

MTO LABORATORY TESTING MANUAL



MINISTRY OF TRANSPORTATION
MATERIALS ENGINEERING AND RESEARCH OFFICE
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CONTINUING RECORD OF REVISIONS MADE
to the
LABORATORY TESTING MANUAL

This sheet should be retained permanently in this page sequence in the Manual.
All revised material should be inserted as soon as received and the relevant entries made by hand in the spaces provided to show who incorporated the Revision and the date this was done. If this practice is followed faithfully it will be a simple matter to tell whether or not this copy of the Manual is up to date since all future Revisions will be dated.

[illegible]

Revision 22 - DETAILS OF REVISIONS – April 2004

- LS-101 CALCULATION OF PER CENT WITHIN LIMITS**
Typing errors in mathematical expression for mean in Sections 3.2, 5.1, 6.1, 6.2, and 6.3 has been corrected.
- LS-102 MINIMUM REQUIREMENTS FOR LABORATORIES CONDUCTING
ENGINEERING MATERIALS TESTING AND EVALUATION SERVICES
FOR THE MINISTRY OF TRANSPORTATION:**
Editorial changes have been made to titles of the Sections 5.3 and 5.4 to include Marshall Mixes.
Editorial changes have made in Section 5.6 to up date the AASHTO test methods.
Sections 5.7 and 5.8 have been added to include the requirements for testing Superpave mixes.
CSA certification requirement in Section 6.5 has been changed to Category 1.
Appendix A is included to identify the requirements for Area Testing Lab contracts.
- LS-294 MEASURING PAVEMENT SURFACE COURSE LIFT THICKNESS:**
This is a new test method.
- LS-295 DETERMINING LIFT THICKNESS USING CONCRETE COVER METER:**
This is a new test method.
- LS-297 THE DETERMINATION OF INDIRECT TENSILE STRENGTH FOR FULL DEPTH
RECLAMATION WITH EXPANDED ASPHALT STABILIZATION:**
This is a new test method.
- LS-604 RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE:**
Sections 1.1 and 3.1 have been amended to reflect the changes to the terminology in ASTM C 127.
Section 5.1 has been revised to include the MTO Report, MERO-002 & 008, Aggregate and Soil proficiency Sample Testing programs for 2002 & 2003 in the references.
Sections 5.3.1 and 5.3.2 have been revised to provide the information pertaining to the introduction of Brechin Quarry No. 2 Control Aggregate.
- LS-605 RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE:**
Sections 1.1, 3.1 and 6.1 have been amended to reflect the changes the in ASTM C 127.
Sections 5.3 and 5.4 are added to provide the mean and limits for the standard reference aggregate.
- LS-606 SOUNDNESS OF AGGREGATES BY USE OF MAGNESIUM SULPHATE:**
Section 3.7 has been revised to include the MTO Report, MERO-002 & 008, Aggregate and Soil proficiency Sample Testing programs for 2002 & 2003 in the references.
Section 10.3 has been revised to provide the information pertaining to the introduction of Brechin Quarry No. 2 Control Aggregate.

Section 9.2 has been editorially changed to provide more clarity for calculating weighted average.

LS-618 RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS:

The error in running time required for Gradings C specified in Section 5.6, Revision 21 has been corrected.

The test data for standard reference aggregate (Brechin Quarry No.1) that was specified in Section 7.3 has been removed

Note 3, reference to the Brechin Quarry No2 control aggregate has been removed.

Revision 21 - DETAILS OF REVISIONS – May 2003

LS-614 FREEZING-AND-THAWING OF COARSE AGGREGATE

Section 2.3 is added to include the MTO Report, MERO-002, Aggregate and Soil proficiency Sample Testing program for 2002 in the references.

Sections 3.8 and 9.4 have been revised to provide the information pertaining to the introduction of Brechin Quarry No. 2 Control Aggregate.

A note under the Figure A.1 has been added to caution the users that the plot is applicable to the control aggregate supplied prior to 2003.

LS-618 RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN THE MICRO-DEVAL APPARATUS:

Section 2.8 is added to include the MTO Report, MERO-002, Aggregate and Soil proficiency Sample Testing program for 2002 in the references.

The requirements for Gradings B and C have been amended in Sections 4.3 and 4.4 by eliminating 6.7 mm sieve.

Sections 3.7 and 7.3 have been revised to provide the information pertaining to the Brechin Quarry No. 2 Control Aggregate.

Running time required for Gradings B and C is specified in Section 5.6 (omitted in Revision 20).

Revision 20 - DETAILS OF REVISIONS – July 2002

LS-102 MINIMUM REQUIREMENTS FOR LABORATORIES CONDUCTING ENGINEERING MATERIALS TESTING AND EVALUATION SERVICES FOR THE MINISTRY OF TRANSPORTATION:

Section 4.1.6: Requirements for Soil & Rock – Medium Complexity Testing has been included.

Section 5.3: This Section has been amended to permit the laboratories that do not have Marshall Immersion Testing capabilities to sub-contract this test to a certified lab possessing the capabilities.

Section 5.5: Requirements for minimum number of technicians performing the referee testing has been amended.

Section 5.8 & 6.13: These two sections have been revised to make reference to the new test procedure LS-293 – Method of Test for Correlating Profile Measuring Devices and Conducting Surface Smoothness Measurements.

Section 8.0: Editorial changes have been made to reflect the changes in the TPM/RFP Version 4.0

LS-292 QUANTITATIVE DETERMINATION OF ASPHALT CEMENT CONTENT BY IGNITION AND ANALYSIS OF REMAINING AGGREGATE FROM BITUMINOUS PAVING MIXTURES:

This is a new test method.

LS-293 CORRELATING PROFILE MEASURING DEVICES AND CONDUCTING SURFACE SMOOTHNESS MEASUREMENT:

This is a new test method.

LS-422 EVALUATION OF AIR ENTRAINING ADMIXTURES FOR CONCRETE:

Section 5.1: Editorial changes have been made in this section to reflect the changes in cement suppliers corporate name.

Section 5.3: Coarse Aggregate grading requirements has been amended to include the 26.5 mm sieve.

LS-423 EVALUATION OF CHEMICAL ADMIXTURES FOR CONCRETE:

Section 5.1: Editorial changes have been made in this section to reflect the changes in cement suppliers corporate name.

Section 5.3: Coarse Aggregate grading requirements has been amended to include the 26.5 mm sieve.

LS-424 EVALUATION OF SUPERPLASTICIZING ADMIXTURES FOR CONCRETE:

Section 5.1: Editorial changes have been made in this section to reflect the changes in cement suppliers corporate name.

Section 5.3: Coarse Aggregate grading requirements has been amended to include the 26.5 mm sieve.

- LS-427 COMPRESSIVE DEFORMATION OF PLAIN BEARINGS:**
This is a new test method.
- LS-428 COMPRESSIVE DEFORMATION OF LAMINATED BEARINGS:**
This is a new test method.
- LS-429 PARALLELISM OF STEEL LAMINATES OF LAMINATED BEARINGS:**
This is a new test method.
- LS-430 BOND STRENGTH BY TENSILE LOAD:**
This is a new test method.
- LS-431 MICROSCOPICAL DETERMINATION OF AIR VOID SYSTEM PARAMETERS IN
HARDEN CONCRETE FOR CONFORMANCE TESTING:**
This is a new test method.
- LS-600 DRY PREPARATION OF AGGREGATES FOR DETERMINATION OF PHYSICAL
CONSTANTS:**

A small editorial change has been made to clause 7.4.
- LS-602 SIEVE ANALYSIS OF AGGREGATES:**

This test method has been reorganized. Requirements for the fine aggregate balance have been added. Requirements for field sampling have been included. Test sample size for 22.4 mm aggregate has been removed from Table 1. Fine aggregate sample sizes have been changed to include a range. A new Gradation Computation Worksheet replaces previous figures.
- LS-607 PERCENT CRUSHED PARTICLES IN PROCESSED COARSE AGGREGATE:**

This test method has been reorganized. Two procedures, Method A and Method B, are given. A new Computation Worksheet replaces previous figures.
- LS-608 PERCENT FLAT AND ELONGATED PARTICLES IN PROCESSED COARSE
AGGREGATE:**

This test method has been reorganized. A new Computation Worksheet replaces previous figures.
- LS-610 ORGANIC IMPURITIES IN CONCRETE SAND:**

Section 4: Use of Laboratory Control Aggregate has been removed.
- LS-618 RESISTANCE OF COARSE AGGREGATE TO DEGRADATION BY ABRASION IN
THE MICRO-DEVAL APPARATUS:**

Sample gradings A, B, and C have been reinstated (omitted from Rev 19). A note has been added to deal with occasional grooves worn into the inside of jars.

**LS-626 THE DETECTION OF ALKALI-REACTIVE COARSE AGGREGATE BY
ACCELERATED EXPANSION OF CONCRETE PRISMS (TANG TEST):**

This is a new test method. It is inserted for information purposes only. Comment is invited to C. Rogers, Soils and Aggregates Section, Ministry of Transportation, Ontario

LS-627 OPEN GRADED DRAINAGE LAYER (OGDL) CORE POROSITY TEST:

Change in name of apparatus from "pot" to "air meter bowl".

LS-705 DETERMINATION OF SPECIFIC GRAVITY OF SOILS:

This has been re-written as a stand-alone test method to follow ASTM Standard D 854-98.

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METHOD FOR ROUNDING-OFF OF TEST DATA AND OTHER NUMBERS

1. SCOPE

1.1 This method describes the procedure to be used for the rounding-off of all numbers.

2. GENERAL

Test values and calculated values are to be rounded in accordance with the criteria prescribed in Section 3.0.

3. CRITERIA

3.1 When the digit beyond the last place to be retained is less than 5, then the digit in the last place retained will remain (see Examples 1 & 2).

3.2 When the digit beyond the last place to be retained is greater than or equal to 5, then the digit in the last place to be retained will be increased by 1 (see Examples 1 & 2).

3.3 When a number is to be rounded, it will be rounded in one step only to the precision required and not rounded in two or more consecutive steps. For example: the number 1.347 can be rounded to 1.35 (to two decimal places). However, it is not acceptable to subsequently take 1.35 and then round it to the value of 1.4 to obtain a precision to one decimal place. In the method described herein, 1.347, rounded to one decimal place would have a value of 1.3.

Note 1: The requirement of rounding in one step does not refer to a rounded result which may have been obtained from a formula that may itself consist of rounded numbers. For example, it is perfectly acceptable to use % passing results which are themselves rounded to produce a rounded fineness modulus.

3.4 If, in special cases, it is desired to round off a number to the nearest 5, 0.5, 0.05, 0.005 etc., then the observed or calculated value (with any number of significant digits) will be doubled, then respectively rounded to the nearest 10, 1, 0.1, 0.01 etc., in accordance with 3.1 to 3.3. The rounded result will then be divided by 2 (see Example 3).

4. EXAMPLES

4.1 Example #1

Rounding to the closest whole number:

4.49 = 4	7.49 = 7
4.50 = 5	7.50 = 8
4.5 = 5	7.5 = 8
4.51 = 5	7.51 = 8

4.2 Example #2

Rounding to the closest 0.1:

7.649 = 7.6	7.349 = 7.3
7.650 = 7.7	7.350 = 7.4
7.65 = 7.7	7.35 = 7.4
7.651 = 7.7	7.351 = 7.4

4.3 Example #3,

Rounding to the closest 0.05:

Two stage procedure as described in 3.4 and shown below, each column representing the procedure of each stage.

1.1249 x 2 = 2.2498	2.2 / 2 = 1.10
1.1250 x 2 = 2.2500	2.3 / 2 = 1.15
1.125 x 2 = 2.250	2.3 / 2 = 1.15
1.126 x 2 = 2.252	2.3 / 2 = 1.15

METHOD FOR CALCULATION OF PER CENT WITHIN LIMITS

1. SCOPE

- 1.1 This method describes the procedure to be used for calculation of Per cent Within Limits.

2. RELEVANT DOCUMENTS

- 2.1 MTO Test Methods LS-100

3. DEFINITIONS

- 3.1 Per cent Within Limits (PWL) is an estimate of the percentage of the population (lot) that is within specification limits, determined by using the mean and standard deviation of the lot.
- 3.2 Mean ($\bar{X}$) is the arithmetic average of a set of test results.
- 3.3 Lot Standard Deviation (s) is the square root of the value found by summing the squares of the difference between each test result and the mean of the test results divided by the number of test results minus one (n-1).
- 3.4 Quality Index (Q_i) is a statistic which, when used with appropriate tables, provides an estimate of PWL of a lot. It can be based on an Upper or Lower Specification Limit, yielding Q_U or Q_L respectively.

4. GENERAL

- 4.1 All test results for a lot will be combined to calculate the Mean and Standard Deviation of the lot which will then be used to determine the Per cent Within Limits (PWL), according to the procedures in Section 5.
- 4.2 Any necessary rounding-off of test results or calculations will be in accordance with LS-100.
- 4.3 The lot mean will be reported to one decimal place. The Lot Standard Deviation, Lower Quality Index, and Upper Quality Index will be reported to two decimal places.

5. CALCULATIONS

- 5.1 The Quality Index, Q_i , for the lower and upper specification limits shall be as determined from the following formulae:

$$Q_L = \frac{\bar{X} - LL}{s} \qquad Q_U = \frac{UL - \bar{X}}{s}$$

where:

Q_L	=	Lower Quality Index Value
Q_U	=	Upper Quality Index Value
LL	=	Lower Specification Limit
UL	=	Upper Specification Limit

5.2 PWL shall be determined from the following formula: $PWL = (P_L + P_U) - 100$

where: PWL = Per cent Within Limits
 P_L = Per cent Within Lower Limit
 P_U = Per cent Within Upper Limit

P_L and P_U are each determined from Table 1 based on Q_L and Q_U and the number of test results (n).

Where a lower limit is not specified, P_L will be 100. Where an upper limit is 100% or is not specified, P_U will be 100.

5.3 Notes for Table 1:

1. Enter the table using the number of test results and Q value.
2. If the value of Q_L or Q_U does not correspond exactly to a value in Table 1, use the next highest value of Q_L or Q_U from the table. The maximum P_L or P_U is 100.
3. Move across the table horizontally from the appropriate Q value to get P_L or P_U .
4. For negative values of Q_L or Q_U , enter the table using the absolute value of Q . P_L or P_U is equal to 100 minus the value from Table 1 for P_L or P_U .

6. EXAMPLES

6.1 Mean ($\bar{X}$) = 35.4 Lower Specification Limit (LL) = 30
Standard Deviation (s) = 3.22 Number of Test Results (n) = 42

$$Q_L = \frac{\bar{X} - LL}{s} = \frac{35.4 - 30}{3.22}$$

$$Q_L = 1.68$$

Look in Table 1 under $n = 42$ (see column $n = 38$ to $n = 69$).

As $Q_L = 1.68$ does not correspond exactly to a value in the table, use the next highest value in the column, 1.73.

Look across the table to the corresponding value of $P_L = 96$.

$P_U = 100$ (no upper limit is specified).

$$\begin{aligned} PWL &= (P_L + P_U) - 100 \\ &= (96 + 100) - 100 \\ &= 96 \end{aligned}$$

6.2 Mean ($\bar{X}$) = 95.3
Standard Deviation (s) = 2.87
Number of Test Results (n) = 12

Lower Specification Limit (LL) = 91.5
Upper Specification Limit (UL) = 97.0

$$Q_L = \frac{\bar{X} - LL}{s} = \frac{95.3 - 91.5}{2.87}$$

$$Q_U = Q_U = \frac{UL - \bar{X}}{s} = \frac{97.0 - 95.3}{2.87}$$

$$Q_L = 1.32$$

$$Q_U = 0.59$$

From Table 1 $P_L = 91$
 $P_U = 72$

$$\begin{aligned} \text{PWL} &= (P_L + P_U) - 100 \\ &= (91 + 72) - 100 \\ &= 63 \end{aligned}$$

6.3 Mean ($\bar{X}$) = 222.4
Standard Deviation (s) = 8.72

Upper Specification Limit (UL) = 220
Number of Test Results (n) = 61

$$Q_U = \frac{UL - \bar{X}}{s} = \frac{220 - 222.4}{8.72}$$

$$Q_U = -0.28$$

From Table 1, a Q_i of 0.28 gives a P_i of 61, however, as Q_U is negative.

$$\begin{aligned} P_U &= 100 - 61 \\ &= 39 \end{aligned}$$

$P_L = 100$ (no lower limit is specified)

$$\begin{aligned} \text{PWL} &= (P_L + P_U) - 100 \\ &= (100 + 39) - 100 \\ &= 39 \end{aligned}$$

TABLE 1: Values for P_L and P_U for a Given Quality Index and Number of Tests
(see notes Section 5.3)

P_L or P_U	Quality Index (Q_L or Q_U)														
	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=18	n=19 to n=25	n=26 to n=37	n=38 to n=69	n=70 to n=200	n>200
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99	1.16	1.47	1.67	1.80	1.89	1.95	2.00	2.04	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97	1.15	1.41	1.54	1.62	1.67	1.70	1.72	1.74	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95	1.14	1.35	1.44	1.49	1.52	1.54	1.55	1.56	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93	1.13	1.29	1.35	1.38	1.40	1.41	1.42	1.43	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.07	1.14	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.96	0.93	0.91	0.90	0.89	0.89	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54	0.54	0.53	0.53	0.53	0.53	0.53	0.52
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20

TABLE 1: Values for P_L and P_U for a Given Quality Index and Number of Tests
(cont'd.)

[illegible]

MINIMUM REQUIREMENTS FOR LABORATORIES CONDUCTING ENGINEERING MATERIALS TESTING AND EVALUATION SERVICES FOR THE MINISTRY OF TRANSPORTATION

1. TERMS OF REFERENCE

For purposes of this document, "Engineering Materials Testing and Evaluation Services" means all aspects of laboratory and field testing required for Preliminary Design, Detail Design and Construction Contract Administration.

The Ministry reserves the right to monitor and/or inspect laboratory testing facilities and their operations by means of duplicate testing, testing of extra materials and/or observing the testing directly. The laboratories shall provide the Ministry with the necessary access to the facility, equipment and personnel to carry out the monitoring activities.

Laboratory testing facilities shall participate in required correlation programs/proficiency sample testing programs conducted by the Ministry or others.

Laboratory testing facilities providing quality assurance testing for Construction Contracts shall not have an affiliation with, or be providing services for, the Contractor, Sub-Contractors, or suppliers to the contract, after construction contract award.

See Appendix A for additional requirements for Area Testing Lab contracts.

2. LABORATORY REQUIREMENTS

Laboratories must have previously participated in the Ministry correlation/proficiency sample testing program or a Ministry recognized equivalent (e.g. AASHTO Materials Reference Laboratory), for the subject material/test.

Laboratories must be prepared to submit evidence of satisfactory performance in past Ministry correlation/proficiency sample testing programs, or evidence of successful participation in a Ministry recognized industry proficiency sample testing program such as those run by the AASHTO Materials Reference Laboratory.

Laboratories must continue to participate in Ministry or Ministry recognized equivalent correlation/proficiency sample testing programs while providing services to the Ministry.

Laboratories must hold applicable certification or accreditation from appropriate bodies as detailed in the specific discipline. Certification shall be valid while providing services to the Ministry. Where equivalent certifications are allowed, equivalency shall be determined by the Ministry.

Laboratories shall provide a copy of all laboratory inspection reports (CCIL, CSA, etc.) to the Ministry upon request.

In the event that the testing is not carried out by the Proponent and is subcontracted to another Company, or another laboratory owned by the Proponent, the subcontracting laboratory must be identified and must meet the requirements.

Test results submitted must be on the letterhead of the laboratory carrying out the test and signed by the person(s) within that laboratory meeting the qualification.

The Proponent shall describe the quality management/ audit process they have in place to ensure that the testing carried out by the contracted laboratories is satisfactory.

Certain testing services require inspection and acceptance of the laboratory by the Ministry. It is the responsibility of the Proponent to make arrangements for such inspection with the appropriate Managers within the Materials Engineering and Research Office, MTO, located at 1201 Wilson Avenue, Downsview.

Laboratories must have a Quality Control Manual describing, as a minimum, the following quality control practices, policies and operational procedures:

- a quality policy statement and commitment,
- management structure and responsibility,
- job descriptions of key staff,
- training policies, health and safety practices,
- house-keeping practices,
- procedures for control of documentation including updating testing manuals, reporting results,
- procedures for protecting confidentiality of data,
- sample identification,
- instrument and equipment maintenance, calibration practices and schedules,
- testing of duplicate samples, blind samples or both,
- testing of reference materials,
- participation in internal/external proficiency sample testing programs,
- procedures for review of sample data and taking corrective action whenever testing discrepancies are detected,
- procedure for dealing with complaints.

As a minimum, this manual shall be updated annually. This Quality Control Manual shall be made available for review at the request of the Ministry. A manual satisfactory to the Ministry shall be required for award of work.

3. STAFF REQUIREMENTS

Work and testing shall be under the direction of a licensed professional engineer, with the following exceptions:

- petrographic examination of concrete, aggregates and rock cores shall be performed by or under the supervision of a geologist.
- aggregate resource prospecting and evaluation shall be performed by or under the supervision of a geologist or a professional engineer with demonstrated experience in aggregate resource prospecting and evaluation.
- chemical analysis of materials shall be performed under the supervision of a qualified analytical chemist.

The supervising engineer, geologist or chemist shall have a minimum of three (3) years experience in the material category in which the work is to be undertaken. This will be demonstrated by providing examples of work supervised or carried out by the professional within the past five (5) years.

The technicians carrying out the work shall hold appropriate certificates for sampling and testing as noted in specific materials testing requirements.

4. MATERIALS TESTING REQUIREMENTS

Specific materials testing requirements are as follows:

4.1 Soils and Aggregates

4.1.1 Aggregates – Low Complexity Testing

The laboratory must be qualified to carry out all of the following tests:

LS-601	Materials Finer than 75 um Sieve in Mineral Aggregates by Washing
LS-602	Sieve Analysis of Aggregates
LS-607	Determination of Percent Crushed Particles in Processed Coarse Aggregate
LS-621	Determination of Amount of Asphalt Coated Particles in Coarse Aggregate

For low complexity aggregate testing, the laboratory requires, as a minimum, CCIL certification as a Type C laboratory, participation in the Ministry aggregate proficiency sample testing program, and obtaining satisfactory laboratory ratings as determined by the Ministry.

Technicians carrying out low complexity aggregate testing shall hold a current certificate from CCIL indicating their proficiency in these tests. A copy of the appropriate certificates shall be submitted.

4.1.2 Aggregates – High Complexity Testing

Laboratory tests in this category include:

- LS-604 Relative Density and Absorption of Coarse Aggregates
- LS-605 Relative Density and Absorption of Fine Aggregates
- LS-606 Soundness of Aggregates by Use of Magnesium Sulphate
- LS-608 Determination of Percent Flat and Elongated Particles in Coarse Aggregate
- LS-609 Procedure for the Petrographic Analysis of Coarse Aggregate
- LS-616 Procedure for the Petrographic Analysis of Fine Aggregate
- LS-614 Freezing and Thawing of Coarse Aggregate
- LS-615 Determination of Potential Alkali-Carbonate Reactivity of Carbonate Rocks by Chemical Composition (CSA A23.2)
- LS-617 Determination of Percent Crushed Particles with Two or More Crushed Faces and Uncrushed Particles in Processed Coarse Aggregate
- LS-618 The Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
- LS-619 The Resistance of Fine Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus
- LS-620 Accelerated Detection of Potentially Deleterious Alkali-Silica Reactive Aggregate by Expansion of Mortar Bars
- LS-623 One Point Proctor Test (OPT)
- AASHTO T84 Specific Gravity and Absorption of Fine Aggregate
- AASHTO T85 Specific Gravity and Absorption of Coarse Aggregate
- AASHTO T176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- AASHTO T304 Uncompacted Void Content of Fine Aggregate (Method A)
- ASTM D 4791 Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
- ASTM D 5821 Determining the Percentage of Fractured Particles in Coarse Aggregate

Laboratories providing high complexity aggregate testing require, as a minimum, CCIL Type D certification for each test listed above, with the exception of petrographic examination (LS-609, LS-616), alkali-reactivity (LS-615, LS-620) and specific gravity and absorption (AASHTO T84, AASHTO 85) as well as participation and satisfactory performance (as determined by the Ministry) in the MTO aggregate proficiency sample testing program.

Technicians carrying out high complexity aggregate testing shall have demonstrated experience in aggregate testing and hold a current certificate from CCIL indicating their proficiency in Type C testing. A copy of the appropriate certificates shall be submitted.

4.1.3 Field Compaction Testing

Where field compaction testing of earth and granulars is to be carried out using a nuclear moisture-density gauge, the operator of the gauge shall have been trained in the safe operation, transportation, and handling of the gauge. The registered owner of the gauge shall hold and maintain a valid radio isotope license for the gauge. The gauge shall have been calibrated within the last 12 months, either by the manufacturer or other qualified agent, against certified density and moisture reference blocks. The certificate of calibration for the gauge shall be available for inspection. Technicians carrying out the field compaction test shall demonstrate their ability to measure density and calculate Quality Index (QI) of compacted lots.

4.1.4 Aggregate Resources Prospecting and Evaluation

This service includes identification of potential glacio-fluvial and glacio-lacustrine sand and gravel, bedrock aggregates, earth borrows deposits, and assessment of aggregate suitability and quantity for aggregate use on Ministry projects. This will be accomplished by field investigation (i.e. digging/drilling, logging and sampling of test pits and quarries), laboratory testing, evaluation of the materials tested and of the aggregate/ bedrock deposit.

Service providers shall demonstrate their competence in this field by submitting a list of previous investigations. The service provider shall also submit satisfactory references from two clients. The references shall be from the clients or projects shown on the list, and shall include the company's name, address, telephone number, contact person, and a detailed description of the services provided.

When work is performed under the supervision of a geologist or engineer, the person actually doing the work shall have a number of years demonstrated experience in aggregate resources prospecting and evaluation.

