$$

Where:

T= Tare weight of beaker, thermometer, and stirring rod, g
F= Weight of beaker, thermometer, stirring rod and residue, g
P= Percent of residue, recorded to the tenth

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