4.1.5 Soil and Rock – Low Complexity Testing

Laboratories qualified in this category shall be capable of carrying out:

- LS-701 Determination of Moisture Content of Soils (ASTM D2216);
- LS-702 Determination of Particle Size Analysis of Soils;
- LS-703/704 Liquid Limit, Plastic Limit and Plasticity Index of Soils;
- LS-705 Determination of Specific Gravity of Soils; and
- LS-706 Moisture-Density Relationship of Soils.

The laboratory is required to participate in the Ministry proficiency sample testing program for soils and obtain satisfactory ratings as determined by the Ministry.

Laboratories capable of describing rock for engineering purposes (i.e. rock core description, percent recovery, and RQD), and carrying out index tests on rock core samples are also included in this category. This testing will normally be done as part of pavement and/or foundation investigations and design.

Laboratories are subject to inspection and acceptance by the Ministry. The inspection and acceptance procedure is a systematic evaluation of equipment and capability of technicians. Capability of the laboratories will be evaluated by checking the availability and condition of the equipment periodically. The competence of technicians carrying out the tests will be assessed by representatives from the Soils and Aggregates Section, Materials Engineering and Research Office, MTO. For this purpose, the technicians will be requested to perform the test(s) in their presence. Accepted laboratories will be placed on a list available from the Soils and Aggregates Section.

4.1.6 Soil and Rock – Medium Complexity Testing

Laboratories qualified in this specialty will be capable of carrying out all the tests that are covered in the Soil and Rock – Low Complexity Testing as well as the tests that are listed below.

- ASTM D 2166 Unconfined Compressive Strength of Cohesive Soil; and
- ASTM D 2435 One-dimensional Consolidation Properties of Soils.

The laboratory is required to participate in the Ministry proficiency sample testing program for soils and to obtain satisfactory ratings as determined by the Ministry.

Laboratories are subject to periodic inspection and acceptance by the Ministry. The inspection and acceptance procedure is a systematic evaluation of equipment and capability of technicians. Capability of the laboratories will be evaluated by checking the availability and condition of the equipment periodically. The competence of the technicians to carry out the tests will be assessed by representatives from the Soils and Aggregates Section, Materials Engineering and Research Office, MTO. For this purpose, the technicians will be requested to perform the test(s) in their presence. Accepted laboratories will be placed on a list available from the Soils and Aggregates Section.

4.1.7 Soil and Rock – High Complexity Testing

Laboratories qualified in this category will be capable of conducting all the tests that are covered in the Soil and Rock - Medium Complexity Testing, as well as the tests that are required to determine shear strength parameters, permeability of granular soils and hydraulic conductivity of low permeable soils. The tests are as follows:

ASTM D 2850	Unconsolidated undrained compressive strength of cohesive soils in triaxial compression;
ASTM D 4767	Consolidated undrained triaxial compression with pore pressure measurement during shearing;
ASTM D 3080	Direct shear test of soils under consolidated drained conditions;
ASTM D 2434	(LS-709) Permeability of granular soils by constant head method; and
ASTM D 5084	Hydraulic conductivity of low permeable soils using a flexible wall Permeameter.

In addition, labs will be capable of carrying out one or more of the following tests on rock core samples:

Point Load Strength Index – ISRM Suggested Method

ASTM D 2938 uniaxial compression

ASTM D 5607 joint shear strength

This category of testing will normally be done as part of foundation investigations and design.

The laboratory is required to participate in the Ministry proficiency sample testing program for soils and to obtain satisfactory ratings as determined by the Ministry.

Laboratories are subject to periodic inspection and acceptance by the Ministry. The inspection and acceptance procedure is a systematic evaluation of equipment and capability of technicians. Capability of the laboratories will be evaluated by checking the availability and condition of the equipment periodically. The competence of the technicians to carry out the tests will be assessed by representatives from the Soils and Aggregates Section, Materials Engineering and Research Office, MTO. For this purpose, the technicians will be requested to perform the test(s) in their presence. Accepted laboratories will be placed on a list available from the Soils and Aggregates Section.

5. BITUMINOUS

5.1 Emulsions and Cutback Asphalt Testing

The laboratory must be qualified to carry out all of the following tests:

LS-200	Method of Test for Penetration of Bituminous Materials
LS-204	Method of Test for Solubility of Bituminous Materials in Trichloroethylene

LS-207	Method of Test for Float of Bituminous Materials
LS-217	Method of Test for Determination of Oil Portion of Distillate of Emulsified Asphalts
LS-219	Method of Test for Viscosity of Emulsified Asphalts
LS-220	Method of Test for Demulsibility of Emulsified Asphalts
LS-223	Sieve Test for Emulsified Asphalt
LS-226	Method of Test for High Float Emulsified Asphalt

Laboratories providing testing of emulsions and cutback asphalts shall have participated in the most recent Ministry monthly correlation program for these materials, and shall have obtained satisfactory proficiency ratings (as determined by the Ministry) in the program.

5.2 Recovered Penetration Testing

The laboratory must be qualified to carry out the following test:

LS-284	Method of Test for Recovery of Asphalt from Solution by Abson or Rotavapor

Laboratories providing testing for penetration of bituminous materials recovered from hot mix by the Abson or Rotavapor procedures shall have a minimum of CCIL Type E certification or Ministry recognized equivalent.

5.3 Hot Mix Asphalt Mix Design and Verification Testing (Marshall)

The laboratory must be qualified to carry out all of the following tests:

LS-600	Method of Dry Preparation of Aggregates for the Determination of Physical Constants
LS-602	Method of Test for Sieve Analysis of Aggregates
LS-604	Method of Test for Relative Density and Absorption of Coarse Aggregate
LS-605	Method of Test for Relative Density and Absorption of Fine Aggregate
LS-261	Method of Test for Preparation of Marshall Specimens
LS-262	Method of Test for Bulk Relative Density of Compacted Bituminous Mixtures
LS-263	Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
LS-264	Method of Test for Theoretical Maximum Relative Density of Bituminous Paving Mixtures
LS-265	Method of Test for Determination of Percent Air Voids in Compacted Dense Bituminous Pavement Mixtures
LS 283	Marshall Immersion Testing

Laboratories that do not have the capability to conduct MTO LS-283 – Marshall Immersion Test, shall have access to a certified laboratory possessing the capabilities to performing this test.

Laboratories providing mix designs or mix design verifications shall have a minimum of CCIL Type A certification or Ministry recognized equivalent.

A minimum of 50 percent of the technicians, or two technicians (whichever is greater) performing mix design and/or mix verification testing shall be CCIL certified (or equivalent).

5.4 Hot Mix Asphalt Quality Assurance Testing (Marshall Mixes)

The laboratory must be qualified to carry out all of the following tests:

- LS-262 Method of Test for Bulk Relative Density of Compacted Bituminous Mixtures
- LS-263 Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
- LS-264 Method of Test for Theoretical Maximum Relative Density of Bituminous Paving Mixtures
- LS-265 Method of Test for Determination of Percent Air Voids in Compacted Dense Bituminous Pavement Mixtures
- LS-282 Method of Test for Quantitative Extraction of Asphalt Cement and Analysis of Extracted Aggregate from Bituminous Paving Mixtures, or
- LS-291 Method of Test for Quantitative Extraction of Asphalt Cement and Mechanical Analysis of Extracted Aggregate from Bituminous Paving Mixtures – Ontario Procedure

Laboratories providing quality assurance testing of hot mix to the Ministry are required to have a minimum of CCIL Type B certification or Ministry recognized equivalent, to participate in the Ministry's monthly hot mix correlation program, and to obtain satisfactory ratings (as determined by the Ministry) in this program.

A minimum of 50 percent of the technicians, or two technicians (whichever is greater) performing quality assurance testing shall be CCIL certified (or equivalent).

5.5 Hot Mix Asphalt Referee Testing

Laboratories providing referee testing services for mix designs and for mix properties shall be on the Ministry's current list for referee laboratories. Amongst other requirements detailed in the Referee Agreement, laboratories shall be CCIL certified (or Ministry recognized equivalent), participate in the Ministry's scheduled hot mix correlation program, and obtain satisfactory ratings (as determined by the Ministry) in the program.

All referee testing shall be performed by technicians who are CCIL certified (or equivalent).

5.6 Performance Graded Asphalt Cement Testing

The laboratory must be qualified to carry out all of the following tests:

AASHTO R28 Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

AASHTO T313 Standard Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

AASHTO T315 Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

ASTM D 4402 Standard Test Method for Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus

Laboratories providing testing of performance graded asphalt cements shall have participated in the most recent AASHTO Materials Reference Laboratory proficiency sample correlation program for PGAC, and shall have obtained satisfactory proficiency ratings (as determined by the Ministry) in the program. Alternatively, the laboratory shall have satisfactorily participated in the most recent Ministry correlation program for PGAC, or in any equivalent correlation program acceptable to the Ministry. Laboratories are subject to inspection and acceptance by the Ministry.

5.7 Hot Mix Asphalt Mix Design and Verification Testing (Superpave)

In addition to the requirements specified under Section 5.3, the laboratory must be qualified to carry out all of the following tests:

AASHTO T84 Specific Gravity and Absorption of Fine Aggregate

AASHTO T85 Specific Gravity and Absorption of Coarse Aggregate

AASHTO T176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

AASHTO T 304 Uncompacted Void Content of Fine Aggregate (Method A)

ASTM D 4791 Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

ASTM D 5821 Determining the Percentage of Fractured Particles in Coarse Aggregate

AASHTO T166 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

AASHTO T209 Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

AASHTO T283 Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

AASHTO T312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

Laboratories providing Superpave mix designs or mix design verifications shall have a minimum of CCIL Type A certification (for Superpave) or Ministry recognized equivalent. Laboratories shall also have CCIL Type D certification for all the aggregate tests listed in this section, with the exception of specific gravity and absorption (AASHTO T84, AASHTO T85).

A minimum of 50 percent of the technicians, or two technicians (whichever is greater) performing mix design and/or mix verification testing shall be CCIL certified for Superpave testing (or equivalent).

5.8 Hot Mix Asphalt Quality Assurance Testing (Superpave Mixes)

In addition to the requirements specified under Section 5.4, the laboratory must be qualified to carry out all of the following tests:

AASHTO T84 Specific Gravity and Absorption of Fine Aggregate

AASHTO T85 Specific Gravity and Absorption of Coarse Aggregate

AASHTO T166 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

AASHTO T209 Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

AASHTO T283 Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

AASHTO T312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

Laboratories providing hot mix quality assurance testing shall have a CCIL Type A or Type B certification (for Superpave) or Ministry recognized equivalent.

A minimum of 50 percent of the technicians, or two technicians (whichever is greater) performing quality assurance testing of Superpave mixes shall be CCIL certified for Superpave testing (or equivalent).

5.9 Penetration Graded Asphalt Cement Testing

LS-200 Method of Test for Penetration of Bituminous Materials

For penetration graded asphalt cement, laboratories shall have participated in the most recent Ministry monthly correlation program for these materials, and shall have obtained satisfactory proficiency ratings (as determined by the Ministry) in the program.

5.10 Hot Mix Pavement Smoothness

LS-293 Method of Test for Correlating Profile Measuring Devices and Conducting Surface Smoothness Measurements

Both profilograph equipment and operators shall be from approved lists provided by MTO for the current construction season.

6. CONCRETE

6.1 Field Testing of Plastic Concrete

The laboratory must be qualified to carry out all of the following tests:

CSA A23.2-1C Sampling Plastic Concrete

CSA A23.2-3C Making and Curing Concrete Compression and Flexural Strength Specimens

CSA A23.2-4C Air Content of Plastic Concrete by the Pressure Method

CSA A23.2-5C Slump of Concrete

Field testing and sampling shall be done by personnel certified by the Canadian Standards Association (CSA), or by the American Concrete Institute (ACI). Field testing technicians shall have successfully completed, as part of the certification requirements, written and practical examinations within the last five years verifying his/her competence to carry out field testing of concrete (slump, air content, temperature and casting of cylinders), have in his/her possession, at all times field testing is to be performed, a card issued by the certifying agency verifying the currency of the individual's certification.

6.2 Compressive Strength of Normal Concrete

CSA A23.2-9C Compressive Strength of Cylindrical Concrete Specimens

The laboratory is required to be certified by Canadian Standards Association, minimum Category 0, and shall have participated in the most recent Ministry proficiency program for testing of concrete compressive strength with no rating less than 3. Participating laboratories receive a letter from the Concrete Section indicating the laboratory's rating.

6.3 Compressive Strength of High Performance Concrete Specimens

LS-426 Method of Testing Compressive Strength of High Performance Concrete Cylinders

The laboratory is required to be CSA certified as a category 0 laboratory or higher and to successfully participate in the Ministry testing program for testing of high strength concrete. The successful laboratories are placed on the list of laboratories qualified for this testing. This list is available from the Concrete Section.

6.4 Flexural Strength of Concrete Using Simple Beam with Third-Point Loading (CSA A23.2-8C)

The laboratory is required to have CSA Category I certification plus CSA certification to carry out CSA standard test method A23.2-8C, Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).

6.5 Obtaining and Testing Drilled Cores for Compressive Strength Testing (CSA A23.2-14C)

The laboratory is required to be CSA Category I certified and to successfully participate in the Ministry Concrete Compressive Strength Proficiency Program (see above, under Compressive Strength of Cylindrical Concrete Specimens – Normal Concrete).

6.6 Accelerating the Cure of Concrete Cylinders and Determining their Compressive Strength (CSA A23.2-10C)

The laboratory is required to have CSA Category I certification plus certification to carry out CSA standard test method A23.2-10C, Accelerating the Cure of Concrete Cylinders and Determining Their Compressive Strength.

6.7 Air-Void System Testing

ASTM C457 Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

The laboratories shall have their operator(s) qualified by successful participation in the Ministry annual proficiency test program. Qualified laboratories and their operators are placed on a list available from the Concrete Section.

6.8 Rapid Chloride Permeability Testing

ASTM C1202 Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration (Rapid Chloride Permeability)

Successful participation in the Ministry biennial proficiency program is required. The successful laboratories are placed on a list available from the Concrete Section.

6.9 Total Chlorides Testing

LS-417 Determination of Total Chloride Ion in Concrete (Acid Soluble)

Successful participation in the Ministry proficiency program is required. The successful laboratories are placed on a list available from the Concrete Section.

6.10 Testing of Admixtures

LS-413 Method of Test for Non-Volatile Content of Chemical Admixtures, Latex Admixtures and Curing Compounds

LS-414 Method of Test for Relative Density of Chemical Admixtures, Air Entraining Admixtures and Curing Compounds

LS-415 Method of Test for pH of Aqueous Solutions by Glass Electrode

Successful participation in the Ministry annual proficiency program is required. The successful laboratories are placed on a list available from the Concrete Section.

6.11 Testing of Curing Compounds

LS-413 Method of Test for Non-Volatile Content of Chemical Admixtures, Latex Admixtures and Curing Compounds

LS-414 Method of Test for Relative Density of Chemical Admixtures, Air Entraining Admixtures and Curing Compounds

LS-416 Method of Test for Settling Rate-Curing Compound

Successful participation in the Ministry annual proficiency program is required. The successful laboratories are placed on a list available from the Concrete Section.

6.12 Grout Testing

CSA A23.2-1B Testing of Flowable Grout (viscosity, bleeding, expansion and compressive strength)-
Field and Laboratory Testing

CSA certification for Category 0 or higher and successful participation in the Ministry proficiency program for testing of cube compressive strength is required. In addition, the laboratory is required to demonstrate that they have the equipment necessary to carry out CSA Standard Test Method A23.2- 1B, Viscosity, Bleeding, Expansion and Compressive Strength of Flowable Grout. The required equipment includes sufficient number of stainless steel moulds to carry out testing in accordance with Special Provision No. 109S45. The laboratory is also required to demonstrate to Ministry staff their ability to perform correctly the testing of viscosity, bleeding and expansion. The successful laboratories are placed on the list of qualified laboratories for this testing. This list is available from the Concrete Section.

6.13 Concrete Pavement Smoothness Testing

LS-293 Method of Test for Correlating Profile Measuring Devices and Conducting Surface Smoothness Measurements

Both profilograph equipment and operators shall be from approved lists provided by MTO for the current construction season.

7. MISCELLANEOUS TESTING

7.1 Geosynthetics

Testing of geosynthetics shall be carried out by a laboratory acceptable to the Ministry for the required test methods.

7.2 Metals

Laboratories are subject to inspection and acceptance by the Ministry. The inspection/acceptance procedure is a systematic evaluation of equipment and technician capability. Laboratory capabilities are evaluated by meeting with the senior management and supervising technicians of the firm. The laboratories are assessed by checking the availability and condition of equipment and the competence of personnel carrying out the tests.

7.3 Paint and Coatings

Laboratories are subject to inspection and acceptance by the Ministry. The inspection/acceptance procedure is a systematic evaluation of equipment and technician capability. Laboratory capabilities are evaluated by meeting with the senior management and supervising technicians of the firm. The laboratories are assessed by checking the availability and condition of equipment and the competence of personnel carrying out the tests. Laboratories providing testing of traffic paints and structural steel coatings shall participate in the AASHTO Material Reference Laboratory paint proficiency testing program and shall have obtained a rating satisfactory to the Ministry.

8. SUBMISSION REQUIREMENTS

When a Company owns or operates more than one laboratory, or uses a sub-contractor, each laboratory or sub-contractor shall be listed separately. The requirements under submissions and qualifications of professional shall be fulfilled for each laboratory.

The following must be submitted as part of the Preliminary Design, Detail Design or Construction Contract Administration Proposal:

- A statement as to which testing and evaluation categories each laboratory is capable of;
- A copy of all the required accreditation or certification documents for each laboratory or sub-contractor laboratory;

- A copy of the individual test and laboratory ratings reports from proficiency sample testing programs for the past two years (where applicable). In addition, when required, letters or memoranda describing the investigation and resolution of low ratings shall also be attached;
- A copy of the description of the quality management/audit process that the Proponent has in place to ensure that testing done by others is satisfactory;
- A statement and demonstration that the proponent or his/her sub-contractor has qualified engineers, geologists and chemists to perform the required work;
- A statement that qualified/certified technicians, when required, will conduct the work (and a copy of the appropriate certificates);
- In the case of aggregate resources prospecting and evaluation, a statement of experience and two references; and
- A list of previous works, within each sub-category, carried out directly or indirectly for the Ministry in the past three years. List contract number (if applicable), region, type of work performed, and completion date.

Note: Alternatively, laboratories which are registered in RAQS do not have to submit evidence of compliance with these requirements.

Appendix A

The Consultant shall not replace any of the persons named in their quotation without prior written approval of the Ministry. The Supervising Engineer must be present in the primary laboratory a minimum of once per week:

The Project Manager must:

- be a company staff member with authority to act on behalf of the company
- have proven ability to manage assignments of similar type and complexity and to deliver completed quality work on time

The Laboratory Supervisor must have demonstrated knowledge of Legislative requirements (Environmental, Occupational Health and Safety, etc.) and shall meet at least one of the following criteria:

1) An individual with a minimum of 10 years of materials testing experience and demonstrated proficiency in performing the tests required; or

2) An individual with a minimum of 3 years of materials testing experience and demonstrated proficiency in performing the tests required plus one of the following credentials:

- Professional Engineer (P. Eng.) licensed by Professional Engineers Ontario
- Bachelor of Science Degree in Civil Engineering,
- Diploma in Civil Engineering Technology or Construction,
- Diploma in Geology.

The Consultant's primary facility shall have:

- A minimum of 2 technicians with CCIL Type B certification plus applicable certification for Superpave testing.
- A minimum of 2 technicians with CCIL Type C certification.
- A minimum of 2 technicians with CSA certification.

The same technicians can be used to satisfy all three of the above requirements. These are minimum requirements only, the Consultant shall provide appropriate staffing levels to meet turnaround times at all times taking into account the seasonal variations in testing volumes.

All testing shall be done under the direct and constant supervision of a certified technician.

METHOD OF TEST FOR PENETRATION OF BITUMINOUS MATERIALS

1. SCOPE

1.1 This method covers determination of the penetration of semi-solid and solid bituminous materials. Materials having a penetration below 350 can be tested using this method. Materials having penetrations between 350 and 500 can be determined by using the special apparatus and modifications given in 9.3.

2. RELEVANT DOCUMENT

2.1 ASTM D 5

3. PROCEDURE

3.1 Procedure of ASTM D 5 shall be followed.

METHOD OF TEST FOR FLASH POINT BY CLEVELAND OPEN CUP

1. SCOPE

1.1 This method describes the test procedure for determining the flash point all petroleum products except fuel oils and those having an open cup flash point below 80°C.

1.2 The test cup is filled to a specified level with the sample. The temperature of the sample is increased fairly at first and then at a slow constant rate as the flash point is reached. At specified intervals, a small test flame is passed across the cup.

2. RELEVANT DOCUMENT

2.1 ASTM D 92

3. PROCEDURE

3.1 Procedure of ASTM D 92 shall be followed.

METHOD OF TEST FOR KINEMATIC VISCOSITY OF ASPHALTS

1. SCOPE

- 1.1 This method describes test procedures for the determination of kinematic viscosity of asphalt cements, cut-back asphalts, distillation residues and road oil.
- 1.2 The test is normally carried out at 60°C and 135°C.
- 1.3 The viscosities, normally measured, range from 20 to 35,000 square millimetres per second.
- 1.4 The Zeitfuchs cross-arm viscometer is the instrument used for the determination of the kinematic viscosity. The minimum efflux time is 60 s.

2. RELEVANT DOCUMENT

- 2.1 ASTM D 2170

3. PROCEDURE

- 3.1 Procedure of ASTM D 2170 shall be followed, except as noted below.

4. EXCEPTION

MATERIALS	TEST TEMPERATURE °C	VISCOSITY RANGE mm ² /s	TUBE CONSTANT
85/100 A.C. 150/200 A.C.	135	200 - 400	3.0
300/400 A.C.	135	120 - 180	1.0
M.I.P.	60	120 - 180	1.0
M.C. 30 R.C. 30	60	30 - 60	0.3
R.C. 70 M.C. 70 S.C. 70	60	70 - 140	1.0
R.C. 250 M.C. 250 S.C. 250	60	250 - 500	3.0
R.C. 800 M.C. 800 S.C. 800	60	800 - 1600	10.0
R.C. 3000 M.C. 3000 S.C. 3000	60	3000 - 6000	30.0

**METHOD OF TEST FOR
KINEMATIC VISCOSITY OF TRANSPARENT AND OPAQUE LIQUIDS
(AND THE CALCULATION OF DYNAMIC VISCOSITY)**

1. SCOPE

1.1 This method covers the procedures for the determination of the kinematic viscosity of liquid petroleum products, both transparent and opaque, by measuring the efflux time of a fixed volume of liquid at a given temperature to flow under gravity through a calibrated glass capillary viscometer.

Note: For the measurements of the kinematic viscosity of asphalts, see ASTM Method D 2170.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D 2170
- 2.2 ASTM D 2171
- 2.3 ASTM D 446
- 2.4 ASTM D 445
- 2.5 ASTM E 1

3. PROCEDURE

- 3.1 Procedures of ASTM D 2170 and ASTM D 2171.

**METHOD OF TEST FOR
SOLUBILITY OF BITUMINOUS MATERIALS
IN TRICHLOROETHYLENE**

1. SCOPE

1.1 This method covers the procedure for determining the degree of solubility in trichloroethylene of bituminous materials containing little or no mineral matter. The sample is dissolved in trichloroethylene and filtered through a glass fiber pad. The insoluble material is washed, dried and weighed.

2. RELEVANT DOCUMENT

2.1 ASTM D 2042

3. PROCEDURE

3.1 Procedure of ASTM D 2042 shall be followed.

METHOD OF TEST FOR DUCTILITY OF BITUMINOUS MATERIALS

1. SCOPE

1.1 The ductility of a bituminous material is the distance in centimeters to which the material will stretch before breaking when pulled apart at a specified speed and temperature.

1.2 The test is normally performed at $25 \pm 0.5^{\circ}\text{C}$ with a speed of 5 cm per min. ± 5.0 percent. Tests are also performed at $4 \pm 0.1^{\circ}\text{C}$ with a speed of 1 cm per min. and at $15.6 \pm 0.1^{\circ}\text{C}$ with a speed of 5 cm per min.

1.3 Ductility is determined for asphalt cements, residues of cutback asphalts and emulsions, recovered asphalts and thin film residues.

2. RELEVANT DOCUMENT

2.1 ASTM D 113

3. PROCEDURE

3.1 Procedure of ASTM D 113 shall be followed.

METHOD OF TEST FOR ABSOLUTE VISCOSITY OF ASPHALT CEMENT

1. SCOPE

1.1 This method covers the procedure for the determination of absolute viscosity of asphalt cements by a vacuum capillary viscometer at 60°C. It is applicable to materials having viscosities in the range of 4.2 to 20 000 pascal seconds (Pa·s).

1.2 The time is measured for a fixed volume of the liquid to be drawn up through a capillary tube by means of vacuum, under closely controlled conditions of vacuum and temperature. The absolute viscosity in poises is calculated by multiplying flow time in seconds by the viscometer calibration factor. This value divided by 10 will give the absolute viscosity in pascal seconds (Pa·s).

2. RELEVANT DOCUMENT

2.1 ASTM D 2171

3. PROCEDURE

3.1 Procedure of ASTM D 2171 shall be followed.

METHOD OF TEST FOR FLOAT OF BITUMINOUS MATERIALS

1. SCOPE

1.1 A "plug" of the material is cooled to 5°C, and placed in the bottom orifice of a float cup. The float cup is placed on the surface of a water bath maintained at the required test temperature, and the time required in s between placing the apparatus on the water, and the water breaking through the material is measured.

1.2 The float test is a measure of consistency of the material.

2. RELEVANT DOCUMENT

2.1 ASTM D 139

3. PROCEDURE

3.1 Procedure of ASTM D 139 shall be followed.

METHOD OF TEST FOR ELASTIC RECOVERY BY DUCTILOMETER

1. SCOPE

1.1 This method describes the procedure for the determination of elastic recovery of asphalt cements or polymer modified asphalt cements using a ductilometer.

2. RELEVANT DOCUMENT

2.1 ASTM D 113

3. PROCEDURE

3.1 Procedure of ASTM D 113 shall be followed, except as noted below.

4. EXCEPTION

4.1 REPORT

Calculate the percent elastic recovery as follows:

$$\% \text{ Elastic Recovery} = \frac{20 - L}{20} \times 100$$

where: L = Final reading in cm

Note: Report the Elastic Recovery to the nearest 0.1 %.

**METHOD OF TEST FOR
DETERMINATION OF RESIDUE BY DISTILLATION
OF EMULSIFIED ASPHALTS**

1. SCOPE

1.1 This test describes a procedure for determining, by distillation, the percent asphalt residue in an emulsified asphalt.

1.2 The residue or asphalt content of the emulsion is required in determination of residual asphalt contents of mixes or applications.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

**METHOD OF TEST FOR
DETERMINATION OF OIL PORTION OF
DISTILLATE OF EMULSIFIED ASPHALTS**

1. SCOPE

1.1 This method determines the amount of solvent present in emulsified asphalt and emulsified asphalt primers.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

**METHOD OF TEST FOR
PARTICLE CHARGE OF EMULSIFIED ASPHALTS
AND EMULSIFIED PRIMERS**

1. SCOPE

1.1 This test is used to differentiate between the anionic, cationic and nonionic types of emulsified asphalts and emulsified asphalt primers. Positively charged particles are classified as cationic and negatively charged particles as anionic. Neutral particles are classified as nonionic.

1.2 The test consists of an electroplating process using a charge source of direct current. The potential should be sufficient to provide a current of at least 8 mA during testing. This is provided by a direct current source of 12 to 15 V.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TEST FOR VISCOSITY OF EMULSIFIED ASPHALTS

1. SCOPE

1.1 This method covers procedures for the measurement of Saybolt Furol viscosity at temperatures of 25°C and 50°C.

1.2 The test provides a measure of consistency.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

2.2 ASTM D 88

3. PROCEDURE

3.1 Procedures of ASTM D 244 and D 88 shall be followed.

METHOD OF TEST FOR DEMULSIBILITY OF EMULSIFIED ASPHALTS

1. SCOPE

1.1 This method is intended to examine the chemical stability of emulsified asphalts.

1.2 A 100 g sample is mixed with a dilute solution of calcium chloride and the percentage by mass of the asphalt present that fails to pass a 1.40 mm (No. 14) wire cloth is determined. Two concentrations of calcium chloride are specified. A small amount of a very dilute solution of calcium chloride, on being added to a rapid setting grade, should produce a high degree of coagulation, while a larger quantity of a stronger solution of calcium chloride added to a slow setting grade should produce no coagulation.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TEST FOR SETTLEMENT OF EMULSIFIED ASPHALT

1. SCOPE

1.1 This method determines the difference in residue content of the top and bottom portions of a column of emulsified asphalt which has been allowed to stand undisturbed for a specified period.

1.2 The period is normally specified as 5 days, but is extended to 7 days for soil cover emulsion.

1.3 The test is a measure of stability.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TEST FOR CEMENT MIXING OF EMULSIFIED ASPHALTS

1. SCOPE

1.1 This method is intended to examine the stability of slow-setting emulsified asphalts.

1.2 The sample is diluted to 55 percent residue with freshly boiled distilled water and 100 mL are mixed with cement. The percentage by mass of the coagulated material that fails to pass a 1.40 mm (No. 14) sieve is determined.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

SIEVE TEST FOR EMULSIFIED ASPHALTS

1. SCOPE

1.1 This method is one of several used to examine the stability of an emulsified asphalt and is applicable to all types and grades of emulsified asphalts.

1.2 The percentage by mass of a 1000 g sample that fails to pass a 850 μm (No. 20) sieve is determined.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TEST FOR COATING FOR EMULSIFIED ASPHALTS

1. SCOPE

1.1 This method is intended to determine the suitability of the emulsion used during the process of mixing with an aggregate. It is used to evaluate medium setting emulsions only.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TEST FOR STORAGE STABILITY OF EMULSIFIED ASPHALT

1. SCOPE

1.1 This method is intended to relate the ability of the emulsified asphalt to remain as a uniform dispersion during storage.

2. RELEVANT DOCUMENT

2.1 ASTM D 244

3. PROCEDURE

3.1 Procedure of ASTM D 244 shall be followed.

METHOD OF TESTS FOR HIGH FLOAT EMULSIFIED ASPHALT

1. SCOPE

1.1 This method applies to liquid asphaltic materials in the form of aqueous emulsions of the anionic high float type.

1.2 High float emulsified asphalt consists essentially of paving asphalts dispersed in an aqueous phase. It may contain a light petroleum distillate. The residual bitumen has non-Newtonian flow characteristics. It exhibits resistance to flow, regardless of penetration of the asphalt.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D 5
- 2.2 ASTM D 88
- 2.3 ASTM D139
- 2.4 ASTM D 244
- 2.5 ASTM D 2042
- 2.6 ASTM D 2171
- 2.7 ASTM E 1
- 2.8 ASTM E 77

3. PROCEDURE

3.1 Procedure of ASTM from each one of the relevant documents above shall be followed, except as noted below.

4. TEST METHOD EXCEPTIONS

4.1 RESIDUE BY DISTILLATION

4.1.1 Use an aluminum-alloy still only as outlined by ASTM D 244, a still with an expansion chamber, a 127 mm ring burner and a thermometer with a total length of approximately 500 mm.

The 127 mm adjustable burner is placed midway up the still at the expansion chamber joint. The amount of heat applied by this burner is regulated to prevent overheating.

4.1.2 Apply heat so that the first drop of distillate is collected within 10 ± 2 min. in the receiver. Continue heating until the temperature rises to approximately 215°C . At this point, move the ring burner approximately level with the bottom of the still, and increase the temperature to $260 \pm 5^{\circ}\text{C}$ maintaining it at this temperature for 15 min. Complete the total distillation in 60 ± 15 min. from the first application of heat.

4.1.3 When pouring the residue from the still, it is essential that contents of the still be swirled for 10 s just prior to pouring. After completing the distillation procedure, the contents of the still must be poured out within 3 min. into the other test apparatus required for further testing (penetration can, 30 mL glass beaker, and float test thimbles). Such test apparatus should be readied and preheated to 260°C (Figure 1), except float test thimbles, beforehand so that the residue and still do not cool below 232°C before pouring. The residue shall not be poured through the sieve as recommended in ASTM.

4.2 PENETRATION

4.2.1 Follow procedure of ASTM D 5, except that: The sample container shall be 55 mm in diameter and 70 mm deep. For penetration above 350, a special penetration needle is required. The needle shall meet all the requirements of ASTM D 5 under Penetration Needle for dimensions and mass except that the minimum exposed length of the needle shall be 50 mm.

4.2.2 Pour the residual asphalt into the preheated penetration container, filling approximately one-half of the container, and then pour approximately 25 mL into a second preheated pouring container. The second container is then used to fill float thimbles and viscosity tubes. Pour remaining residue into the penetration container to fill it to a depth of approximately 60 mm. Immediately remove penetration can from the hot plate, and place on a paper towel on top of approximately 20 mm thick plywood, all on a counter top. Cover the can with a 600 mL, low form beaker with spout.

4.2.3 These containers should be on a hot plate so that there is no jelling of the high float residue. Split sample into containers directly from still as shown in Fig. 1. After pouring into penetration container, do not stir sample.

4.2.4 Follow the general procedure for the penetration test as outlined in ASTM D 5, except that time for penetration sample to cool shall be 1.5 to 2 h in air, and 1.5 to 2 h in water.

4.3 FLOAT TEST

4.3.1 Follow the general procedure for the float test as outlined ASTM D 139, except that the residue from the distillation shall be poured into a 30 mL glass beaker, and not through a 300 µm sieve, and then immediately into the float thimble. If the residue has been allowed to cool, it shall be reheated to 260°C, and poured into the collar. It may be necessary to cap off the collar with a second pour because of possible shrinkage. Float test should be completed on the same day as the distillation test.

5. APPARENT VISCOSITY OF HIGH FLOAT RESIDUES

5.1 SCOPE: This method describes procedures primarily designed to determine apparent viscosities of residues obtained by distilling High Float Emulsified Asphalts.

The test is carried out at 60°C. It is applicable to materials having viscosity in the range from 20 to 3000 + Pa·s. The modified Koppers Viscometer is the instrument used for the determination of the apparent viscosity.

5.2 DEFINITIONS: Viscosity is the resistance to deformation or internal friction of a liquid expressed as the ratio of the shear stress to shear rate, whether this ratio is constant or not. The SI unit of viscosity is 1 Pa·s (PASCAL-SECOND), and is equivalent to 10 P (Poise).

5.3 SUMMARY OF METHOD: The time is measured for a fixed volume of the liquid to be drawn up through a straight open-end capillary tube by means of vacuum, under closely controlled conditions of vacuum and temperature. The apparent viscosity in Poise is calculated by multiplying the flow time in seconds by the appropriate viscometer calibration factor or calculated viscometer constant. This value divided by 10 will give the apparent viscosity in Pascal seconds (Pa·s).

5.4 APPARATUS

5.4.1 Calibrated-Modified Koppers Vacuum Viscometers And Holders: Required viscometer sizes: 25, 50, 100, 150, 200, 400 (Fig. 2).

5.4.2 Thermometers: Calibrated liquid-in-glass thermometers ASTM 47C in accordance with the requirements of ASTM E-1.

5.4.3 Constant Temperature Bath: A bath suitable for immersion of the viscometer so that the liquid reservoir or the top of the capillary, whichever is uppermost, is at least 20 mm below the upper surface of the bath liquid and with provisions for visibility of the viscometer and thermometer. The efficiency of the stirring and the balance between heat losses and heat input shall be such that the temperature of the bath medium does not vary by more than $\pm 0.03^{\circ}\text{C}$ over the length of the viscometer or from viscometer to viscometer in the various bath positions at 60°C.

5.4.4 Vacuum System: A vacuum system capable of maintaining a vacuum to within ± 0.5 mm of the desired level up to and including 300 mm Hg. The essential system is shown schematically in Fig. 3. A vacuum pump is suitable for the vacuum source.

5.4.5 Timer: A stopwatch or other timing device graduated in divisions of 0.1 s or less, and accurate to within 0.05 % when tested over intervals of not less than 15 min.

5.4.6 Beakers: 30 mL, low form with spout.

5.4.7 Aspirator

5.4.8 Vacuum Tubing

5.4.9 Bath: Capable of maintaining temperature at $135 \pm 10^{\circ}\text{C}$.

5.4.10 Graph Paper: Full logarithmic 1 x 1, 2 x 2 cycles.

5.4.11 Sample Preparation Oven: A suitable oven for semi-continuous operations with control of temperature up to $202 \pm 2^{\circ}\text{C}$. It should have a fast heating rate capability in order not to delay testing when needed on short notice, and capable of maintaining temperature at $195 \pm 2^{\circ}\text{C}$ (Fig. 6).

5.5 PREPARATION OF SAMPLE

5.5.1 Pour a suitable portion of the total distillation residue at 260°C into a 30 mL beaker, and allow to cool to $180 \pm 5^{\circ}\text{C}$. Stir this portion of the sample at 1 rev/s for 10 s. At the end of a 10 s period, charge the viscometer filling tube as in 7.6.

5.5.2 If the residue is at room temperature, cut a test sample of about 20 to 35 g from the source container with a warm spatula, and place in an oven at $195 \pm 2^{\circ}\text{C}$, and heat until contents are at $180 \pm 5^{\circ}\text{C}$. Stir the sample at 1 rev/s for 10 s. At the end of a 10 s period, charge the viscometer filling tubes as in 3.7.

5.5.3 If the residue does not have sufficient fluidity at $180 \pm 5^{\circ}\text{C}$, it may be heated to minimum temperature necessary to achieve fluidity for pouring. This temperature must then be reported with the test data. Select the viscometer size that will be suitable for the material to be tested.

5.6 TEST METHOD

5.6.1 Select a calibrated clean dry viscometer that will give a flow time between 50 and 200 s for the Bulb C.

5.6.2 An anticipated MK Viscometer required is as follows:

HF-250-s	-	size 50
HF-150-s	-	size 100, 150 or 200
HF-100-s	-	size 150, 200

5.6.3 Maintain the bath at the test temperature to within $\pm 0.03^{\circ}\text{C}$.

5.6.4 Apply the necessary corrections, if any, to all thermometer readings.

5.6.5 Insert the viscometer in a holder, and place the viscometer filling tube and capillary tube separately into an oven which is maintained at $195 \pm 2^{\circ}\text{C}$, and preheat for 5 min. to assist in eliminating air bubbles when the sample is poured.

5.6.6 Pour the prepared sample slowly from the 30 mL beaker into the viscometer filling tube to within ± 2 mm of the fill line.

5.6.7 Allow the charged viscometer filling tube to stay in an oven maintained at $195 \pm 2^{\circ}\text{C}$ for a period of 10 ± 2 min. to allow large air bubbles to escape.

5.6.8 Remove the viscometer filling tube and capillary tube from the oven, and then properly position the capillary tube into the filling tube (Note 1).

5.6.9 Transfer the viscometer into an oil bath maintained at $60 \pm 0.03^{\circ}\text{C}$, and position the viscometer in the bath so that the uppermost timing mark is at least 20 mm below the surface of the bath liquid.

5.6.10 Establish a 300 ± 0.5 mm Hg vacuum in the vacuum system, and connect the vacuum system to the viscometer with the toggle valve or stopcock closed in the line leading to the viscometer.

Note 1: Capillary action on certain small diameter viscometer tubes may cause a rise of the sample above the first timing mark. If this is a problem, the capillary tube should be withheld from contact with the sample for a few minutes prior to running the test, then positioned quickly, and allowed to equilibrate a minute or two.

5.6.11 After the viscometer has been in the bath for 30 ± 5 min., start the flow of asphalt in the viscometer by opening the toggle valve or stopcock in the line leading to the vacuum system.

5.6.12 Measure, to within 0.1 s, the time required for the leading edge of the meniscus to pass between successive pairs of timing marks.

5.6.13 Upon completion of the test, remove the viscometer from the bath, and place it in an oven or bath maintained at $135 \pm 5^\circ\text{C}$. Clean the viscometer thoroughly by several rinsings with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent (Note 2). Dry the tube by passing a slow stream of filtrated dry air through the capillary for 2 min., or until the last trace of solvent is removed.

Note 2: A mixture of equal parts of stoddard solvent and 1.1.1 trichloroethane is recommended. Withdraw specimen and solvent with the aid of the vacuum, flushing more solvent until tube is clean. Rinse with acetone.

5.7 REPORTING OF RESULTS

5.7.1 It is suggested that a form sheet, as shown in Figure 4, be used to record the measured and calculated data.

5.7.2 Viscosity for each bulb is calculated as follows:

$$V = (t \times f) / 10$$

where: V = viscosity in pascal seconds, Pa-s
 t = fill time for bulb in question, s
 f = viscometer constant, P/s

5.7.3 Shear rate is calculated for each bulb as follows:

$$SR = \frac{SC}{t}$$

where: SR = shear rate in reciprocal seconds, s^{-1}
 SC = shear constant
 t = fill time for bulb in question, s

5.7.4 Plot the viscosity versus shear rate for the different bulbs on log log paper as shown by the rheogram in Figure 5.

5.7.5 Report the Apparent Viscosity test result obtained from the rheogram at the appropriate shear rate, which is,

0.5 s⁻¹ for HF-100S and HF-150S, and

1.0 s⁻¹ for HF-250S

5.7.6 Always report the test temperature and vacuum with the test result. For example, apparent viscosity, in Pa-s, at 60°C and 300 mm Hg vacuum.

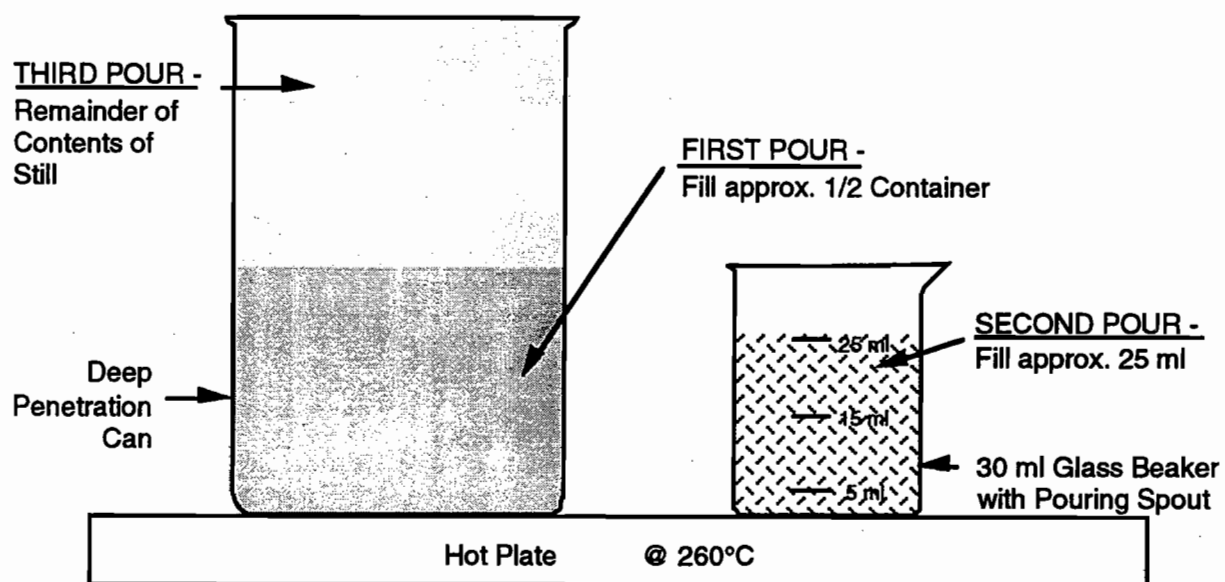
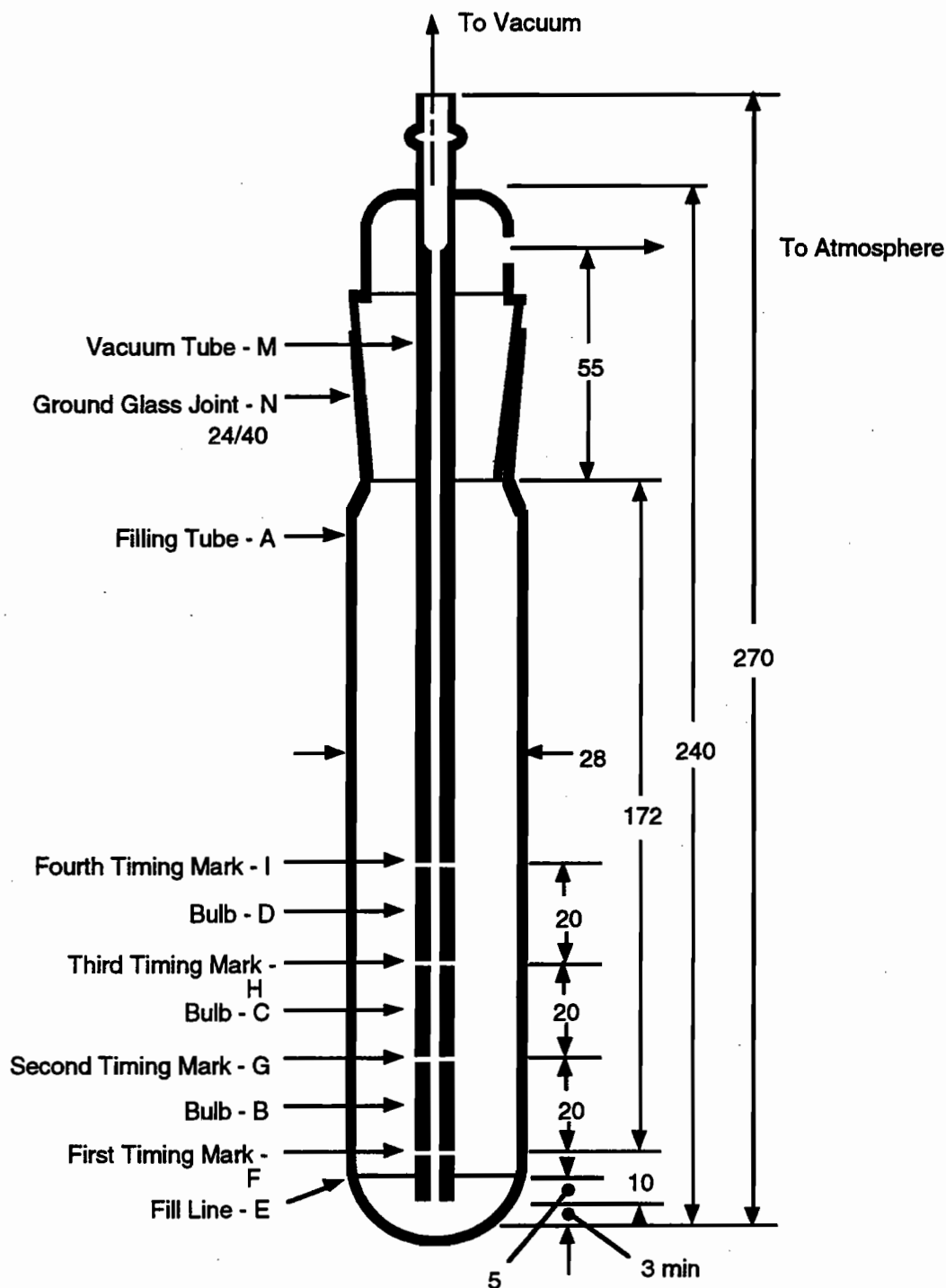


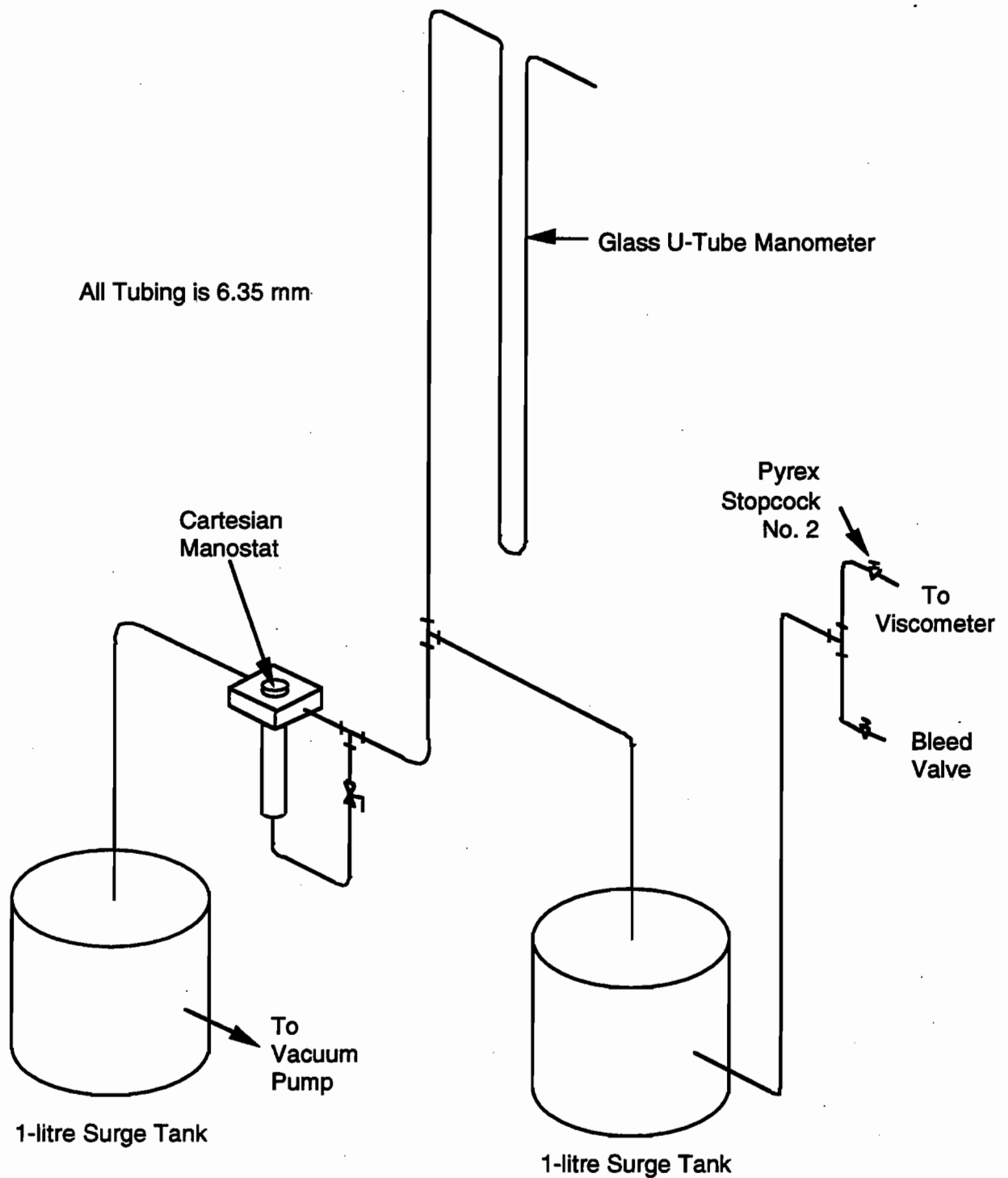
Figure 1



All dimensions are in millimetres.

Modified Koppers Vacuum Capillary Viscometer

Figure 2



Vacuum System for Vacuum Capillary Viscometer

Figure 3

TEST DATA REPORT FORM

Sample No. 124 Viscometer No. K188 Vacuum Hg 300 mm Date 89 02 09

Bulb	Time s	Viscometer Constant P.s ⁻¹	Viscosity P.s	Shear Constant	Shear Rate s ⁻¹
B	46	126.5	582	80	1.7
C	106.2	62.7	666	80	0.75
D	176.3	41.4	730	80	0.45
E	258.0	31.0	800	80	0.31
F	346.9	24.79	860	80	0.23

Temp. 60°C Type Viscometer MK Size 200

Remarks: _____
by: _____

TEST DATA REPORT FORM

Sample No. 123 Viscometer No. K443 Vacuum Hg 300 mm Date 89 02 09

Bulb	Time s	Viscometer Constant P.s ⁻¹	Viscosity P.s	Shear Constant	Shear Rate s ⁻¹
B	85.3	7.86	67	320	3.75
C	206.6	3.92	81	320	1.55
D	376.0	2.611	98	320	0.85
E	600.9	1.975	119	320	0.53
F	894.4	1.592	142	320	0.36

Temp. 60°C Type Viscometer MK Size 50

Remarks: _____
by: _____

Figure 4

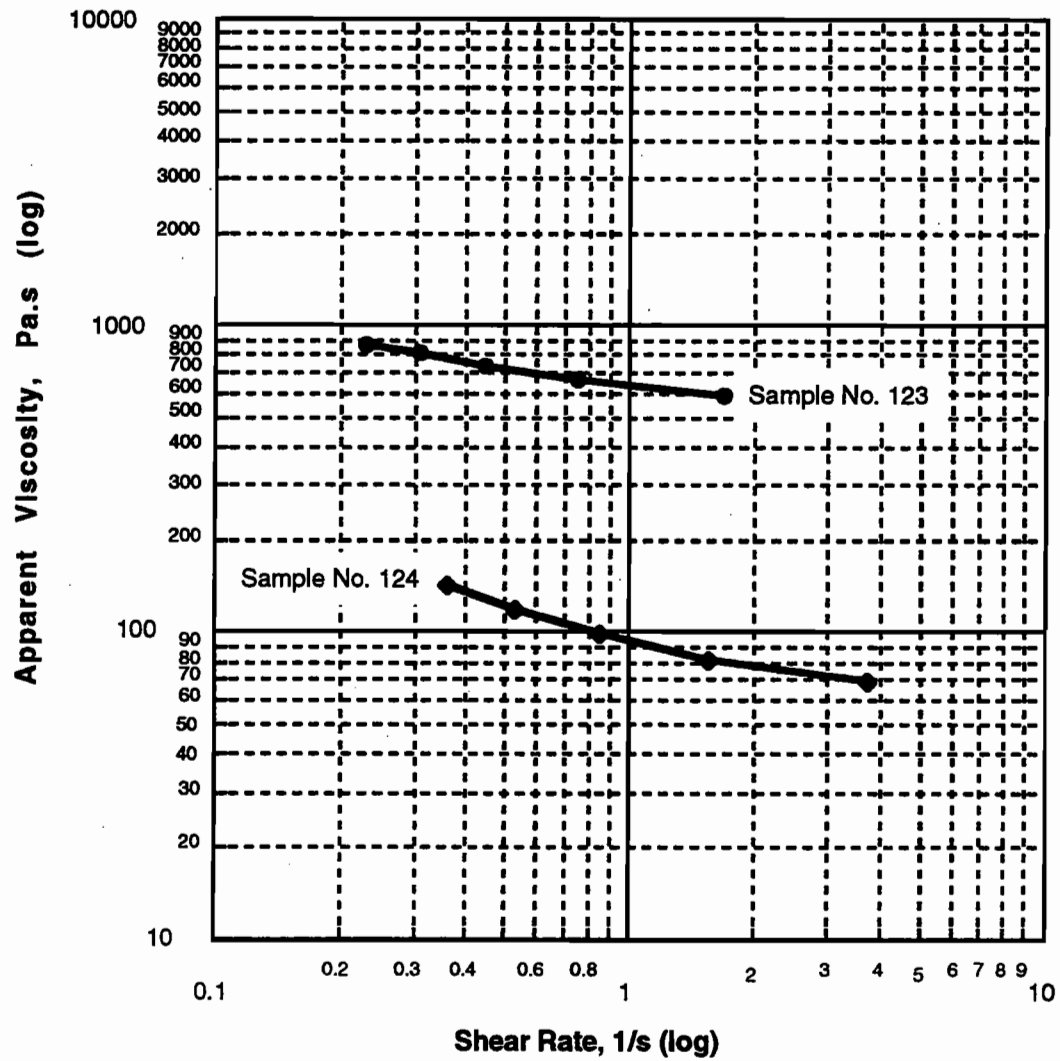


Figure 5

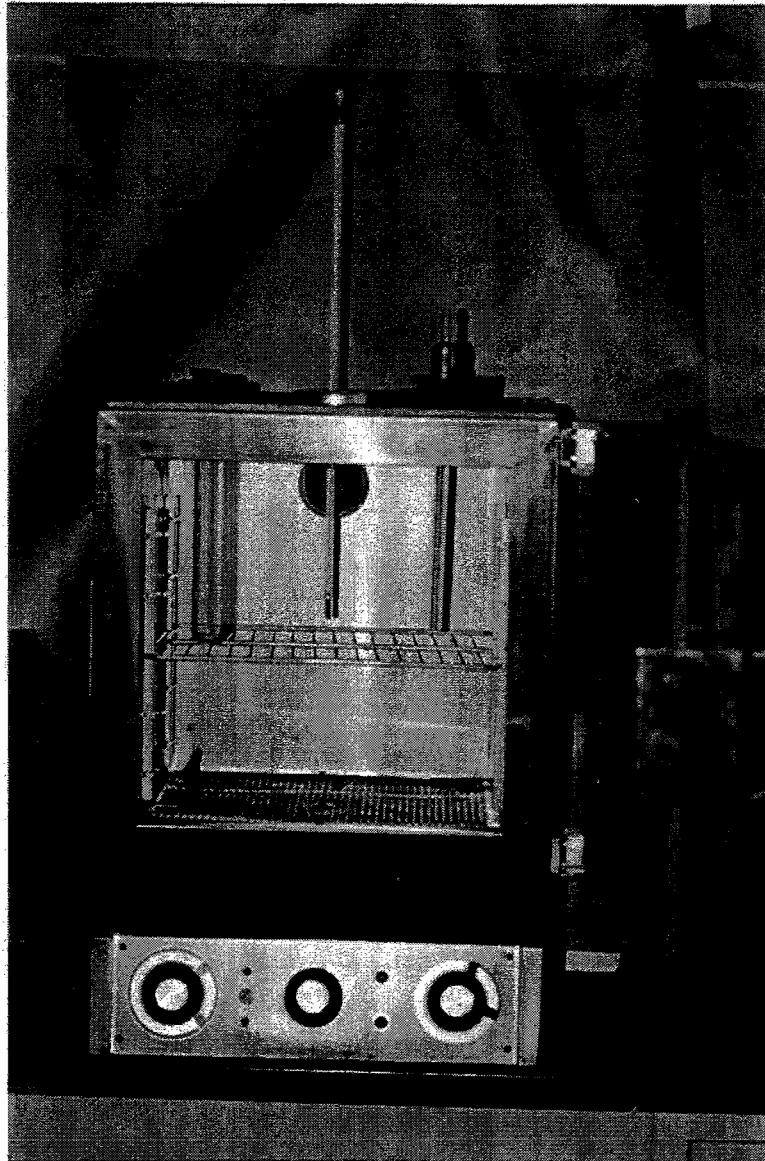


Figure 6 Oven with tube installed.

METHOD OF TEST FOR PREPARATION OF MARSHALL SPECIMENS

1. SCOPE

1.1 This method describes a procedure for the preparation of Marshall test specimens used in the design of bituminous mixtures, as well as specimens from field samples required for the determination of Marshall properties of dense and open-graded bituminous pavement mixtures.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D1559 - 89
- 2.2 Asphalt Institute MS-2

3. APPARATUS

- 3.1 METAL CONTAINERS: Of sufficient capacity, required for heating aggregates in the oven.
- 3.2 MARSHALL MOULDS: Conform to details shown in Figure 1.
- 3.3 COMPACTION HAMMER: Hand Type. Total mass of 7853 ± 16 g with a sliding weight mass of 4536 ± 9 g (including finger guard) free falling 457 ± 1.5 mm onto a flat circular tamping foot. Hammer shall conform to Figure 2 and dimensions in Table 1. The hammer foot shall be flat with square (not rounded) edges.
- 3.4 COMPACTION PEDESTAL: For hand compaction, a hardwood block (having an average dry weight of 0.67 to 0.77 g/ml), nominal size 203.2 mm x 203.2 mm x 457.2 mm high, capped with a 304.8 mm x 304.8 mm x 25 mm thick steel plate (Figure 3) and equipped with a compaction mould holder (not shown) secured to the top plate to position and hold the mould during compaction. The hardwood block shall be secured to a concrete block of nominal size 457.2 mm x 457.2 mm x 228.6 mm, which in turn shall rest on a 50.8 x 50.8 x 25.4 mm cork and neoprene pad at each corner.
- 3.5 MECHANICAL COMPACTION: Instead of a hand-operated hammer, a mechanically-operated hammer may be used provided that it has been calibrated to give results comparable to the hand - operated hammer. A typical mechanical compactor set-up is shown in Figure 5. Other makes/models may differ.
- 3.6 METAL TROUGH: Round bottom, of suitable size to charge moulds with hot mix.
- 3.7 OVENS: Of suitable capacity and capable of maintaining the specified temperatures for drying and heating aggregates, and heating compaction moulds and paving mixtures.
- 3.8 HOT PLATE / OVEN: Thermostatically controlled and capable of heating asphalt cement to a temperature range of 100 to 180°C, and to maintain the required temperature at $\pm 3^\circ\text{C}$.

- 3.9 METAL GARDEN TROWEL: Rounded end, slightly curved blade, 180 mm long, approximately 75 mm wide at the top, and 50 mm wide at the bottom.
- 3.10 SPATULA: Rounded end, rigid blade, about 250 mm long and 25 mm wide.
- 3.11 MIXER: A mechanical mixer, capable of producing a well-mixed, homogeneous mixture of the required amount in the allowable time. See Figure 6 for an example.
- 3.12 KETTLE / CONTAINER: Of sufficient capacity to hold approximately 4.5 L of asphalt cement.
- 3.13 BALANCE: 5 kg capacity, accurate to 0.1 g.
- 3.14 METAL SCOOP: Flat bottomed - for batching aggregates.
- 3.15 THERMOMETERS / ELECTRONIC TEMPERATURE PROBES: Suitable for measuring temperature of aggregates, asphalt and bituminous mixtures in the range of 10 to 204°C with sensitivity of $\pm 1^{\circ}\text{C}$.
- 3.16 THERMOMETER / TEMPERATURE PROBES: Suitable for measuring water bath and air bath temperatures with a range from 20 to 70°C with accuracy of $\pm 0.2^{\circ}\text{C}$.
- 3.17 GLOVES: Heat resistant for handling hot equipment.
- 3.18 STOP WATCH OR TIMER: With an accuracy of ± 0.1 second.
- 3.19 MIXING BOWL: For hand mixing. Of sufficient capacity to mix material required for preparing the Marshall specimen.
- 3.20 FLAT PANS: Approximately 350 mm x 250 mm x 60 mm deep for drying and batching of aggregates.
- 3.21 PAPER DISCS: Made of non-absorbent material, cut to the proper size to fit in the Marshall mould (Premanufactured paper discs are acceptable).
- 3.22 METAL OR WOODEN BAR: To be placed across the top diameter of the mould for aligning and supporting two thermometers or probes in the proper location in the uncompacted mixture in the mould in order to measure the temperature prior to compaction. Two holes are drilled in order that the two thermometers or probes are 25 mm from the inside wall of the mould with the lower tip of the stem approximately 40 mm into the loose mixture.
- 3.23 BRIQUETTE EXTRUDER: Steel, in the form of a disk with a diameter not less than 100 mm and 13 mm thickness. The extruder shall be any device, either electrically or hand operated that will force the briquette from the mould at a uniform rate without causing any deformation to the specimen.
- 3.24 HOT PLATE/ELECTRIC PAN: Thermostatically controlled and capable of heating to a temperature of $135^{\circ}\text{C} \pm 5^{\circ}\text{C}$ required to heat compaction hammers (Placing the hammer upright on a sand pad approximately 12 mm deep in an electric frying pan has been found to be satisfactory for this purpose).
- 3.25 FLAT PANS: Approximate dimensions 400 mm x 300 mm x 50 mm for heating field samples. Smaller pans (approximate dimensions 200 x 200 x 50) are suitable for heating briquette sized portions.
- 3.26 ALUMINUM FOIL OR SUITABLE COVER: For covering pans during mix heat-up process.

3.27 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.

4. PREPARATION OF MIX DESIGN SAMPLES

4.1 The following assumes that the desired blend of aggregates has been determined, and a weigh card prepared. Also, the aggregates have been dried, and split into sieve fractions.

4.2 Arrange the individually sized coarse aggregate(s) and fine aggregate(s) in bags or in suitable containers on a bench, in order of decreasing sieve sizes. The pass 2.36 mm from the coarse aggregate(s) and from the fine aggregate(s) shall be placed in separate flat-bottomed pans of appropriate size. Using the flat-bottom scoop, weigh up into separate pans for each test specimen a sufficient quantity of oven-dried sample of the selected aggregates, so that the total mass will result in a compacted briquette 63.5 ± 2.5 mm in height. The quantity of material will have to be adjusted if the mixing is for preparing more than one specimen. Trial briquettes may have to be completed in order to determine the proper material weight for each mix. Place the aggregates in an oven maintained at a temperature not exceeding 28°C above the mixing temperature specified by the proprietor of the asphalt cement product (see Note 1). Heating time shall be a minimum of 16 hours, normally overnight.

Note 1: The mixing and compaction temperatures for asphalt cements are typically supplied by suppliers or proprietors of the asphalt cement. For refinery run products, these are obtained from the temperature-viscosity chart for the selected asphalt cement. For engineered asphalts and some polymer modified products, the suppliers of these products must be consulted for their mixing and compaction temperature recommendations. Suppliers typically specify the mixing and compaction temperatures each as a range. The midpoint of the range shall be used for these procedures. See Figure 4 for an example of details.

4.3 Preheat the metal trough and Marshall moulds in the oven to a temperature of $135^{\circ}\text{C} \pm 5^{\circ}\text{C}$.

4.4 Preheat the mixing bowl in the same oven as the aggregate.

4.5 Preheat the metal trowel and spatula on the hot plates or in the same oven as the Marshall moulds.

4.6 Heat the asphalt cement to the mixing temperature specified by the proprietor of the asphalt cement using either an oven or hot plate. The asphalt cement should not be held at mixing temperatures for more than 1 hour prior to compaction. Suitable shields, baffle plates or sand pads shall be used on the surface of the hotplate to prevent localized overheating.

4.7 When the asphalt cement has reached the desired temperature, remove the container of aggregate from the oven and quickly place it in the mixing bowl that has been previously tared on the balance. If the aggregate mass is not within ± 1 g of the originally batched mass prior to overnight heating adjust the batch by the addition of preheated pass 2.36 mm material from the primary fine aggregate. Using the mixer, dry mix the aggregate for 15 seconds.

4.8 After dry mixing, form a crater in the centre of the aggregate in the bowl, quickly add in the required amount of asphalt cement to give the required asphalt cement content, and mix 45 seconds or until the aggregate is coated. Do not mix longer than 1.5 minutes. Report any mixing problem such as coating of aggregate or balling of mix.

Note 2: The asphalt content is calculated as a percentage by mass of total mix, e.g. for a total mass of 1180 g of aggregate and A.C. content of 5.0 %

$$\text{Mass of A.C. required} = \frac{1180 \times 5}{100 - 5} = 62.1 \text{ g}$$

$$\text{Total mix} = 1180 \text{ g} + 62.10 \text{ g} = 1242.1 \text{ g}$$

4.9 At the end of the wet mixing cycle, using the pre-heated spatula, scrape as much of the mix as possible from the mixing paddle and scraper blade.

4.10 Spread the mixture into the metal trough using a back and forth motion. Scrape all the loose mixture in the bowl into the trough.

4.11 The temperature of the mixture immediately prior to compaction shall be that temperature specified by the proprietor for the asphalt cement being used. Specimens below the minimum temperature requirement shall be discarded. In no case shall the mixture be reheated.

5. PREPARATION OF FIELD SAMPLES

5.1 Use a sample obtained in accordance with approved methods.

5.2 In order to be consistent, any material received in the laboratory from the paving site in a hot condition, i.e. >100°C, shall be allowed to cool to room temperature and then reheated.

5.3 REDUCING FIELD SAMPLE TO TESTING SIZE: Large field samples shall be reduced to the appropriate size for testing. Two methods of reducing the field sample to the testing size are acceptable: quartering or splitting using a riffle splitter.

5.3.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A convectional or forced air oven, maintained at 110°C, or a microwave oven (see Note 3) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 4). The sample shall be mixed on the surface until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the testing size is obtained.

Note 3: Caution: Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metal particles in some mixtures may render the microwave oven unsafe for the heating of these mixtures.

Note 4: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

5.3.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A convectional or forced air oven, maintained at 110°C, or a microwave oven (see Note 3 above) may be used for this purpose. The mix may agglomerate if it is too cold or stick to the splitter if too hot. A temperature range of 90°C to 110°C has been found to be generally satisfactory. Heat lamps may be used to keep the walls of the splitter box warm (see Note 4 above). Chutes shall be cleaned after each split. The use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found suitable.

5.4 Obtain from the sample by the splitting/quartering, sufficient material (approximately 4000 g) in order to prepare 3 Marshall briquettes.

Optional procedure for working with briquette sized batches: If desired, the 4000 g may be further reduced to 3 batches at this point, each to a size which will yield the briquette of the desired height (see Note 8 below). Care should be taken to ensure that the batches are of uniform composition, i.e., visually consistent.

Note 5: Materials required for other testing such as MRD and extraction can be obtained at the same time.

5.5 Spread the mixture in a flat pan (see Section 3.25), cover with aluminium foil or suitable cover and heat in an oven to a temperature not more than 5°C above the desired compaction temperature. A microwave oven shall not be used for this purpose. During heating the sample may be stirred and temperature checked by forming a mound and measuring with a temperature probe. The compaction temperature for the reheated loose paving mixture shall be supplied by the proprietor of the asphalt cement and/or the mix supplier.

Note 6: For field samples, keep the mix in the oven only long enough to achieve the desired compaction temperature. Preparation of multiple specimens will require that the oven be charged sequentially to ensure that all specimens are in the oven for approximately the same duration.

5.6 When the desired temperature has been reached, transfer the mix to a metal trough.

Note 7: For testing field samples, the moulds, trough and hammer are heated to the same temperature as in the preparation of mix design samples, i.e., 135 ± 5°C.

6. COMPACTION PROCEDURE

6.1 Remove the mould assembly from the oven and place on a non-conducting surface (19 mm plywood has been found suitable) and then place a paper disc in the mould. Using the metal trowel remove the mix from the trough. Place the mixture into the mould, ensuring that the bottom of the trowel is in contact with the bottom of the trough so that the mixture is not removed in layers.

For field mixes which are still around 4000 g in mass (i.e., not reduced to briquette sized portions), divide the mix into three approximately equal portions on the trough, and charge three moulds with the

required amount of mix, taking care not to segregate the mix in the process (see Note 7). When using a single compaction set up, return two of the moulds to the oven to prevent mix cool down.

Note 8: The actual mass required shall be sufficient to produce a compacted briquette 63.5 ± 2.5 mm in height. Refer to mix design for determining the mass required to yield this height.

6.2 Rod the mixture in the mould with the spatula 25 times, 15 times around the outside, 10 around the centre. When rodding around the outside, keep the spatula blade flat against the inside of the mould. When rodding around the centre, do not change direction of the blade. After rodding smooth the surface to a slightly rounded shape.

6.3 Place the metal or wooden bar on the top of the collar, and insert the two thermometers or probes into the pre-drilled holes so that the bottom of the thermometers or probes are approximately 40 mm into the centre of the mixture.

6.4 When the average mix temperature as indicated by the two thermometers or probes is in accordance with Section 4.11 (for mix design work) or Section 5.5 (for field samples), remove the probes and the bar.

6.5 When cooling to compaction temperatures, the mould(s) shall remain on the wooden board to minimize excessive temperature gradients.

6.6 Place the second paper disc on top of mix and place the mould assembly on the compaction pedestal in the mould holder. Compact the specimen by applying 75 blows per side at a rate 60 ± 5 blows per minute (see Note 9). The drop mass shall be allowed to hit and rebound with a secondary hit between drops. During compaction, the operator shall hold the axis of the compaction hammer as nearly perpendicular as possible to the base of the mould assembly (see Note 10). After compaction remove the base plate, collar and paper disks. Then allow the mould to cool until warm to the touch (approximately 40°C). Fans may be used when more rapid cooling is desired. Cooling by submerging in water is not permitted. For each additional briquette repeat the process.

Note 9: For mechanical compactors, it will be necessary for the laboratory to establish the mechanical equivalency for the equipment as compared to 75 blows per side of the hand hammer. This equivalency may be unique for each mix tested.

Note 10: The handle of the compaction hammer should be held freely by one hand in as nearly a vertical position as possible. This will result in some wobbling of the handle about the vertical during compaction. This wobbling provides a desirable kneading action of the specimen during compaction. Consequently, no mechanical device or other support shall be used to restrict or support the handle in the vertical position during compaction.

Note 11: When a significant number of samples are to be prepared, it is recommended that compaction of each briquette be performed by two technicians, alternating technicians on each face.

6.7 Remove the specimen from the mould by means of an extrusion jack or other compression device, and then place flat side down on a smooth, level surface until ready for testing.

6.8 Allow the extruded briquettes to stand on a smooth flat surface at room temperature for a minimum of one hour before any further testing is performed. Test for Marshall Stability requires the briquettes to sit at room temperature a minimum of 12 hours.

7. GENERAL NOTES AND PRECAUTIONS

7.1 To ensure consistency during hand compaction, place an empty mould in the compaction mould holder and rest the hammer in the mould. While standing, the operator's eye level should be the same height as the bottom of the hammer handle. If the eye level is below, place a step stool adjacent to the compaction pedestal to adjust the operator's height accordingly.

7.2 Mechanical mixing is preferred in the preparation of mix design samples.

7.3 The concrete block shall be restrained against lateral movement.

7.4 Handle all hot equipment with heat resistant gloves.

7.5 Always use the hand guards with the hand hammers.

7.6 Wear proper protective safety gear for each operation.

7.7 For mechanical compaction with the bevelled tamping foot, the position of the foot (i.e. the thick edge to the front, sides or back) may change the level of compaction. Therefore, the foot must be positioned the same way for all briquettes made for the same mix.

7.8 The manual hammer shall meet the following additional requirements: the major hammer parts (foot, handle, sliding mass) shall bear unique identifying number(s), either etched or stamped to make the marking indelible and permanent. The manufacturer of the hammer shall provide a dated document certifying that the assembled hammer bearing the unique identifying number(s) complies with the requirements of Table 1. The document shall also provide the total weight of the hammer and the weight of the sliding mass at manufacture, including the weight of the finger guard.

7.9 Compaction Proficiency Testing: It is recommended that laboratories conduct regular checks to ensure the proficiency of the laboratory's compaction set-up and procedures. This can be done by preparing Marshall specimens of a mix whose bulk relative density has been established through multi-laboratory testing. As a minimum, this proficiency testing should be done/repeated whenever

- (a) there is a change in, or repair to, any major equipment used (hammer, pedestal, ovens etc.);
- (b) there is a change in personnel conducting the test;
- (c) routinely every 100 sets of briquettes;
- (d) whenever a laboratory is physically moved; and/or
- (e) at start-up (e.g. after winter shutdown)

Records of such proficiency testing should be maintained as part of the laboratory's quality manual.

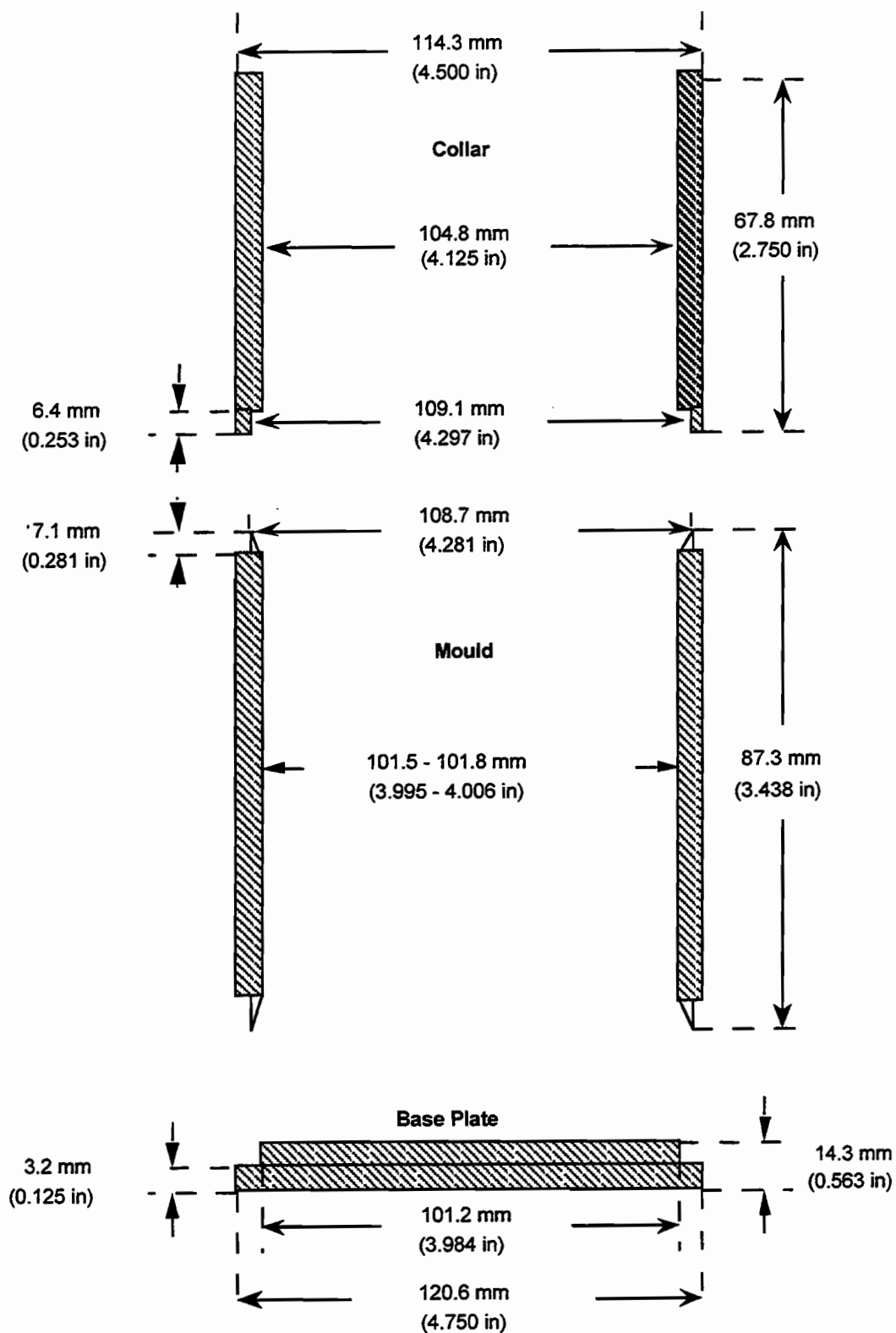


Figure 1
Dimensions for 4" Compaction Mould

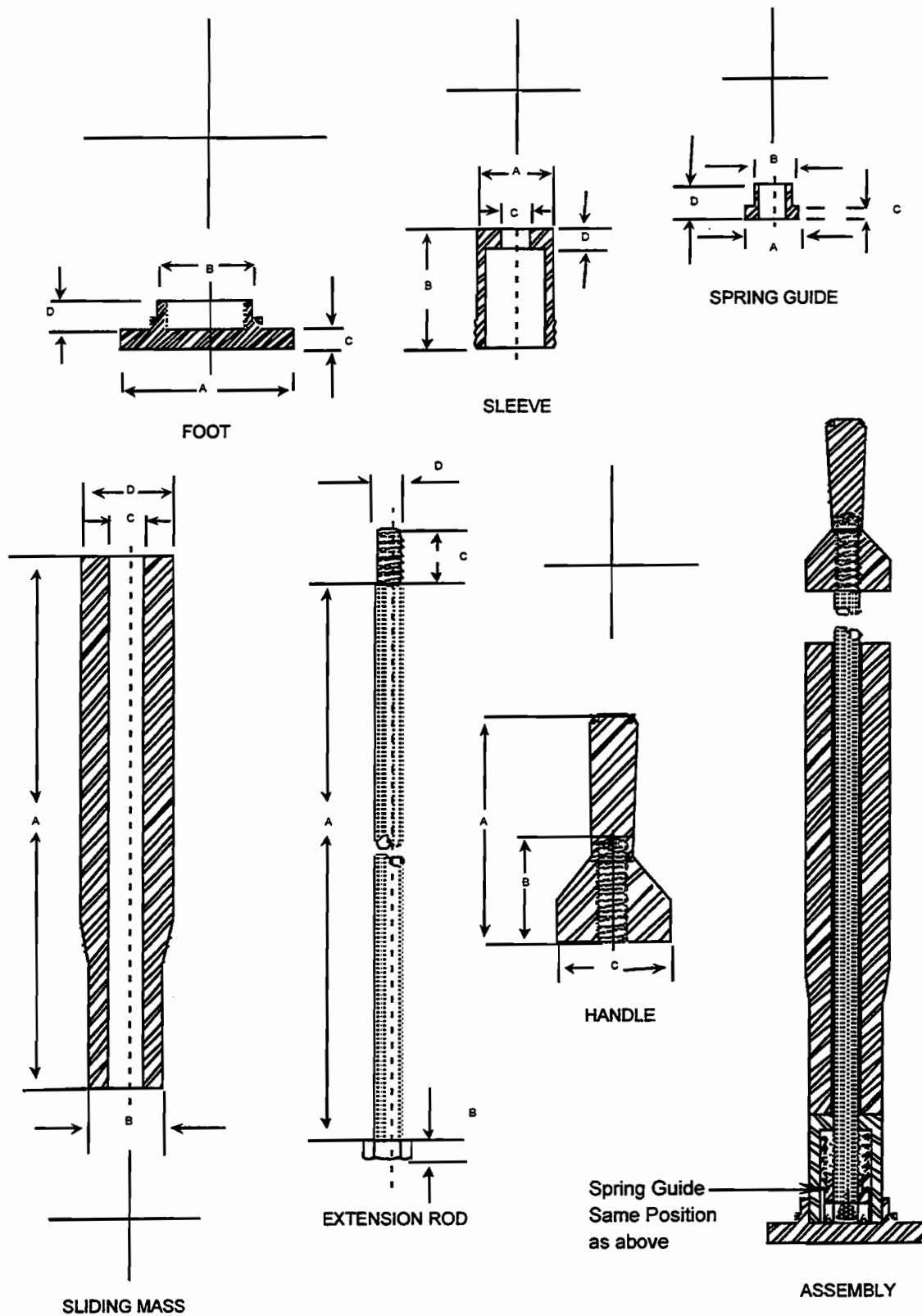


Figure 2
Dimensions for Manual Marshall Compaction Hammer

Table 1
Dimensions for Marshall Manual Compaction Hammer (1)

Measurement Location*	Specifications (3)				
	inches	Tolerance (in)	mm	Tolerance (mm)	grams
Handle					
A	5.25	± 0.50	133.3	± 12.7	-
B	2.00	± 0.50	50.8	± 12.7	-
C	2.25	± 0.25	57.2	± 6.4	-
Foot					
A	3.880	± 0.010	98.6	± 0.3	-
B	2.250	± 0.005	57.2	± 0.1	-
C	0.500	± 0.005	12.7	± 0.1	-
D	0.630	± 0.010	16.0	± 0.3	-
Sleeve					
A	1.750	± 0.005	44.4	± 0.1	-
B	2.50	± 0.25	63.5	± 6.4	-
C	0.630	± 0.025	16.0	± 0.6	-
D	0.35	± 0.05	8.9	± 1.3	-
Spring Guide					
A	1.250	± 0.005	31.8	± 0.1	-
B	1.00	± 0.10	25.4	± 2.5	-
C	0.240	± 0.035	6.1	± 0.9	-
D	0.70	± 0.05	17.8	± 1.3	-
Extension Rod					
A	32.0	± 0.5	812.8	± 12.7	-
B	0.50	± 0.05	12.7	± 1.3	-
C	1.63	± 0.12	41.4	± 3.1	-
D	0.63	± 0.010	16.0	± 0.3	-
Sliding Mass					
A	12.00	± 0.01	304.8	± 0.3	4535 ± 9**
B	1.75	± 0.10	44.5	± 2.5	-
C	0.675	± 0.025	17.1	± 0.6	-
D	2.25	± 0.15	57.2	± 3.8	-
Spring (2) - unconfined	2.1		53.3		-
confined	1.50		38.1		-
I/D coil	> 0.94***		> 23.88***		-
wire diameter	0.155		3.94		-
Overall Mass	-		-		7853 ± 16**

* See Figure 2 for dimension locations.

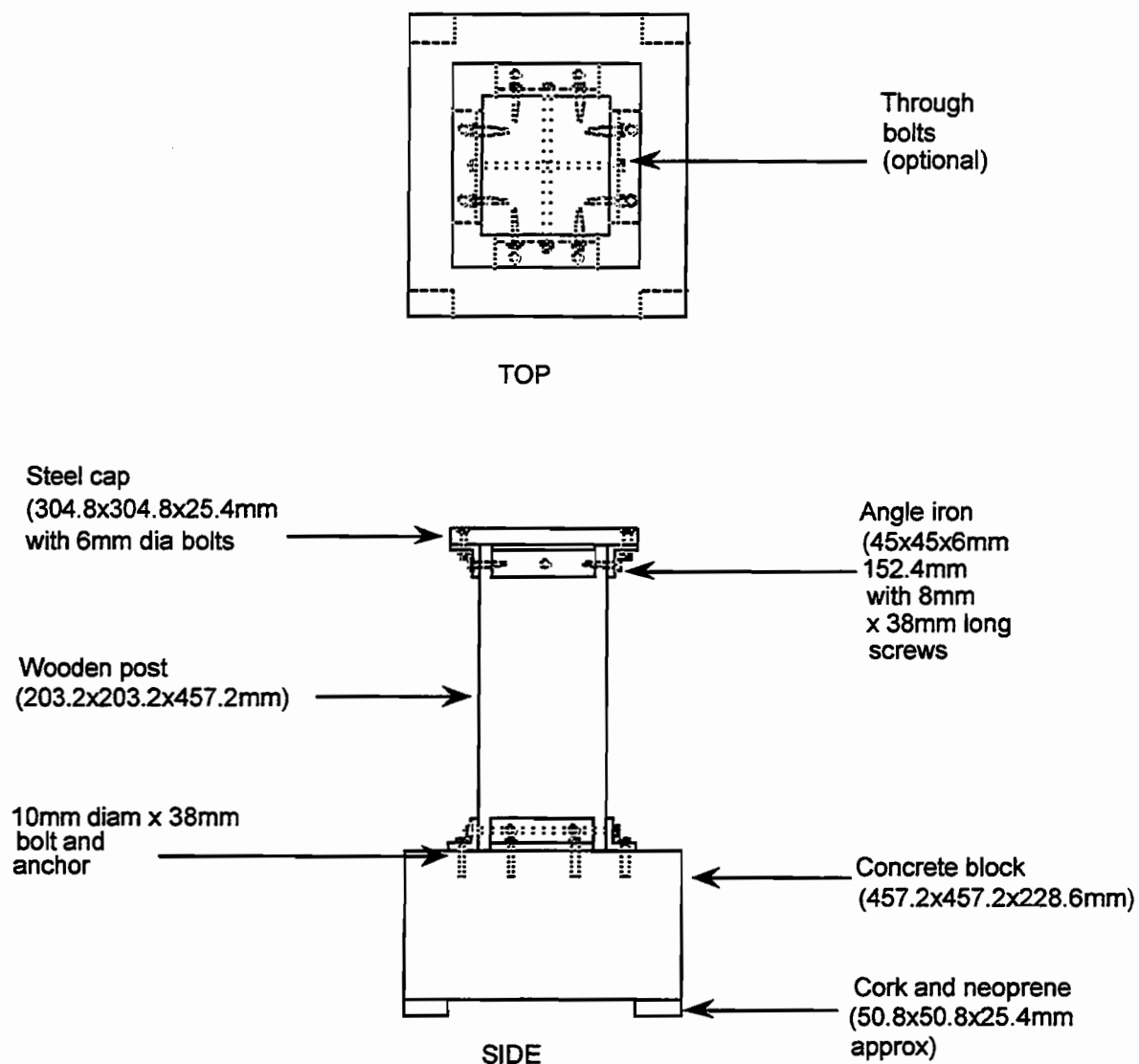
** Including finger guard

*** Just slightly larger than .94" (23.88mm)

(1) See Section 7. General Notes and Precautions for additional requirements pertaining to hammers

(2) Spring: # of coils = 5

(3) Irrespective of the tolerances permitted for the various components, the free fall of the sliding mass shall be 457 mm ± 1.5 mm.



Note: Dimension Tolerances:

Concrete Block:	± 25 mm
Wooden post:	± 5 mm
Angle iron	± 5 mm, except thickness which is ± 1 mm

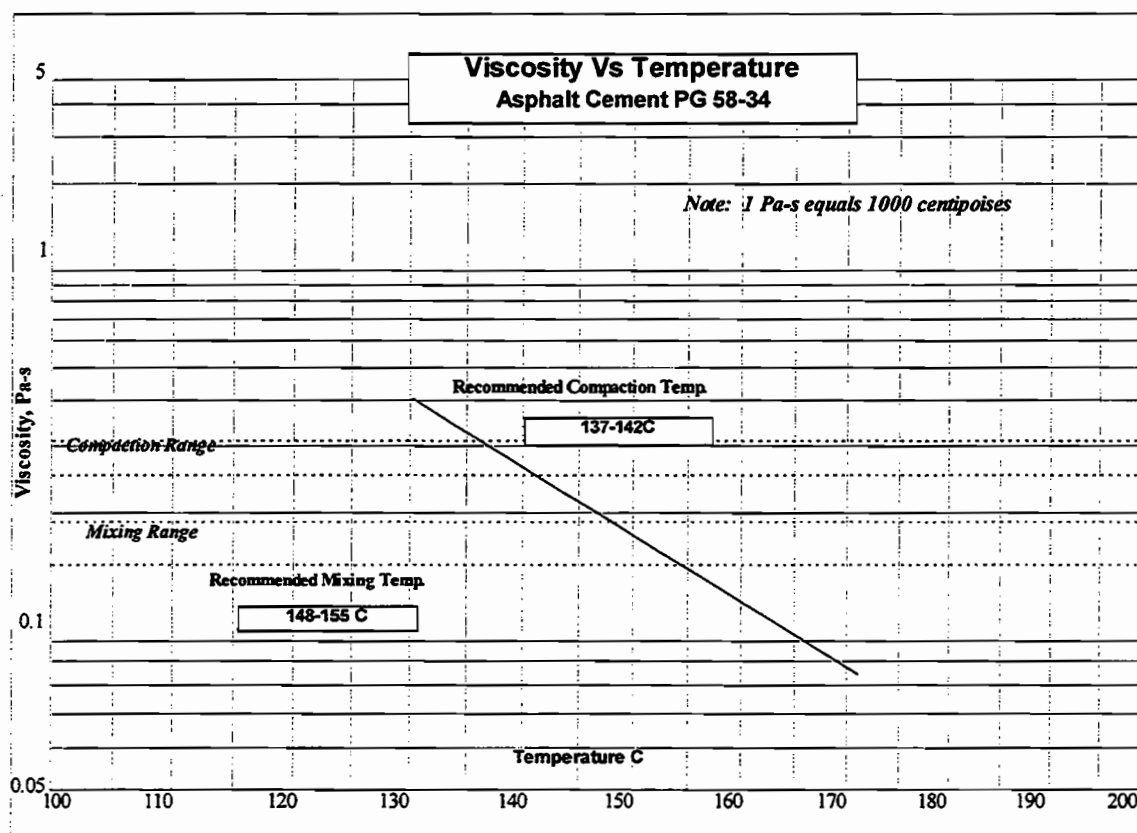
Figure 3
Compaction Pedestal (without mould holder)

Determination of the Laboratory Mixing and Compaction Temperatures of Hot Mix for Design of Pavement Mixtures

The viscosity temperature relationship of an asphalt cement is used as a guide for establishing the mixing and compaction temperature in the laboratory. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.17 ± 0.02 Pa.s is the mixing temperature. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.28 ± 0.03 Pa.s is the compaction temperature. This has been the guide for Marshall mix design criteria and the relationship continues to be valid for laboratory purposes within Superpave. In Ontario the mixing and compaction temperature are the temperatures where the asphalt cement has viscosities of 0.17 and 0.28 Pa.s respectively.

The Brookfield Viscometer, a rotational device (ASTM D 4402), is used to determine the mixing, compaction, and pumping temperatures in the Superpave system. Viscosity measurements at 135° C and 165° C are plotted on a Loglog viscosity vs. log temperature chart shown below and the mixing and compaction temperature interpolated.

The procedure for establishing the mixing and compaction temperatures for the laboratory is valid for refinery produced asphalt cements and may not be valid for some polymer modified asphalt cements. The supplier of these asphalt cements must be consulted for their mixing and compaction temperature recommendations.



The relationship between temperature and viscosity in this example shows the idealized laboratory mixing and compaction ranges. The asphalt cement is a “super lubricant” at the mixing temperature and a “super glue” somewhere around the compaction temperature range .

Figure 4
Sample Temperature Viscosity Chart

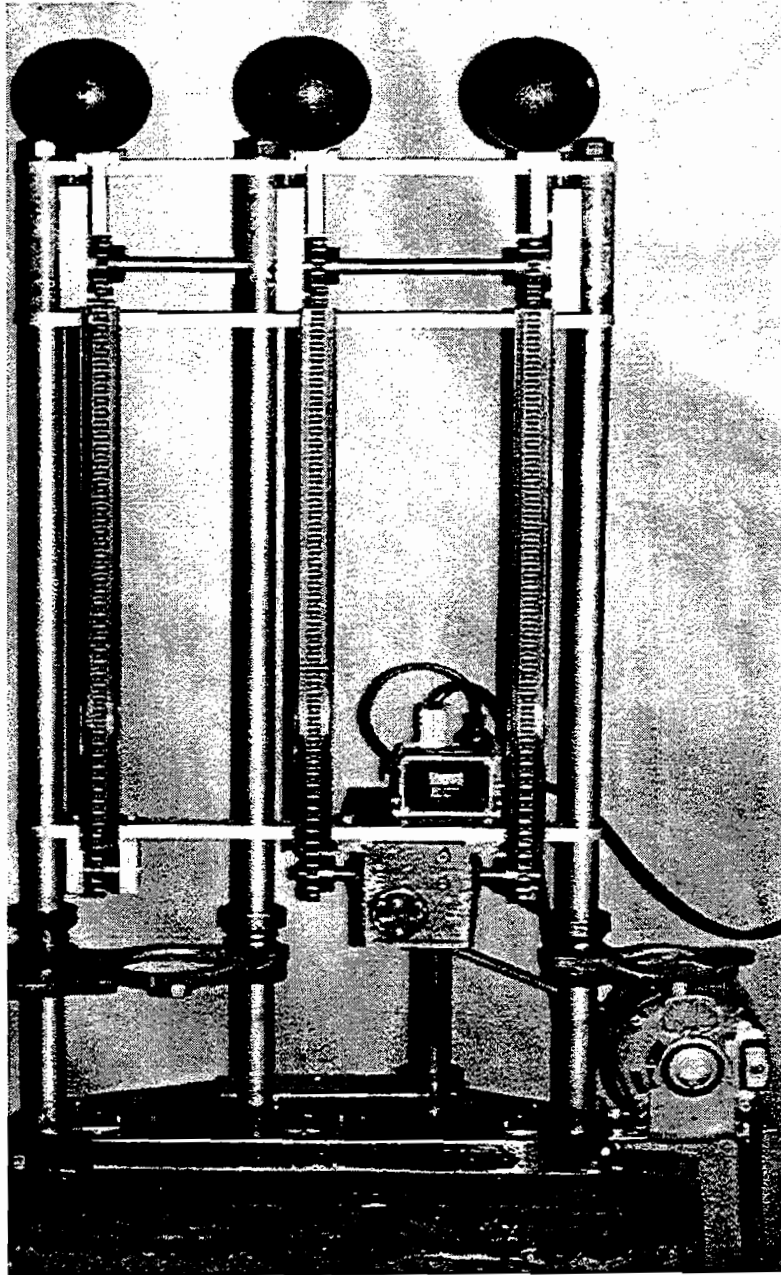


Figure 5
Mechanical Compactor

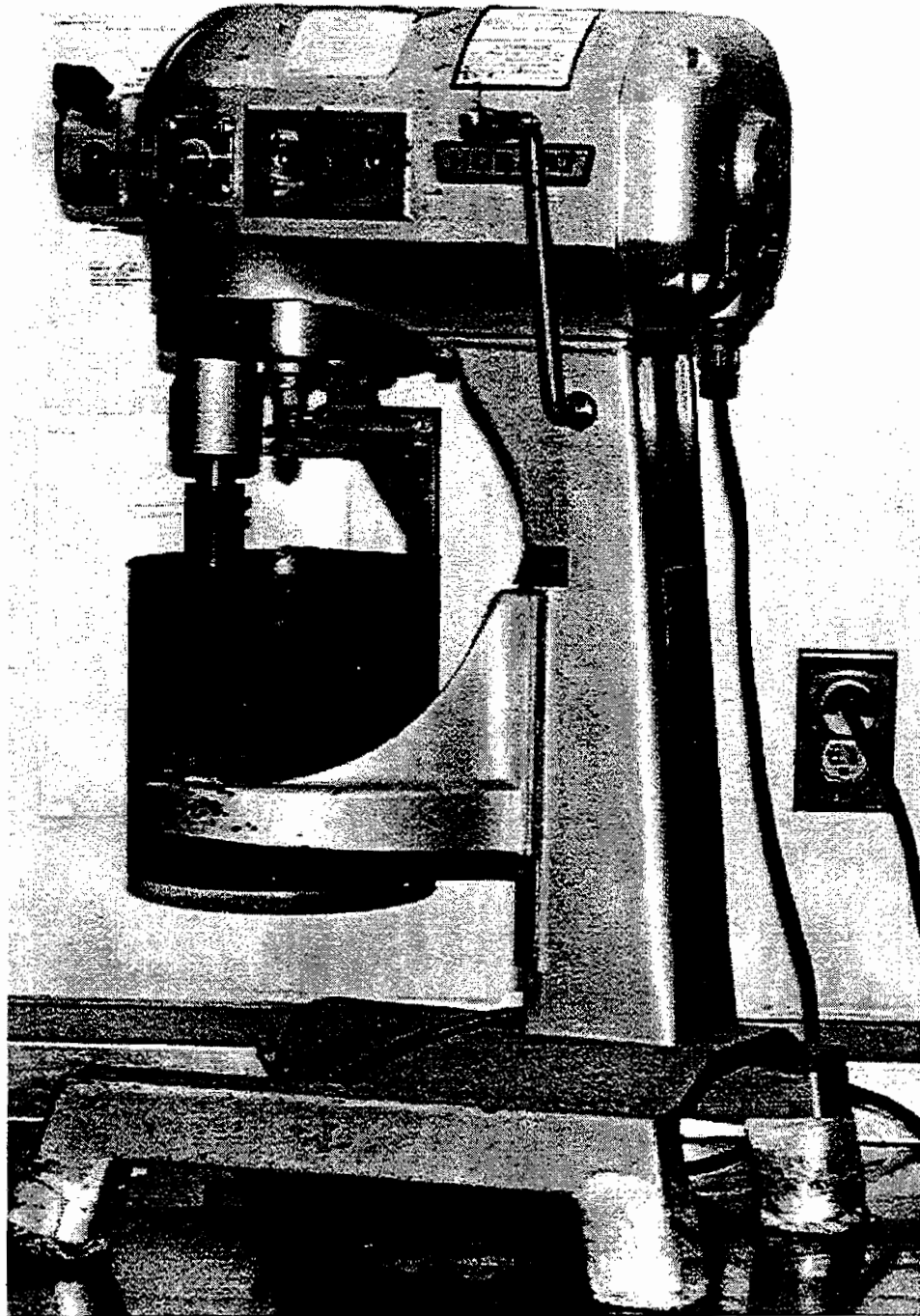


Figure 6
Mechanical Asphalt Mixer

METHOD OF TEST FOR BULK RELATIVE DENSITY OF COMPACTED BITUMINOUS MIXTURES

1. SCOPE

1.1 This method covers the procedure for the determination of the bulk relative density of compacted bituminous mixtures.

1.2 This method should be used only with densely graded or practically non-absorptive compacted mixtures such as Marshall briquettes and small sections of pavement samples.

2. RELEVANT DOCUMENTS

2.1 ASTM D 2726

3. PROCEDURE

3.1 Procedure of ASTM D 2726 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 PROCEDURE

4.1.1 Carefully brush off any loose particles adhering to the sample. For pavement sample (e.g., cores) taken immediately over a granular base, any imbedded granular material should be cleaned off. Determine the mass of the sample in air and record it (A_D).

4.1.2 For all samples determine the sample mass in water at 25°C after it has been immersed for 4 ± 1 minutes. Record the mass (B_1) and the temperature of the water.

Note: When testing multiple specimens, it is acceptable to soak the specimens in a water bath at the specified temperature. The total time of immersion (in the water bath plus during weighing) shall be within the specified limits.

4.1.2.1 When a Marshall briquette is being weighed, place the briquette with the side (curved section) resting on the bottom of the basket, ensuring that no air bubbles are trapped beneath the sample.

4.1.2.2 When a pavement sample is being weighed, place the sample with its side or end on the bottom of the basket ensuring that no air bubbles are trapped beneath the sample.

4.1.3 Remove the sample from the water, place the briquette with the side (curved face) on a damp towel. Carefully roll the specimen back and forth on a damp towel, enough to dry its surface. After surface drying the curved face, flip the specimen to surface dry the other two sides. For other pavement samples surface dry each face with a damp towel. Also dab dry any visible water film on surface cavities. Determine and record the mass (A_2) of the sample in air.

4.1.4 Dry pavement sample s at $110 \pm 5^{\circ}\text{C}$ to a constant mass to obtain the correct dry mass in air (A_C). It will be necessary to break up or separate the pavement sample in the pan to completely dry the sample. (This step is not necessary for laboratory prepared briquettes).

4.1.5 Determine the mass of all samples to 0.1 g accuracy.

4.2 CALCULATIONS

4.2.1 Calculate the Bulk Relative Density (B.R.D.) of the sample as follows:

$$\text{B.R.D.} = \frac{A_1}{(A_2 - B_1)}$$

where

A_1 = mass of sample in air, g

A_D for laboratory prepared briquettes

= A_C for oven dried pavement samples.

A_2 = surface dry mass of sample in air after water immersion, g

B_1 = mass of sample in water, g

4.2.2 If the test temperature differs from 25°C , a correction to the B.R.D. will be made in accordance with the following:

$$\text{B.R.D. (at } 25^{\circ}\text{C)} = \text{B.R.D. (at test temperature)} \times K$$

where: K = correction factor listed in Table 1 for test temperature

4.3 GENERAL NOTES AND PRECAUTIONS

4.3.1 When determining the mass of samples in water both the basket and handle, where provided, must be completely immersed in water.

4.3.2 Be certain that no air bubbles are adhering to the wire basket when it is immersed in water.

4.3.3 Use as thin a wire as possible to suspend the basket from the balance.

4.3.4 For Marshall briquettes, all bulk relative density determinations shall be done in triplicate.

If the B.R.D. of any one briquette is more than 0.015 from the mean of the triplicate values, recheck calculations and, if necessary, re-weigh. If the briquette density remains more than 0.015 from the mean then discard this value and recalculate the mean.

4.3.5 Mass of pavement samples may vary from 1000 to 2000 g.

4.3.6 Pavement samples must be free of cracks.

4.3.7 The water in the weigh bucket must be maintained as close to 25°C as possible.

Table 1
Correction Factors

TEMPERATURE	CORRECTION FACTOR
°C	K
20	1.001162
21	1.000950
22	1.000728
23	1.000495
24	1.000253
25	1.000000
26	0.999738
27	0.999467
28	0.999187
29	0.998898
30	0.998599

METHOD OF TEST FOR RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES USING MARSHALL APPARATUS

1. SCOPE

1.1 This method describes the procedure for determining the Marshall stability and Marshall flow values of bituminous mixes in the form of Marshall briquettes. The stability, defined as the maximum load developed during the test, is expressed in newtons. The flow, defined as the deformation of the sample up to the moment just past the peak load, i.e., the movement of the upper head relative to the lower head, is expressed in 0.25 mm units.

1.2 The Marshall briquettes are brought to test temperature in a water bath and then tested by means of the Marshall testing apparatus.

2. RELEVANT DOCUMENTS

2.1 ASTM Designation D 1559 - 89

2.2 MTO Method LS-261

3. PROCEDURE

3.1 Procedure of ASTM D 1559 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 Prepare specimens as outlined in MTO Method LS-261.

4.2 The flow values may be determined by the timing method. The calculation is as follows:

where T = time in s (average of two measurements taken by two different technicians)

D = deflection of proving ring in 0.00254 mm increments (this is the Marshall stability reading)

C = .007 (this constant must be determined for each test machine and may vary slightly)

4.3 Results are recorded on the Bituminous Mix Form (Figure 1).

5. REPORTING OF RESULTS

5.1 Marshall stability is reported in Newtons and is generally the average of three specimens, except when a briquette is discarded based on BRD (see LS-262).

5.2 Marshall flow is reported in increments of 0.25 mm.

5.3 Note the number of specimens used to obtain the average value of stability and flow recorded.

6. GENERAL NOTES

- 6.1 All metal parts of the testing machine, the breaking head and the surface of the briquettes, must be free from foreign matter and loose particles.
- 6.2 The jack head base plate must be kept tight on the elevating screw.
- 6.3 The briquettes must be allowed to cure for at least 12 h before testing.
- 6.4 Centre the briquette on the breaking head before testing.
- 6.5 To assure that the Marshall breaking heads meet ASTM dimensional requirements, a clear plastic template with scribed reference lines is available.
- 6.6 At no time should any solution be used to coat the inside of the breaking head.
- 6.7 Equipment should be calibrated a minimum of once every twelve months.

METHOD OF TEST FOR THEORETICAL MAXIMUM RELATIVE DENSITY OF BITUMINOUS PAVING MIXTURES

1. SCOPE

1.1 This method covers the determination of the theoretical maximum relative density of bituminous paving mixtures containing aggregates of low-absorption as well as mixtures containing porous aggregates. Included are mixtures prepared for mix design purposes, uncompacted paving mixtures and samples prepared from compacted pavement such as cores.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D 2041
- 2.2 Asphalt Institute MS-2

3. APPARATUS

- 3.1 BEAKERS: Stainless steel, 4000 ml capacity, no spout.
- 3.2 BALANCE: 4000 g capacity with an accuracy of ± 0.1 g.
- 3.3 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.
- 3.4 WIRE BASKET: Made from copper, stainless steel or brass wire mesh, 160 ± 5 mm diameter x 180 ± 5 mm high to contain sample and beaker when weighing in water.
- 3.5 WIRE: Thin as possible to suspend the basket from the balance. The use of fishing line leaders has been found to be satisfactory.
- 3.6 VACUUM CELL: Stainless steel beaker or other container fitted with a plexiglass top.
- 3.7 PUMP: Vacuum – capable of maintaining a residual pressure in the vacuum cell of at least 30 mm of Hg.
- 3.8 FILTERING FLASKS: Three 1000 ml Erlenmeyer filtering flasks with rubber stoppers.
- 3.9 RESIDUAL PRESSURE MANOMETER: To be connected directly to the vacuum vessel and which should be capable of measuring residual pressure below 30 mm of Hg.
- 3.10 MANOMETER OR VACUUM GAUGE: Suitable for measuring the vacuum being applied in close proximity of the pump. This is required to check the reading given by the residual pressure manometer.
- 3.11 MANIFOLD: Standard 19 mm (0.75 in) I.D. galvanized water pipe fitted with up to 4 quick action valves and a bleeder valve.
- 3.12 BLEEDER VALVE: Needle valve to control flow of air into the system for pressure control.

- 3.13 SILICA GEL: Tell tale (3 mm – 1mm size).
- 3.14 TUBING: Rubber, vacuum, minimum 6.4 mm (0.25 in) I.D.
- 3.15 TROWEL: Metal, garden type.
- 3.16 CONSTANT TEMPERATURE WATER BATH: Capable of maintaining a temperature of $25 \pm 1^\circ\text{C}$.

Note 1: Residual pressure in the vacuum vessel, measured in millimetres of mercury, is the difference in the height of mercury in the Torricellian leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum vessel.

Note 2: One residual manometer may serve two vacuum vessels through the use of a two position three port valve (show in Figure 3 so that the residual pressure in each vessel may be measured alternately and independently of the other during the test).

Note 3: The Torricellian vacuum leg of the manometer occasionally acquires one or more bubbles of air that introduce error into the residual pressure reading. By the addition of the vacuum gauge this error can often be quickly detected by the differences between two vacuum measurements. Other potential problems such as partial restriction of the vacuum line in the silica gel can be detected in this way.

Note 4: If all 4 quick action valves are to be used at the same time the bleeder valve or an additional valve which opens to atmosphere may be used as a vacuum breaker. The latter is preferred because it minimizes the time required to adjust the needle valve for successive tests.

Note 5: The foregoing does not include apparatus required for the preparation of samples (both field and mix design). Reference can be made to LS 261 if this is required.

4. SAMPLE SIZE

4.1 For mix design work and for loose field samples, the size of the test sample shall be governed by the 'Designated Large Sieve' size of the mix and shall conform to the requirements as shown in the following table:

Size Of Test Sample

Designated Large Sieve Size MTO Sieve Designation, mm	Minimum Mass of Sample kg
2.36	0.5
9.5	1.5
13.2	1.5
16.0	2.0

4.2 The Designated Large Sieve is a sieve size specifically designated for testing purposes. Its definition for the various mix types is as follows:

2.36 mm for HL 2;

9.5 mm for HL 1, HL 3, HL 3A, Dense Friction Course or Open Friction Course;

13.2 mm for HL 4 Binder or Surface Course;

16.0 mm for HL 8, Medium Duty Binder Course, or Heavy Duty Binder Course.

5. PREPARATION OF MIX DESIGN SAMPLES

5.1 The following assumes that the desired blend of aggregates has been determined, and a weigh card prepared. Also, the aggregates have been dried, and split into sieve fractions.

5.2 Arrange the individually sized coarse aggregate(s) and fine aggregate(s) in bags or in suitable containers on a bench, in order of decreasing sieve sizes. The pass 2.36 mm from the coarse aggregate(s) and from the fine aggregate(s) shall be placed in separate flat-bottomed pans of appropriate size. Using the flat-bottom scoop, weigh up, into separate pans for each test specimen, a sufficient quantity of oven-dried sample of the selected aggregates, so that the total mass will yield a sample of the specified size. Place the aggregates in an oven maintained at a temperature not exceeding 28°C above the mixing temperature specified by the proprietor of the asphalt cement product. Heating time shall be a minimum of 16 hours, normally overnight.

5.3 Preheat the mixing bowl in the same oven as the aggregate.

5.4 Preheat the metal trowel and spatula on the hot plates or in an oven.

5.5 Heat the asphalt cement to the mixing temperature specified by the proprietor of the asphalt cement using either an oven or hot plate. The asphalt cement should not be held at the mixing temperatures for more than 1 hour prior to its use. Suitable shields, baffle plates or sand pads shall be used on the surface of the hot plate to prevent localized overheating.

5.6 When the asphalt cement has reached the desired temperature, remove the container of aggregate from the oven, and quickly place it in the mixing bowl that has been previously tared on the balance. If the aggregate mass is not within ± 1 g of the originally batched mass prior to overnight heating adjust the batch by the addition of preheated pass 2.36 mm material from the primary fine aggregate. Using the mixer, dry mix the aggregate for 15 seconds.

5.7 After dry mixing, form a crater in the centre of the aggregate in the bowl, quickly add in the calculated amount of asphalt cement to give the desired asphalt cement content, and mix 45 seconds or until the aggregate is coated. Do not mix longer than 1.5 minutes. Report any mixing problem such as coating of aggregate or balling of mix.

5.8 At the end of the wet mixing cycle, using the pre-heated spatula, scrape as much of the mix as possible from the mixing paddle and scraper blade.

5.9 Spread the mixture into the metal trough using a back and forth motion. Scrape all the loose mixture in the bowl into a flat pan.

5.10 Place the mixture into a metal pan of sufficient size to yield a spread rate of 20-22 kg/m², cover with aluminum foil or other suitable cover, and place in an oven maintained at 135° C for two hours. Stir the mix occasionally during this period.

5.11 Following this conditioning period, allow the mix to cool to room temperature. During the cool down period, separate the particles by hand, taking care to avoid fracturing the aggregates, so that the particles of the fine aggregate portion are not larger than 6.3 mm.

Note 6: The mixing and compaction temperatures are typically supplied by suppliers or proprietors of the asphalt cement. See Figure 1 for details.

Note 7: While the determination of maximum theoretical relative density can be done for any asphalt cement content, the precision of the test is best when the mixture is close to the design asphalt content. Also, the test shall be done in duplicate or triplicate.

6. PREPARATION FROM LOOSE FIELD SAMPLES

6.1 Obtain loose field samples in accordance with specified procedures. Plate or loose mix samples shall be reduced to the proper size (See ASTM D 2041, item 7.2). Two methods of reducing the field sample to the testing size are acceptable: quartering or splitting using a riffle splitter. Testing shall be done in duplicate.

6.1.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A conventional oven maintained at 110°C or a microwave oven (see Note 8) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 9). The sample shall be mixed on the surface until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the testing size is obtained.

Note 8: Caution: Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metal particles in some mixtures may render the microwave oven unsafe for the heating of these mixtures.

Note 9: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

6.1.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A conventional oven maintained at 110°C or a microwave oven (see Note 8 above) may be used for this purpose. The mix may agglomerate if it is too cold or stick to the splitter if too hot. A temperature range of 90°C to 110°C has been found to be generally satisfactory. Heat lamps may be used to keep the walls of the riffle splitter warm (see Note 9 above). Chutes shall be cleaned after each split. The

use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found to be suitable.

6.2 Spread the mixture out on a rectangular pan, dry to constant mass in an oven maintained at a temperature of $110 \pm 5^{\circ}\text{C}$ and allow to cool to room temperature. Constant mass is defined as no change in mass in excess of 0.1 % for each 30 minute drying period. During the cool down period, separate the particles by hand, taking care to avoid fracturing the aggregates, so that the particles of the fine aggregate portion are not larger than 6.3 mm.

7. PREPARATION FROM COMPACTED PAVEMENT SAMPLES

7.1 Dry the entire core or sawn sample to a constant mass by placing the pan containing the material in an oven maintained at a temperature of $110 \pm 5^{\circ}\text{C}$. Constant mass is defined as no change in mass in excess of 0.1 % for each 30 minute drying period.

Note 10: Pavement samples used in this test may also require the determination of their bulk relative density. Such samples may contain residual moisture from the sawing/coring operation. These samples should have their mass in water and their surface dry mass determined prior to drying (see LS-262).

7.2 After the core or sawn sample has been dried to constant mass, trim to a depth approximately equivalent to the "Designated Large Sieve" size of the particles to remove the particles which were cut during the coring/sawing operation.

7.3 Allow the material to cool down to room temperature. During this cool down period, separate the particles by hand, taking care to avoid fracturing the aggregates, so that the particles of the fine aggregate portion are not larger than 6.3 mm.

Note 11: If, for a mix with a "Designated Large Sieve" size of 16 mm, the mass of the pavement cored/sawn sample after trimming is less than 1000 g, the MRD shall not be determined. For cores this would represent a sample of less than 25.4 mm (1 inch) thickness and would not be considered typical.

8. PROCEDURE

8.1 Set up the equipment for this test as shown in Figures 2 or 3. Transfer the loose mixture into a vacuum cell which has been previously calibrated for its mass in air and water. Add sufficient water at approximately 25°C to completely cover the sample.

8.2 Place the plexiglass top on the vessel ensuring a tight seal, and gradually reduce the pressure to 30 ± 1 mm Hg. Maintain this pressure for 15 minutes with periodic (or continuous) agitation to ensure that all the air has been removed. At the end of the specified time, release the vacuum slowly.

8.3 Suspend the container and contents in the water bath and determine the mass after 10 ± 1 minute immersion. Record the temperature of the water in the water bath if different from 25°C .

Note 12: For testing multiple samples, the containers and their contents may be submerged in a water bath at about 25° C, so that the total time of immersion (in the water bath and during subsequent weighing) is 10 ± 1 minutes.

8.4 For porous aggregates or aggregates that are not thoroughly sealed by a bituminous film, refer to ASTM D2041-95, Section 11 to conduct a supplemental procedure.

9. CALCULATION

9.1 Calculate the theoretical maximum relative density (MRD) as follows:

$$\text{MRD} = \frac{(D - E)}{(D - E) - (G - H)}$$

where:

D = mass of beaker and mixture in air, g

E = mass of beaker in air, g

G = mass of beaker and mixture in water at test temperature, g

H = mass of beaker in water at test temperature, g

9.2 If the temperature varies from 25° C, a correction to the MRD will be made in accordance with the following:

$$\text{MRD (@ 25 °C)} = \text{MRD (at test temperature)} \times K$$

where: K = correction factor listed in Table 1 for the test temperature

10. REPORTING OF RESULTS

10.1 All results are entered on a Bituminous Mix Form Sheet (Figure 4).

10.2 For duplicate testing, the results are considered acceptable if their range is less than 0.011.

11. GENERAL NOTES AND PRECAUTIONS

11.1 Most aggregates will absorb water if extensive asphalt stripping occurs while the test sample is under vacuum.

11.2 If the vacuum pump cannot produce the residual pressure required (30 ± 1 mm Hg), check the pressure at the vacuum pump. If this pressure is less than 30 mm Hg and the pressure at the vacuum vessel is not, check for blockage of the system in the silica gel tube or flask. If pressure at the pump is higher than the 30 mm Hg check the cell lids, valves and all tubing and connections for air leaks. Use heavy vacuum grease and/or hose clamps to seal connections. Do NOT use grease on the lid seals.

11.3 Check the oil level in the vacuum pump regularly. If water is present, drain the old oil, remove all moisture, and add clean oil.

11.4 Dry silica gel has a deep blue colour. When the silica gel is pink in colour, it is wet, and should be removed from the flasks and dried in an oven overnight so that it can be re-used.

- 11.5 When determining the mass of the sample in water, the basket and beaker must be completely immersed.
- 11.6 After vacuuming, care must be taken to avoid exposing the mixture to air before the mass in water is measured.
- 11.7 When determining the mass in water, check that no air bubbles are adhering to the wire basket or beaker (particularly under the lip).
- 11.8 It is not necessary for the water to boil continuously to ensure that all the air has been removed. Table 2 shows that water at 25° C will not boil unless the residual pressure is 23.756 mm Hg or lower.
- 11.9 Increasing the temperature of the water in the vacuum cell above 30°C will give rise to higher boiling rates, which will adversely affect the ability to maintain the system at the required absolute pressure.
- 11.10 The water in the container should be maintained as close to 25° C as possible. Where more than one vessel is being used, vessel pressures will show slightly different pressures unless the temperature of the water is approximately the same in each vessel.

Determination of the Laboratory Mixing and Compaction Temperatures of Hot Mix for Design of Pavement Mixtures

The viscosity temperature relationship of an asphalt cement is used as a guide for establishing the mixing and compaction temperature in the laboratory. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.17 ± 0.02 Pa.s is the mixing temperature. The temperature to which the asphalt cement must be heated to produce a viscosity of 0.28 ± 0.03 Pa.s is the compaction temperature. This has been the guide for Marshall mix design criteria and the relationship continues to be valid for laboratory purposes within Superpave. In Ontario the mixing and compaction temperature are the temperatures where the asphalt cement has viscosities of 0.17 and 0.28 Pa.s respectively.

The Brookfield Viscometer, a rotational device (ASTM D 4402), is used to determine the mixing, compaction, and pumping temperatures in the Superpave system. Viscosity measurements at 135° C and 165° C are plotted on a Loglog viscosity vs. log temperature chart shown below and the mixing and compaction temperature interpolated.

The procedure for establishing the mixing and compaction temperatures for the laboratory is valid for refinery produced asphalt cements and may not be valid for some polymer modified asphalt cements. The supplier of these asphalt cements must be consulted for their mixing and compaction temperature recommendations.

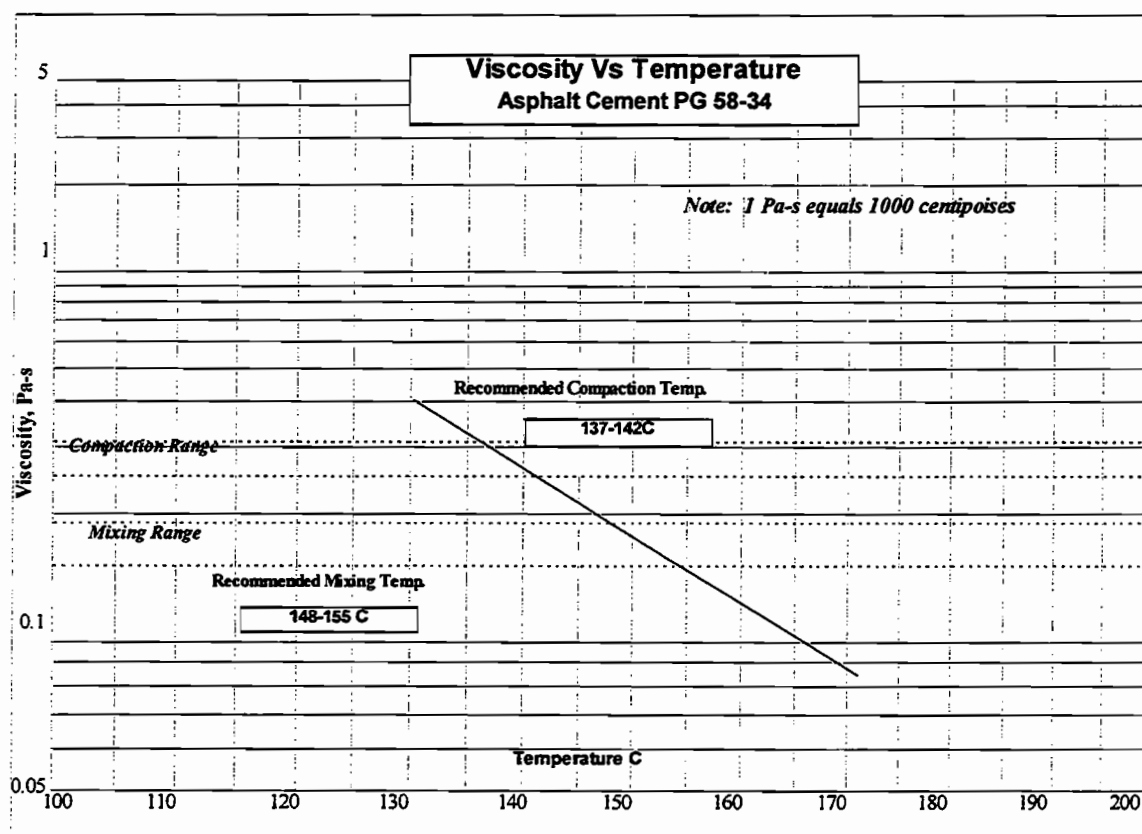


Figure 1

Sample Temperature Viscosity Chart

The relationship between temperature and viscosity in this figure shows the idealized laboratory mixing and compaction ranges. The asphalt cement is a "super lubricant" at the mixing temperature and a "super glue" somewhere around the compaction temperature range.

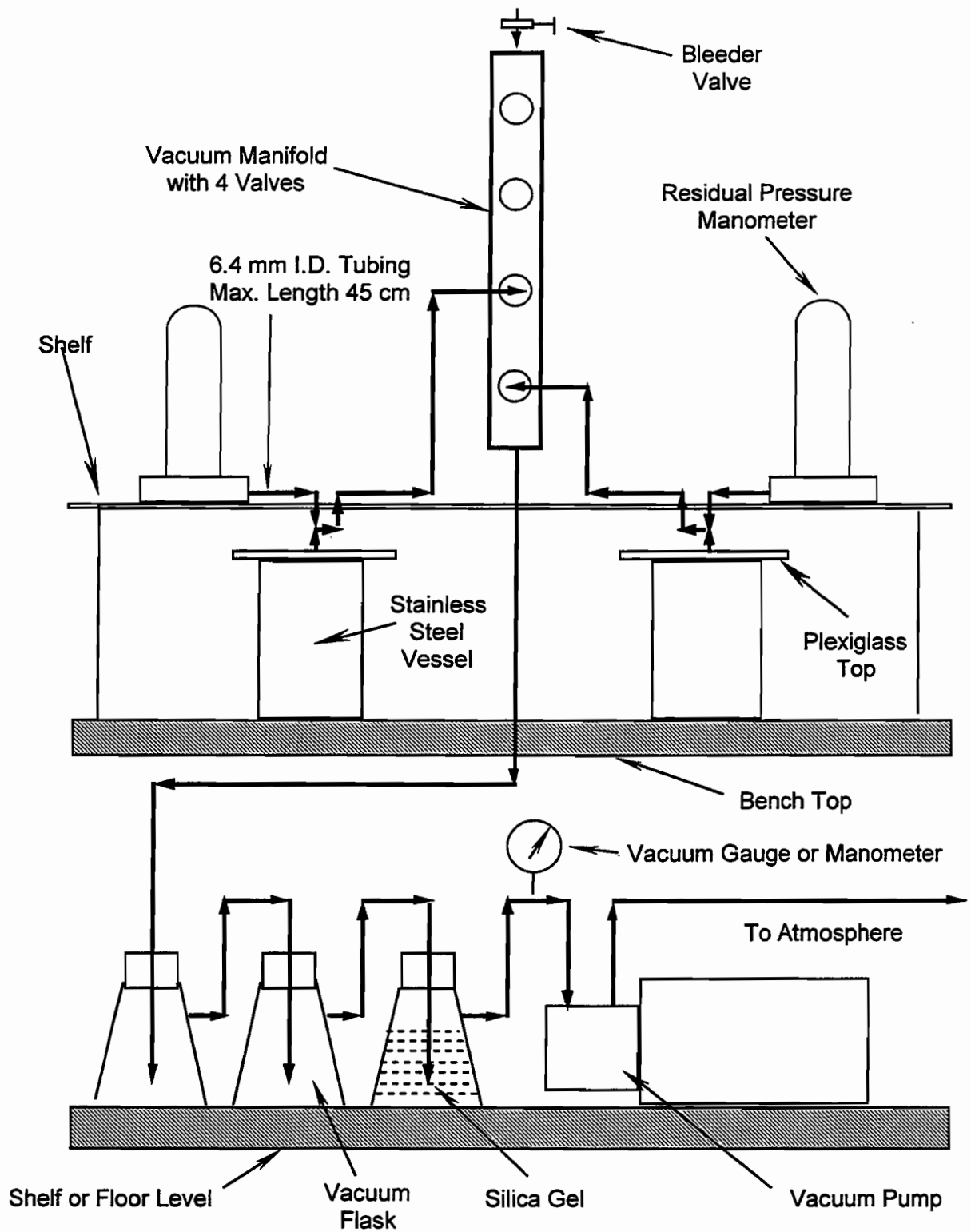
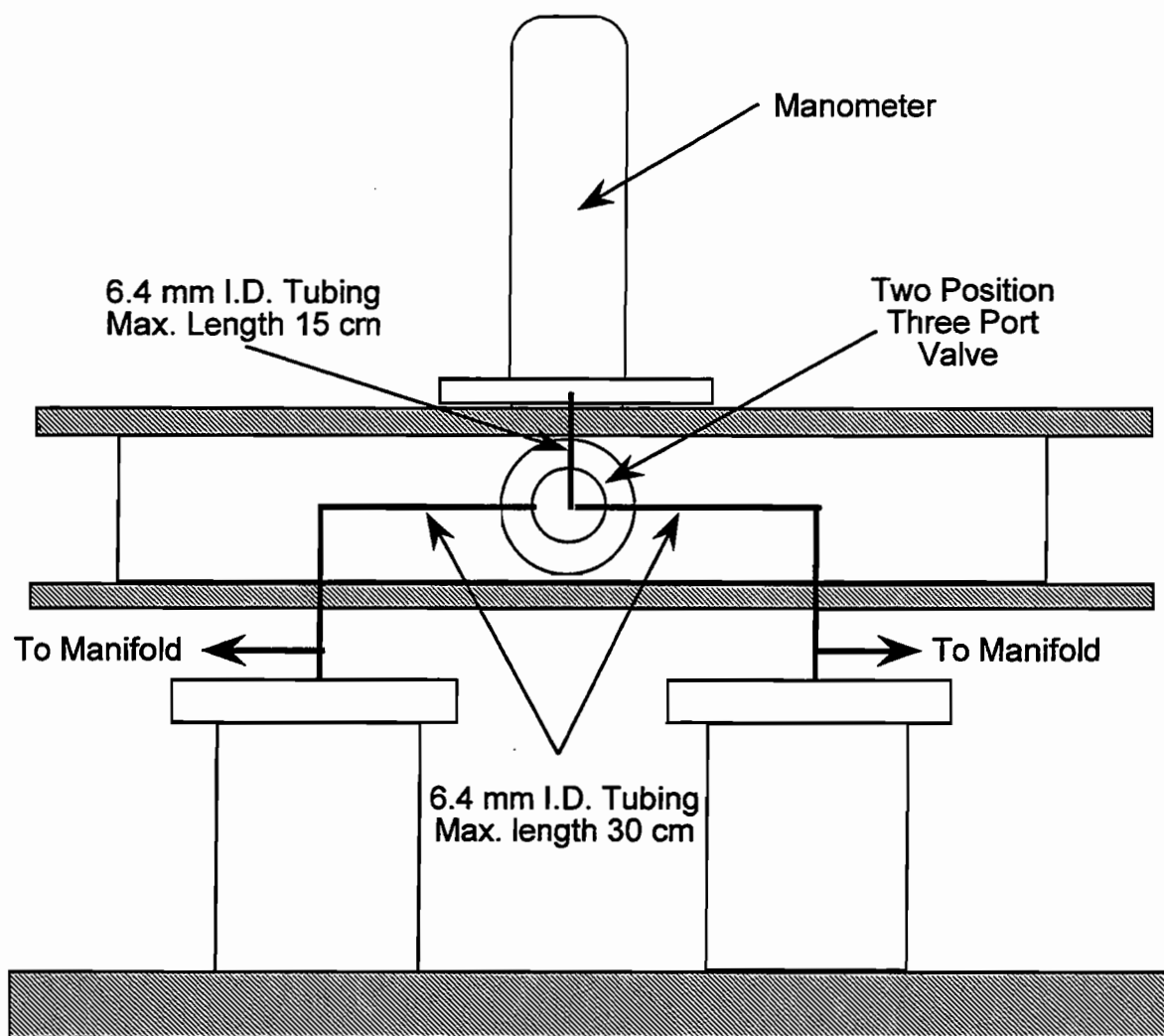


Figure 2
Vacuum Saturation System



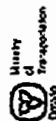
MRD equipment using one manometer for two vessels

Note: Tubing between the manometer and the vessels must be kept as short as possible to enable accurate pressure readings.

Figure 3

Vacuum Saturation System - Alternative Setup

BITUMINOUS MIX FORM



Ontario

MARSHALL TEST VALUES

PROPERTY	SAMPLE NUMBER	AVERAGE
STABILITY (DIAL)		
FLOW NO 1 (s)		
FLOW NO 2 (s)		
AVERAGE FLOW (s)		

VISUAL OBSERVATIONS

BRIQUETTE APPEARANCE	D, M, R, VR
COATING (E.A.G.)	D, M, R, SF, F
STRIPPING	F, F, Q
C. AGG. FRACTURE	NI, SI, M, H
WETNESS OBSERVED IN FRACTURED C.A.	NI, SI, M, H
	Y N

SUMMARY OF TEST RESULTS

VOIDS (%)	S.D.
FLOW (1.25 mm)	
CORRECTED STABILITY (N)	
** V.M.A. (%)	

MIX TYPE %A.C.

% PASS 4.75mm

BLEND

AGGREGATE SAMPLE NO.

C/A

SAND

RA/SEC.

RAP

PROPERTY	SAMPLE NUMBER	AVERAGE
A ₁ MASS OF COMPACTED SPECIMEN IN AIR		
A ₂ SURFACE DRY MASS OF SPECIMEN IN AIR AFTER IMMERSION IN WATER		
B ₁ MASS OF COMPACTED SPECIMEN IN WATER		
B ₂ VOLUME = A ₂ - B ₁		
C BULK RELATIVE DENSITY = $\frac{A_1}{B_1}$		
D MASS OF FLASK AND MIXTURE IN AIR		
E MASS OF FLASK IN AIR		
F MASS OF MIXTURE IN AIR = D - E		
F ₁ SURFACE DRY MASS OF MIXTURE IN AIR		
G MASS OF FLASK & MIXTURE IN WATER		
H MASS OF FLASK IN WATER		
I ₁ MASS OF MIXTURE IN WATER = G - H		
I ₂ VOLUME = F - I ₁		
J S.D. VOLUME = $\frac{I_2 - I_1}{I_1}$		
J ₁ MAXIMUM RELATIVE DENSITY = $\frac{F}{I_2}$		
J ₂ S.D. MAXIMUM RELATIVE DENSITY = $\frac{F}{I_1}$		
K PERCENT VOIDS IN MIXTURE = $\frac{J - J_1}{J_1} \times 100$		
K ₁ S.D. PERCENT VOIDS IN MIXTURE = $\frac{J - J_2}{J_2} \times 100$		

*S.D. MEANS SURFACE DRY
**V.M.A. CALCULATED ON % VOIDS IN MINERAL AGGREGATE FORM
***ALL RELATIVE DENSITIES ARE CORRECTED TO 25°C
****INDICATE BY CIRCLED Y FOR YES OR N FOR NO



Figure 4

Table 1
MRD Correction Factors

TEMPERATURE		CORRECTION FACTOR	
°C		K	
20		1.001162	
21		1.000950	
22		1.000728	
23		1.000495	
24		1.000253	
25		1.000000	
26		0.999738	
27		0.999467	
28		0.999187	
29		0.998898	
30		0.998599	

Table 2
Influence Of Water Temperature On Pressure*

TEMPERATURE OF WATER	PRESSURE AT WHICH BOILING OCCURS		CORRESPONDING VACUUM AT WHICH BOILING OCCURS	
°C	mm of Hg	Inches of Hg	mm of Hg	Inches of Hg
20	17.535	0.69	742.47	29.23
21	18.650	0.73	741.35	29.19
22	19.827	0.78	740.17	29.14
23	21.068	0.83	738.93	29.09
24	22.377	0.88	737.62	29.04
25	23.756	0.94	736.24	28.98
26	25.209	0.99	734.79	28.93
27	26.739	1.05	733.26	28.87
28	28.349	1.12	731.65	28.80
29	30.043	1.18	729.96	28.74
30	31.824	1.25	728.18	28.67
31	33.695	1.33	726.31	28.59
32	35.663	1.40	724.34	28.52
33	37.729	1.49	722.27	28.43
34	39.898	1.57	720.10	28.35
35	42.175	1.66	717.83	28.26

*Note: Data taken from 55th Edition Handbook of Chemistry and Physics, Page D159.

**METHOD OF TEST FOR
DETERMINATION OF PERCENT AIR VOIDS IN COMPACTED DENSE
BITUMINOUS PAVEMENT MIXTURES**

1. SCOPE

1.1 This method covers determination of the percent air voids in compacted dense bituminous paving mixtures.

2. RELEVANT DOCUMENTS

2.1 ASTM D 3203

3. PROCEDURE

3.1 Procedure of ASTM D 3203 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 Calculate the percent air voids in a compacted bituminous paving mixture as follows:

$$\text{percent air voids} = \frac{J - c}{J} \times 100$$

J = theoretical maximum relative density of bituminous mix.

c = bulk relative density of compacted mix.

4.2 Report results to one decimal place.

METHOD OF TEST FOR DETERMINATION OF V.M.A. IN COMPACTED BITUMINOUS MIXTURES

1. SCOPE

1.1 This method covers the calculations required to determine the Voids in Mineral Aggregate (V.M.A.) of a compacted bituminous mixture.

2. RELEVANT DOCUMENTS

2.1 MTO Methods LS-262, LS-604, LS-605

3. DEFINITIONS

3.1 V.M.A. in a thoroughly compacted paving mixture consists of the volume of intergranular void space between the aggregate particles that includes the air voids and the effective asphalt content expressed as a percentage by volume of the total volume of the sample.

4. CALCULATIONS

4.1 V.M.A. (Figure 1)

$$\begin{aligned} \text{V.M.A.} &= \frac{G_b - G_c}{G_b} \times 100 \\ &= 100 - \frac{D_b(100 - \% \text{ A.C.})}{G_b} \\ \text{where } G_b &= \frac{100}{\frac{\% \text{ Co. Agg.}}{\text{BRD Co. Agg.}} + \frac{\% \text{ Fi. Agg. \#1}}{\text{BRD Fi. Agg. \#1}} + \frac{\% \text{ Fi. Agg. \#2}}{\text{BRD Fi. Agg. \#2}} + \dots} \\ \text{and } G_c &= \frac{D_b \times (100 - \% \text{ A.C.})}{100} \\ G_b &= \text{bulk relative density of aggregate} \\ G &= \text{compacted relative density of aggregate} \\ D_b &= \text{bulk relative density of compac} \\ \text{BRD} &= \text{bulk relative density (LS-604 \& LS-605)} \end{aligned}$$

5. REPORTING OF RESULTS

5.1 Report V.M.A. in % to nearest 0.1 % on the Bituminous Mix Form, (see Figure 2).

6. NOTES

6.1 If the plant check gradation and AC content is very close to the mix design, then the G_C calculation from the mix design may be used.

6.2 If the plant check gradation varies by 5.0% or more from the design, then the BRD's for the coarse and fine aggregates must be used to calculate the V.M.A. Both the G_C calculation and the BRD's for the coarse and fine aggregate(s) should be noted in the remarks column of the Bituminous Mix Design Report (Figures 3,4; Respectively, front and back sides of report.).



Ministry of
Transportation and
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% VOIDS IN MINERAL AGGREGATE

DATE _____ CONTRACT NO. _____

MATERIALS

MATERIALS	LAB. NO.	B. R. D.	WATER ABSORP.
RECLAIM ASPHALT PAV'T. (R.A.P.)			
COARSE AGGREGATE			
COARSE AGGREGATE PASS #4.75mm			
FINE AGGREGATE # 1			
FINE AGGREGATE # 2			
MINERAL FILLER			

MIXES SELECTED

	1	2	3	4
% R.A.P.				
% CO. AGG.				
% FINE AGG. # 1				
% FINE AGG. # 2				
% M.F.				
% A.C.	1			
	2			
	3			

CALCULATIONS

1. BULK RELATIVE DENSITY OF COMPACTED MIX (D_b)

1	2	3	4

2. BULK RELATIVE DENSITY OF AGGREGATE (G_b)

100						
$\frac{\% \text{ Co. AGG.}}{\text{B.R.D. Co. AGG.}}$	+	$\frac{\% \text{ Fi. AGG. \#1}}{\text{B.R.D. Fi. AGG. \#1}}$	+	$\frac{\% \text{ Fi. AGG. \#2}}{\text{B.R.D. Fi. AGG. \#2}}$	+	...
1		2		3		4

3. VOIDS IN COMPACTED AGGREGATE (V.M.A.) %

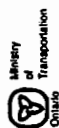
$$\% \text{ V.M.A.} = 100 - \frac{D_b (100 - \% \text{ A.C.})}{G_b}$$

1	2	3	4

PH-CC-372 (Formerly OBM153)

Figure 1

BITUMINOUS MIX FORM



MARSHALL TEST VALUES

PROPERTY	SAMPLE NUMBER	AVERAGE
STABILITY (DIAL)		
FLOW NR 1 (s)		
FLOW NR 2 (s)		
AVERAGE FLOW (s)		

VISUAL OBSERVATIONS

MIX APPEARANCE	D, M, R, VR
BRIQUETTE APPEARANCE	D, M, R, SF, F
COATING	P, F, G
STRIPPING	NIL, SL, M, H
C. AGG. FRACTURE	NIL, SL, M, H
WETNESS OBSERVED IN FRACTURED C.A. ***	Y N

SUMMARY OF TEST RESULTS

VOIDS (%)	± 3 D
FLOW (.25 mm)	
CORRECTED STABILITY (N)	
*** V.M.A. (%)	

MIX TYPE _____ %A.C. _____

% PASS 4.75mm _____

BLEND _____ S.D. ☐

AGGREGATE SAMPLE NO. _____

C/A _____

SAND _____

SA/SCR. _____

RAP _____

REMARKS : _____

SAMPLE NO. _____

DATE _____

CONTRACT NO. _____

PROPERTY	SAMPLE NUMBER	AVERAGE
A ₁ MASS OF COMPACTED SPECIMEN IN AIR		
A ₂ SURFACE DRY MASS OF SPECIMEN IN AIR AFTER IMMERSION IN WATER		
B ₁ MASS OF COMPACTED SPECIMEN IN WATER		
B ₂ VOLUME = $A_2 - B_1$		
C *** BULK RELATIVE DENSITY = $\frac{A_1}{B_2}$		
D MASS OF FLASK AND MIXTURE IN AIR		
E MASS OF FLASK IN AIR		
F MASS OF MIXTURE IN AIR = D - E		
F ₁ SURFACE DRY MASS OF MIXTURE IN AIR		
G MASS OF FLASK & MIXTURE IN WATER		
H MASS OF FLASK IN WATER		
I ₁ MASS OF MIXTURE IN WATER = G - H		
I ₂ VOLUME = $F - I_1$		
I ₃ S.D. VOLUME = $F_1 - I_1$		
J *** MAXIMUM RELATIVE DENSITY = $\frac{F}{I_2}$		
J ₁ S.D. MAXIMUM RELATIVE DENSITY = $\frac{F}{I_3}$		
K PERCENT VOIDS IN MIXTURE = $\frac{J - C}{J} \times 100$		
K ₁ S.D. PERCENT VOIDS IN MIXTURE = $\frac{J_1 - C}{J_1} \times 100$		

*S.D. MEANS SURFACE DRY
 ***V.M.A. CALCULATED ON % VOIDS IN MINERAL AGGREGATE FORM
 ***ALL RELATIVE DENSITIES ARE CORRECTED TO 25°C
 ***INDICATE BY CIRCILING Y FOR YES OR N FOR NO



PH-CC-351 93-02

Figure 2



CONTRACT NO.		HOT MIX TYPE / USE		ITEM NO.	
HWY.		LOCATION			
TESTING LAB.			JOB MIX FORMULA NO.		
LAB. MIX NO.			Issued by Qual Assurance		
			DATE SAMPLES REC'D.		
			DATE COMPLETED		
TEST DATA CERTIFIED BY: _____					

JOB MIX FORMULA - GRADATION PERCENT PASSING *												
% AC	26.5	19.0	16.0	13.2	9.5	4.75	2.36	1.18	600	300	150	75
MARSHALL	REQUIREMENTS		SELECTED		% CA # 1				% RAP			
% VOIDS (min.) (max.)					% CA # 2				% AC RAP			
FLOW (min.)					% FA # 1				RAP PEN			
STAB. (min.)					% FA # 2				BRIQ. BRD			
% VMA (min.)					% FA # 3				MRD			
					Gb				MRD (SD)			

ASPHALT CEMENT	
SUPPLIER	PENETRATION

ADDITIVE		
SUPPLIER	TYPE	AS % OF AC

AGGREGATE TYPE	SOURCE / INVENTORY NO.	AGGREGATE TYPE	SOURCE / INVENTORY NO.
COARSE AGG. # 1		FINE AGG. # 2	
COARSE AGG. # 2		FINE AGG. # 3	
FINE AGG. # 1		RAP	

[illegible]

* FINES RETURNED TO THE MIX (%)

REMARKS:

REVIEWED BY: _____ (MTO) DATE: _____

Figure 3

BITUMINOUS MIX DESIGN: Contract No. _____ Mix Type / Use _____
Lab Mix No. _____

% Voids.	Marshall Stability (N) X 1000
Bulk Relative Density	Marshall Flow (0.25mm)
Maximum Relative Density	% VMA
A.C. %	A.C. %

VISUAL OBSERVATIONS: _____

Figure 4

METHOD FOR THE DETERMINATION OF PERCENT COMPACTION OF COMPACTED BITUMINOUS PAVEMENT MIXTURE

1. SCOPE

1.1 This method covers the determination of the percent compaction of a sample of compacted bituminous pavement. The bulk relative density of a sample of bituminous paving mixture is compared to the bulk relative density of the sample recompacted by the Marshall compaction method.

2. RELEVANT DOCUMENTS

2.1 MTO Method LS-261

2.2 MTO Method LS-262

3. TEST PROCEDURES

3.1 Determine the bulk relative density of the pavement sample according to test procedures outlined in MTO Method LS-262.

3.2 Place the pavement sample inside the oven (refer to MTO Method LS-261 Section 3.8) and heat to the appropriate temperature indicated in LS-261 Section 4.1. Using the Marshall apparatus, proceed to compact one briquette as described in MTO Method LS-261 Sections 7.1 or 8.1.

3.3 Determine the bulk relative density of the recompacted briquette according to test procedures outlined in MTO Method LS-262.

4. CALCULATION

4.1 % compaction = $\frac{A}{B} \times 100$

where A = bulk relative density of pavement sample
 B = bulk relative density of the recompacted briquette

5. REPORTING OF RESULTS

5.1 Calculate results to one decimal place.

6. GENERAL NOTES

6.1 The pavement sample taken for establishing the bulk relative density must be free of cracks, and may consist of a minimum 150 mm diameter core with a mass of approximately 1300 g, or a sawn sample of the same mass.

**METHOD OF TEST FOR
QUANTITATIVE EXTRACTION OF ASPHALT CEMENT
AND ANALYSIS OF EXTRACTED AGGREGATE
FROM BITUMINOUS PAVING MIXTURES**

1. SCOPE

1.1 This method covers the quantitative determination of asphalt cement in a bituminous paving mixture. The paving mixture is extracted with trichloroethylene or methylene chloride solvent and the extract is corrected for mineral fines content using high speed centrifuge or ashing methods.

1.2 The extracted aggregate is washed to remove fines smaller than 75 µm and the remaining aggregate is used for sieve analysis.

1.3 *This standard may involve hazardous materials, operations, and equipment and does not purport to address all of the safety concerns associated with their use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. RELEVANT DOCUMENTS

- 2.1 ASTM C 702
- 2.2 ASTM D 2172
- 2.3 ASTM E 11
- 2.4 AASHTO T 164

3. REAGENT

3.1 Trichloroethylene - Reagent grade chemical or grade of sufficiently high purity to permit use without lessening the accuracy of the determination.

3.2 Methylene chloride - Reagent grade chemical or grade of sufficiently high purity to permit use without lessening the accuracy of the determination. If this reagent is used, substitute 'methylene chloride' for the word 'trichloroethylene' throughout the method.

4. APPARATUS

4.1 **BALANCES:** of sufficient capacity and sensitivity for miscellaneous weighing, with associated accessories such as balance pans.

4.2 **DRYING PANS:** Seamless enamel, stainless steel, or aluminum pans with a minimum of 10 square mm horizontal surface area per gram of sample, shall be used for drying the extracted

aggregate as well as the washed aggregate. Rectangular metal pans of nominal size 250 x 400 x 50 mm have been suitable for the determination of moisture content.

4.3 CENTRIFUGE EXTRACTOR: Either electrically or hand operated, complete with 1000 g minimum capacity bowl. For the electrically operated extractor, it is necessary to have a controlling device that will allow the speed to be set at 1800 r.p.m.

Note 1: Rotarex extractors have been found to be suitable for this test. Due to the nature of the solvent used, this equipment must be installed in a properly ventilated location (i.e. a fume hood or equivalent).

4.4 DRAIN TUBE: Neoprene, preferably with a 150 mm long glass insert.

4.5 FILTER PADS: Smooth, heavy weight, medium fast, low ash, qualitative type paper - E & D Grade 627 or equivalent.

4.6 MISCELLANEOUS ITEMS: 0.5 L container, 150 mm spike, 80 mm x 12 mm stainless steel spatula, stiff brush, a rubber spatula and a 75 mm wide blade scraper. Wider blades have been used successfully for quartering (1.6 x 100 x 400 mm).

4.7 TORQUE WRENCH: 9.5 mm drive, calibrated in N-m with a capacity of approximately 22 N-m. This can be used either with a 19.1 mm socket with two slots milled out of the sides to fit over the steel rod in the extractor unit funnel, or with a 9.5 mm drive socket brazed into the middle of the funnel.

4.8 EXTRACT CONTAINERS: Any suitable containers which will permit the quantitative transfer of extract and mineral fines to the high-speed centrifuge. The containers should have a capacity sufficient to accommodate the volume of extract from each rotarex cycle.

4.9 TACHOMETER: A strobe type tachometer capable of determining rotational speeds in the range of 1,000 to 10,000 r.p.m.

4.10 GRADUATED CYLINDER: 500 ml capacity to measure the rate of flow of the extract during the recovery of mineral fines. Use 2000 ml cylinders if they are being used as receivers for the total volume of extract.

4.11 HIGH-SPEED CENTRIFUGE: As described in ASTM D-2172 Section 11.6.2.1.

4.12 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.

5. SAMPLE SIZE

5.1 The size of the test sample shall be governed by the 'Designated Large Sieve' size of the mix and shall conform to the requirements as shown in the following table:

Size Of Test Sample

Designated Large Sieve Size MTO Sieve Designation,	Minimum Mass of Sample
mm	kg
2.36	0.5
9.5	1.5
13.2	1.5
16.0	2.0

5.2 The Designated Large Sieve is a sieve size specifically designated for testing purposes. Its definition for the various mix types is as follows:

2.36 mm for HL 2;

9.5 mm for HL 1, HL 3, HL 3A, Dense Friction Course or Open Friction Course;

13.2 mm for HL 4 Binder or Surface Course;

16.0 mm for HL 8, Medium Duty Binder Course, or Heavy Duty Binder Course.

5.3 For moisture content, a minimum sample size of 1000 g is required for all types of paving mix.

6. SAMPLE PREPARATION FROM LOOSE PAVING MIXTURES

6.1 Obtain loose field samples in accordance with specified procedures. Plate or loose mix samples shall be reduced to the proper size. Two methods of reducing the field sample to the testing size are acceptable: quartering or splitting using a riffle splitter.

6.1.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A conventional oven maintained at 110°C or a microwave oven (see Note 2) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 3). The sample shall be mixed on the surface until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the testing size is obtained.

Note 2: Caution: Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metal particles in some mixtures may render the microwave oven unsafe for the heating of these mixtures.

Note 3: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

6.1.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A conventional oven maintained at 110°C or a microwave oven (see Note 2 above) may be used for this purpose. The mix may agglomerate if it is too cold or stick to the splitter if too hot. A temperature range of 90°C to 110°C has been found to be generally satisfactory. Heat lamps may be used to keep

the walls of the splitter box warm (see Note 3 above). Chutes shall be cleaned after each split. The use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found suitable.

7. SAMPLE PREPARATION FROM COMPACTED PAVING MIXTURES

When testing core samples for asphalt cement content and sieve analysis, the core shall be warmed just sufficiently to enable the trimming of the curved surface to remove particles which were cut during the coring process. The depth trimmed shall be equivalent to the 'Designated Large Sieve' size for the particular mix type, except for HL 2 mix when the depth trimmed shall be approximately 4.75 mm. Dry the trimmed core to constant mass (see Section 8) to remove moisture.

8. DETERMINATION OF MOISTURE CONTENT

8.1 In extraction test calculations, asphalt cement content is obtained by subtracting the extracted aggregate mass from the original mass of the test sample. If moisture is present in the original sample it will appear as asphalt cement in the final calculation unless a correction is made. This is done by determining the amount of moisture in a separate 1000 g portion and adjusting the mass of the extraction test portion or, if time permits, heating the extraction test portion to a constant dry mass. The first method has the advantage that the two procedures can be run concurrently. Either method is acceptable.

8.2 Weigh the test portion obtained for moisture content determination and record the mass to 0.1 g. Place the test portion in an oven maintained at $110 \pm 5^\circ\text{C}$ and dry to a constant mass.

Note 4: Constant mass is defined as no change in mass in excess of 0.1% or 1 g, whichever is less, for each 30 minute drying period.

8.3 Reweigh the test portion and calculate its moisture content rounding off to the nearest 0.01% as follows:

$$\% \text{ Moisture Content, (Z)} = \frac{(M_a - M_d)}{M_d} \times 100$$

where: M_a = Original mass of mix, g

M_d = Mass of oven dry mix, g

8.4 Adjust the original mass of the test portion used for extraction in accordance with Section 11.2.

8.5 If the method of drying the original test portion is followed, then use the dried mass as the original mass in subsequent calculations.

9. EXTRACTION PROCEDURE

9.1 Measure and record the mass of the test portion to the nearest 0.1 g (W_1).

9.2 Carefully transfer the mix from the balance pan to the extractor bowl keeping the funnel in place during the transfer.

9.3 Fill the 0.5 L container with trichloroethylene and wash any of the mixture remaining in the balance pan into the extractor bowl. Put the remaining solvent into the bowl, while gently breaking down the mix with the spike or spatula. Distribute the mix evenly around the bowl to avoid off-balance loading. Clean all fines and asphalt off the spike or spatula with solvent and ensure all aggregate particles are covered by the solvent (see Note 5).

Note 5: For larger size bowls, increase the amount of solvent to ensure total coverage of the aggregate.

9.4 Dry the filter paper at 110°C to constant mass, to the nearest 0.1 g (M_f). The filter paper should be weighed immediately after drying. Filters may be preweighed, i.e. an established dry mass for each filter (hot) may be determined prior to using the filter. This dry, hot mass may then be used as the "original mass of the filter" in the calculations. After pre-drying, the filters must be kept in a dust proof container until used. Place the filter paper, with fine side up, on the bowl. Place the cover on the bowl (and over the filter paper) and tighten with the torque wrench. Apply a torque of 11.3 N-m to the funnel (Note 6). Allow the sample to soak for 15 minutes.

Note 6: For larger size extractor bowls, the laboratory shall have a written protocol to ensure uniform tightening of the lids.

9.5 At the end of the 15 minute soak period, with the bowl in the extractor and the cover in place, start the extractor slowly.

9.6 With the hand operated extractor, turn the handle slowly, gradually increasing the speed of the handle to 60 r.p.m. (which is equivalent to 1800 r.p.m. of the bowl for the electrically powered extractor). With the electrically powered extractor start the machine slowly, allowing it to increase to a maximum of 1800 r.p.m. (See Note 7). Maintain this rate until the solvent ceases to flow and just drips. Collect and retain the extract in the extract containers.

Note 7: Operate larger size extractors in accordance with manufacturer's instructions.

9.7 Stop the extractor and remove the small cover over the funnel (if applicable). Pour 0.5 L of solvent through the funnel into the bowl (see Note 5 above) and rotate the bowl back and forth by hand to dislodge any material adhering to the side of the bowl. Replace the funnel cover, allow the sample to soak for 10 minutes and repeat centrifuging as described in Section 9.6.

9.8 Repeat this procedure, reducing the soaking period to 5 minutes (see Note 8). Be sure that the solution coming through the drain tube is a light straw colour. Spin until the dripping ceases and continue for an additional 2 minutes thus ensuring a fairly dry aggregate sample.

Note 8: RHM, RAP and samples containing slag or absorptive aggregate may require a 15 minute soak period for each repeat of the procedure.

9.9 The extract container may now contain the total extract and washings from each rotarex cycle to be used for the determination of mineral fines in the extract in accordance with Section 10.

9.10 Remove the extractor bowl and set it on a suitable stand under adequate ventilation. Carefully remove the cover leaving the filter in place. Tap the filter surface all around with the metal spatula so that any loose material drops into the bowl. Lift the filter pad from the bowl and carefully invert the filter over a drying pan to avoid loss of fines. Brush or scrape the fines from the filter into the drying pan. Loosen the aggregate from the sides of the extractor bowl with a rubber spatula (while keeping the bowl tilted) and, using a stiff brush, transfer the remainder of the material from the bowl into the drying pan. Any fines adhering to the bowl must be brushed into the drying pan. Any fines adhering to the brush must also be transferred to the drying pan. Bend the filter pad into a tent shape and place it on the drying pan. Place the drying pan in the oven. Dry to a constant mass at $110 \pm 5^{\circ}\text{C}$ taking care not to char or burn the filter pad.

9.11 Provided low ash filter rings are used, an alternative procedure for the determination of mineral fines in the filter ring may be used (see Section 9.17).

9.12 At the end of the drying period remove the pan from the oven.

Note 9: Because dry aggregate absorbs moisture when exposed to air, determine the mass of the extracted aggregate immediately after cooling to 90 to 100°C to avoid damage to the balance. A dial thermometer tared with the weighing pan has been found to be useful in determining when a suitable weigh temperature is reached.

9.13 Immediately after drying, determine the mass of the filter pad to the nearest 0.1 g and record. This mass is the total of the original tared mass plus the mass of the fines trapped in the filter fibres.

9.14 Calculate the mineral fines in the filter as follows:

$$\text{Mass of mineral fines in filter, } (W_3) = M_{ff} - M_f$$

where: M_{ff} = Mass of filter after extraction, g

M_f = Mass of filter, g

9.15 Immediately after drying, carefully transfer the hot aggregate from the drying pan into the balance pan, brushing any fines adhering to the drying pan into the balance pan. Determine the mass of the dried aggregate (M_{ba}), while still warm, to 0.1 g, and record (see Note 9 above).

9.16 Calculate the mass of dried aggregate as follows:

$$\text{Mass of dried aggregate, } (W_4) = M_{ba} - M_b$$

where: M_{ba} = Mass of balance pan plus dried aggregate, g

M_b = Mass of balance pan, g

9.17 If low ash (ash residue not greater than 0.2%) filter pads are used, dry to constant mass as required by Section 9.4, then carefully fold the filter pad and stand it on the aggregate in the weighing pan. Burn the pad by igniting it with a match or Bunsen burner. Determine the mass of the dried aggregate and filter pad mineral fines (M_{baf}).

9.18 Calculate the mass of the dried aggregate plus filter pad mineral fines as follows:

$$\text{Mass of dried aggregate plus filter pad mineral fines } (W_3 + W_4) = M_{baf} - M_b$$

where: M_{baf} = Mass of balance pan, dried aggregate and filter pad mineral fines, g
 M_b = Mass of balance pan, g

9.19 As an alternate to the rotarex extraction method, the reflux method can be utilized. Refer to ASTM D2172-95, test method B for a complete description of this method.

10. DETERMINATION OF MINERAL FINES IN EXTRACT

10.1 This procedure uses a high speed centrifuge as described in ASTM D-2172 Section 11.6.2.

10.2 Transfer extract from containers to high speed centrifuge receiving funnel and correct for fines. The high speed centrifuge should be operated as per manufacturer's instructions.

10.3 Calculate mineral fines in the extract as follows:

Mass of mineral fines in extract, $(W_5) = M_{cf} - M_c$

where: M_{cf} = Mass of cup plus fines, g

M_c = Mass of cup, g

10.4 For an alternative procedure for the determination of mineral fines (Ashing Method), refer to ASTM D2172, Section 11.6.1.

11. ASPHALT CEMENT CONTENT CALCULATION

11.1 Calculate the asphalt cement content in the test portion to two decimal places making use of appropriate work sheets.

11.2 If moisture is present in the mix and the sample has not been dried to constant mass to eliminate moisture, adjust the original mass of the mixture for the test portion or test increments as follows:

$$\text{Dry mass of mixture, } (W_2) = \frac{W_1}{(100 + Z)} \times 100$$

where: W_1 = Original mass of test portion, g

Z = Moisture content, %

11.3 For the test portion calculate the total mass of the dry aggregates as follows:

Total mass of dry aggregate, $(W_6) = W_3 + W_4 + W_5$

where: W_3 = Mass of mineral fines on the filter

W_4 = Mass of dry aggregates

W_5 = Mass of mineral fines in the extract

11.4 The mass of the asphalt cement can be determined for the test portion as follows:

Mass of asphalt cement, $(W_7) = W_2 - W_6$

where: W_2 = dry mass of mixture, g

W_6 = dry mass of aggregate, g

11.5 The asphalt cement content expressed as a percentage of the moisture free mix is calculated as follows:

$$\text{Asphalt cement content, \% (W}_8\text{)} = \frac{W_7}{W_2} \times 100$$

11.6 If an extraction test is carried out in two portions, the results shall not be averaged but shall be combined to calculate a single asphalt cement content.

12. ANALYSIS OF EXTRACTED AGGREGATE

12.1 WASHING OF AGGREGATE: After the mass (W_4) of the test portion of dried aggregate has been determined, return the sample to the drying pan and cover the sample with water. Add a sufficient amount of wetting agent (see Note 10) to ensure a thorough separation of materials finer than 75 μm from the coarser particles. The contents of the container shall be agitated vigorously taking care not to splash out any material, and then the wash water shall be immediately decanted over the nest of two sieves consisting of a 1.18 mm sieve superimposed on a 75 μm sieve. The use of a hand, a metal spoon or a spatula to stir and agitate the aggregate in the wash water has been found to be satisfactory (see Note 11).

Note 10: Wetting agents such as Calgon or Alconox may be pre-mixed with water at 50 g/L. 100 ml of this solution is then added to the first wash of each test. One drop of liquid dishwashing detergent in the first soak has been found to be a suitable alternative. It has been found advantageous to allow the first wash to soak for five minutes after the addition of the wetting agent and preliminary agitation.

Note 11: The agitation shall be sufficiently vigorous to completely separate the particles finer than 75 μm from the coarser particles and bring them into suspension, in order that they may be removed by decanting the wash water. Care shall be taken to avoid, as much as possible, decanting of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

12.2 Return all the material retained on the nested sieves by flushing into the washed sample in the drying pan. The washed aggregate shall be dried to a constant mass at a temperature of $110 \pm 5^\circ\text{C}$ and the mass determined to the nearest 0.1 g (W_9) (see Note 9 above).

12.3 SIEVE ANALYSIS: Transfer cooled aggregate into the nest of coarse and fine sieves. Agitate on a mechanical sieve shaker. A satisfactory end point in sieving is considered to have been reached when an additional 1 minute of sieving by hand fails to change the mass on any sieve by more than 1%. This is usually about twelve minutes. On completion of the sieving operation, separate the sieves. Each sieve shall be placed within a round stainless steel bowl and shaken manually, checking to see if additional material passes through. Any additional material should be transferred to the next smaller sieve size. When emptying the sieves, gently strike the rim of the inverted sieve with the wooden handle of the sieve brush. This helps to dislodge aggregate particles from the cloth. Individual particles stuck in coarser sieves may also require help. Following this, brush the bottom surface of the

sieve cloth with a circular motion. In no case should the particles be turned or manipulated through the sieves by hand. Weigh and record cumulatively (e.g. each successive size is to be added to the previous total) on the appropriate work sheet, the mass of the fraction retained on each sieve.

12.4 CALCULATION OF AGGREGATE FRACTIONS: Calculate the percent passing on each sieve in the test portion as follows:

$$\% \text{ passing on sieve } x = 100 - \frac{W_x \times 100}{W_6}$$

where W_x = cumulative mass retained on that sieve

W_6 = total mass of dry aggregate

12.5 When the extraction test is done in two portions, the gradation analysis shall be performed on the total sample.

13. EXAMPLE CALCULATIONS

13.1 MOISTURE CONTENT:

i) Percent moisture in sample of mix:

Mass of sample plus moisture (M_a)	1000.3 g
Mass of dried sample (M_d)	998.1 g
% Moisture (Z)	$= \frac{1000.3 - 998.1}{998.1} \times 100$
	$= 0.22 \%$

ii) ADJUST ORIGINAL MASS OF TEST PORTION:

Original mass of test portion (W_1)	1020.4 g
Dry mass of test portion (W_2)	$= \frac{1020.4}{100 + 0.22} \times 100$
	$= 1018.2 \text{ g}$

13.2 ASPHALT CEMENT CONTENT:

i) Dry mass of test portion (W_2)	1018.2 g
ii) Dry mass of Aggregate:	
Dry mass of aggregate plus pan (M_{ba})	1160.8 g
Mass of pan (M_b)	- <u>200.0</u> g
Dry mass of aggregate (W_4)	$= 960.8 \text{ g}$
iii) Dry Mass of Mineral Fines in Filter:	
Mass of filter after extraction (M_{ff})	15.2 g
Mass of filter (M_f)	- <u>14.4</u> g
Mass of mineral fines in filter (W_3)	$= 0.8 \text{ g}$
iv) Dry mass of Aggregate and Mineral Fines in Filter if Filter is Burned:	
Mass of aggregate, mineral fines and pan (M_{bat})	1161.6 g

Mass of pan (M_b)	-	<u>200.0</u> g
Mass of aggregate plus fines ($W_4 + W_3$)	=	961.6 g
v) Mass of Mineral Fines in Extract (High Speed Centrifuge)		
Mass of cup and mineral fines after centrifuging (M_{cf})		142.3 g
Mass of cup (M_c)	-	<u>141.1</u> g
Mass of mineral fines (W_5)	=	1.2 g
vi) Total Dry Mass of Aggregate if Filter Weighed:		
Dry mass of aggregate (W_4)		960.8 g
Mass of mineral fines in filter pad (W_3)		0.8 g
Mass of mineral fines in extract (W_5)	+	<u>1.2</u> g
Total dry mass of aggregate (W_6)	=	962.8 g
vii) Total Dry Mass of Aggregate if Filter Burned:		
Dry mass of aggregate plus mineral fines ($W_4 + W_3$)		961.6 g
Mass of mineral fines in extract (W_5)	+	<u>1.2</u> g
Total dry mass of aggregate (W_6)	=	962.8 g
viii) Mass of Asphalt Cement:		
Mass of dry test portion (W_2)		1018.2 g
Mass of dry aggregate plus fines (W_6)	-	<u>962.8</u> g
Mass of asphalt cement (W_7)	=	55.4 g
Percent asphalt cement (W_8) = $\frac{55.4}{1018.2} \times 100 = 5.44\%$		

13.3 AGGREGATE FRACTIONS:

Total dry mass of aggregate (W_6)		962.8 g
% passing 9.5 mm sieve	= $100 - \frac{(213.3)}{(962.8)} \times 100$	= 77.8
% passing 600 μ m sieve	= $100 - \frac{(689.4)}{(962.8)} \times 100$	= 28.4

13.4 SWING BACK GRADING (Optional): This is the grading of the coarse aggregate and fine portions of the aggregate (retained and passing respectively on the 4.75 mm sieve) when either fraction is considered to be the total sample. For the fine aggregate the calculation is as follows:

13.4.1 The percent passing the 4.75 mm sieve in the total grading, divided into the percent passing each subsequent sieve and the result multiplied by 100, will give the fine aggregate gradation expressed as a percent passing each sieve.

13.4.2 Example:

Given for the full gradation:

% passing the 4.75 mm sieve is 52.1

% passing the 2.36 mm sieve is 40.9

% passing the 1.18 mm sieve is 33.0

then for the fine gradation:

$$\% \text{ passing the 2.36 mm sieve} = \frac{40.9}{52.1} \times 100 = 78.5$$

$$\% \text{ passing the 1.18 mm sieve} = \frac{33.0}{52.1} \times 100 = 63.3$$

13.4.3 To "swing back" the grading of the coarse aggregate fraction of the extracted aggregate, the following procedure is used. The percent retained on the 4.75 mm sieve in the total grading, is divided into the percent retained on each of the coarse aggregate sieves in the total gradation and the result is multiplied by 100, to give the coarse aggregate grading expressed as the percent retained on each sieve.

13.4.4 Example:

Given for the full gradation:

% passing the 13.2 mm sieve is 92.5

% passing the 9.5 mm sieve is 75.4

% passing the 4.75 mm sieve is 52.4

then for the coarse gradation

$$\% \text{ ret'd on the 13.2 mm sieve} = \frac{(100 - 92.5)}{(100 - 52.4)} \times 100 = 15.8$$

$$\% \text{ ret'd on the 9.5 mm sieve} = \frac{(100 - 75.4)}{(100 - 52.4)} \times 100 = 51.7$$

14. REPORTING OF RESULTS

14.1 The results will be based on a single test and shall be reported as follows:

14.1.1 The asphalt cement content shall be reported as a percentage of the total mass of the mix to two decimal places.

14.1.2 The cumulative mass and the cumulative percentages passing for each sieve shall be reported to one decimal place. As well, the cumulative percentage may be recorded as a graph on the appropriate semi-log grading chart.

14.1.3 The swing back gradings, if required, shall be recorded as percentage retained or passing for each sieve, accurate to one decimal place, and shall be reported as described in Section 11.4.

14.2 Where the test sample requires splitting to satisfy minimum mass requirements and two tests are carried out, results will be based on the sums of the values from the two test portions or increments, using two bowls. Results shall be reported with the following changes in calculations:

14.2.1 The asphalt cement content shall be expressed as the cumulative percentage content for the two test increments, to two decimal places.

Example:

	<u>Bowl A</u>	<u>Bowl B</u>
Dry mass of sample (W_2)	1018.2 g	1023.8 g
Mass of A.C. (W_7)	56.7 g	56.9 g
A.C. Content, %	$= \frac{(56.7 + 56.9)}{(1018.2 + 1023.8)} \times 100$ $= 5.56$	

14.2.2 The cumulative mass and the cumulative percentages passing each sieve shall be calculated as follows:

Example:

	<u>Bowl A</u>	<u>Bowl B</u>
Total Dry mass of Aggregate (W_6)	962.7 g	968.3 g
Cumulative Dry Mass on 9.5 mm Sieve	213.3 g	214.4 g
% Passing the 9.5 mm Sieve	$= 100 - \frac{(213.3 + 214.4)}{(962.7 + 968.3)} \times 100$ $= 79.0$	

15. GENERAL NOTES

15.1 When testing cold mix such as SC 800 Patching Material, the sample must be dried at $110 \pm 5^\circ\text{C}$ to a constant mass to remove all solvents before testing.

15.2 Aggregates in the pans and the SMM cups are weighed while still warm to avoid absorption of moisture. In order to avoid undue variation in this process it is recommended that on removal from the drying oven all samples be weighed at 90 to 100°C .

15.3 Extreme care must be exercised when transferring aggregates from one container to another to avoid any loss of particles.

15.4 Prior to using, check each sieve for the condition of the mesh, the soldered edges and the nest for correct order of descending sizes.

15.5 Calibrate the r.p.m. of the centrifuge extractor and high speed centrifuge using a strobe tachometer at least once per construction season.

15.6 All balances should be calibrated at least once a year, at the start of the construction season.

15.7 If some asphalt remains in the aggregate after the third washing, repeat the extraction process until the solution is a light straw colour.

15.8 The extractor bowl cover must be fastened to the bowl tightly enough to minimize the loss of fines. Uniform torquing of the bowl lids will prevent varying loss of the fines. In order to tighten the cover on the extractor bowl with a torque wrench, the extractor funnel units have been modified as in Section 9.4. Marks should be made (using a hacksaw, paint etc.) on the steel rod to ensure the torque wrench is centred.

15.9 All extractor bowls and covers must be matched to ensure a tight fit and permanently marked to prevent mismatching.

15.10 Ensure that the funnel is in place in the bowl when the mix is being transferred from the balance pan to the bowl in order to prevent clogging of the threads with material.

15.11 Non-uniform colour and texture of the flow patterns, which continue beyond the inner rim of the extractor bowl on the filter indicate an excess loss of fines. Check for a tight fit of the cover. Burrs on the bowl or cover can cause a poor fit. Do not strike the machined surface of the bowl when using the brush to dislodge particles of aggregate sticking to its surface. Overfilling the bowl with solvent can cause a loss of fines through the cover air vents.

15.12 All equipment and testing for LS-282 including DETERMINATION OF MINERAL FINES IN EXTRACT (Section 10) shall be located in one laboratory building only.

16. PRECISION AND BIAS

16.1 Single operator precision for asphalt cement content is considered acceptable if the difference in asphalt cement content between two replicate mix samples is 0.20% or less.

16.2 The bias for asphalt cement content is considered acceptable if the content for each of two mix samples used to determine precision is within 0.20% of the known asphalt cement content.

17. SAFETY

17.1 Solvents should be used only under a hood or with an effective surface exhaust system in a well-ventilated area, since the solvents are all toxic to some degree.

17.2 Respiratory protection is required if airborne concentration exceeds TLV (Threshold Limit Value). Air respirators for organic fumes are advised.

17.3 Safety goggles, protective clothing and impervious gloves are recommended.

17.4 Solvent manufacturers' recommendations listed in the product MSDS should be followed.

17.5 In case of spills of trichloroethylene or methylene chloride, appropriate respirators must be worn. Refer to the product MSDS.

17.6 Eating, drinking, or smoking are not allowed in the working area of the laboratory.

METHOD OF TEST FOR RESISTANCE TO STRIPPING OF ASPHALT CEMENT IN BITUMINOUS MIXTURE BY MARSHALL IMMERSION

1. SCOPE

1.1 This method covers a procedure for determining the resistance to stripping of bitumen-aggregate mixtures, compacted by the double plunger method, when immersed in water.

1.2 This method compares the Marshall stability values of air-cured specimens with the stability values of duplicate samples that have been cured in water, thus producing an index of percent retained stability.

2. RELEVANT DOCUMENTS

2.1 MTO Method LS-261

2.2 MTO Method LS-263

2.3 ASTM D 1074

2.4 ASTM D 1075

2.5 ASTM D 1559

3. DEFINITIONS

3.1 The index of percent retained stability is obtained by determining the Marshall stability values of a set of three specimens that have been immersed in water and expressing it as a percentage of the Marshall stability values of a duplicate set of air cured samples.

3.2 A numerical stripping rating is given to the specimens based on the degree of asphalt stripping from the surfaces of the coarse and fine aggregate particles when the specimens are broken open after curing in water.

4. APPARATUS

4.1 METAL CONTAINERS: Approximate 1000 g capacity, required for aggregates when heated in the oven.

4.2 WATER BATH: Capable of maintaining a temperature of $25 \pm 0.3^{\circ}\text{C}$ complete with perforated shelf located 50 mm above the bottom of the tank for holding specimens and supports. The shelf shall hold at least six specimens and supports.

4.3 WATER BATH: Of suitable capacity, capable of maintaining a temperature of $60 \pm 1.0^{\circ}\text{C}$.

4.4 AIR BATH: Capable of maintaining a temperature of $60 \pm 1.0^{\circ}\text{C}$ complete with a perforated shelf for holding specimens. The shelf shall hold at least six specimens.

- 4.5 COMPACTOR: A compression machine that is capable of providing an accurately controlled rate of vertical deformation.
- 4.6 MARSHALL MOLDS: Conforming to details as shown in Figure 4. Six required. Only one Marshall mold collar is required.
- 4.7 MOLD SUPPORTS: Steel bars, 75 mm in length and 25 mm by 25 mm square to provide temporary support for the molds. Two required.
- 4.8 TOP PLUNGER: A steel cylinder, 50 mm in diameter and 120 mm height. Two 25 mm thick x 100 mm diameter steel plates are welded to each end of the cylinder. (Figure 3)
- 4.9 BOTTOM PLUNGER: A steel circular plate, 100 mm in diameter and 33 mm in height. (Figure 3)
- 4.10 SUPPORT PLATES: Steel plates 100 mm in diameter and approximately 15 mm in height. Six required.
- 4.11 MIXER: A mixer using a 6 L capacity mixing pot with an "egg beater" or wire type of mix paddle. Hobart type mixer is suitable.
- 4.12 OVEN: Of suitable capacity and capable of maintaining a temperature between 93°C and 149°C. (Required to heat the Marshall molds and trough).
- 4.13 OVEN: Of suitable capacity and capable of maintaining a temperature range of 100 to 180°C $\pm 2.8^{\circ}\text{C}$. Required to dry the aggregates prior to batching, (105 to 110°C), as well as heating the aggregates prior to mixing with asphalt cement.
- 4.14 HOT PLATE: Capable of heating the asphalt cements to the specified mixing temperature $\pm 2.8^{\circ}\text{C}$.
- 4.15 THERMOMETERS/TEMPERATURE PROBE: Thermometers/probes suitable for measuring temperatures of aggregate, asphalt and bituminous mixtures in the range of 10 to 204°C with sensitivity of $\pm 2.8^{\circ}\text{C}$. Thermometers or probes are also required which are suitable for measuring water bath and air bath temperatures with a range from 20 to 70°C with sensitivity of $\pm 0.2^{\circ}\text{C}$.
- 4.16 METAL TROUGH: A round bottom trough approximately 750 mm in length and 125 mm wide at the top.
- 4.17 SPECIMEN SUPPORTS: Of galvanized sheet metal consisting of a bottom and three sides for support. They support the specimens in the water baths. Six required.
- 4.18 MAGNIFYING GLASS: Approximately 10x power.
- 4.19 BRIQUETTE EXTRUDER: 1-1/3 tonnes capacity lift jack or converted Marshall testing machine.
- 4.20 MAGNIFIER LAMP: Luxo
- 4.21 BALANCE: 5 kg capacity, sensitive to 0.1 g.
- 4.22 KETTLE: Sufficient capacity to hold approximately 1.0 L of asphalt cement.
- 4.23 METAL SCOOP: Flat bottomed- for batching aggregates.
- 4.24 GLOVES: Heat resistance for handling hot equipment.

4.25 STOPWATCH OR TIMER

4.26 MARSHALL TESTING MACHINE: Meeting the requirements in ASTM D1559, Sections 3.7, 3.8. See Notes 2 and 3.

5. PREPARATION OF SPECIMENS

5.1 Prepare the aggregates using the procedure described in MTO Method LS-261, "Method of Preparation of Marshall Specimens Section 4. Test Procedure 4.1.1 and 4.1.2". Prepare 6 batches.

5.2 Place the aggregate in an oven maintained at a temperature not exceeding 28°C above the temperature that will yield a viscosity of $170 \pm 20 \text{ mm}^2/\text{s}$ for the asphalt used. Heating time shall be a minimum of 16 hours, normally overnight.

5.3 Preheat the mixing bowl in the same oven.

5.4 Preheat the metal trough, top and bottom plungers and the Marshall molds minus the base plates in the oven maintained at a temperature between 93 and 149°C.

5.5 Heat the asphalt on the hot plate to a temperature at which the viscosity is $170 \pm 20 \text{ mm}^2/\text{s}$ (Mixing temperature). The asphalt cement should not be held at the mixing temperatures for more than 1 hour prior to compaction. Suitable shields, baffle plates or sand pads shall be used on the surface of the hotplate to prevent localized overheating.

5.6 When the asphalt and aggregate have reached the desired temperatures, remove the container of aggregate from the oven and quickly place it in the mixing bowl. Dry mix the aggregate for 15 s.

5.7 After dry mixing, make a small depression in the center of the aggregate in the bowl and quickly add the required amount of asphalt (see Note 1) and mix for 45 seconds or until the aggregate is coated. Do not mix longer than 1-1/2 minutes. Report any mixing problems such as coating or balling of the mix.

Note 1: The asphalt content is calculated as a percentage by mass of total mix, e.g. for a total mass of 1180 g of aggregate and A.C. content of 5.0 %.

$$\begin{aligned}\text{Mass of A.C. required} &= \frac{1180 \times 5}{100 - 5} &= & 62.1 \text{ g} \\ \text{Total mix} &= 1180 \text{ g} + 62.10 \text{ g} &= & 1242.1 \text{ g}\end{aligned}$$

5.8 At the end of the wet mixing cycle, scrape as much mix as possible from the paddle.

5.9 While the mixing is in progress, remove the trough, mold, top and bottom plungers from the oven. Spread the mixture into the metal trough, using a back and forth motion. Place the bottom plunger on the lower platen of the compactor. Place the Marshall mold and collar over the lower plunger so that the mold is supported by the two steel bars. Using a metal trowel, transfer the mix

from the trough into the mold. Remove the mold collar. Form the mix into a slight mound at the top, but do not rod. Place the top plunger into the mold keeping it vertical until the initial load is applied.

Note 2: The temperature of the mixture immediately prior to compaction shall be within a range that will produce a viscosity of $280 \pm 30 \text{ mm}^2/\text{s}$ for the asphalt cement being used, otherwise the briquette shall be discarded. Refer to the temperature/viscosity chart for the asphalt cement in use. In no case shall the mixture be reheated.

5.12 Apply the initial load of 22,250 N, release the load and remove the two steel bars to allow full double plunger action. Apply a load of 166,800 N and hold for 2 minutes.

5.13 At the end of the 2 minute period release the load, remove the top plunger, transfer the briquette from the bottom plunger and place onto one of the support plates. Allow the briquette to cool to room temperature. Prepare the remaining five briquettes in the same manner. The plungers will not require additional heating if there is no delay.

6. TEST PROCEDURES

6.1 After cooling to room temperature extrude the test specimens using a mechanical extruder (1-1/3 tonnes capacity jack and frame), or a modified Marshall testing machine. Then place the specimens in the air bath maintained at $60^\circ\text{C} \pm 1^\circ\text{C}$ and leave for 16 to 18 h, usually overnight.

6.2 At the end of the 16 to 18 h period remove the briquettes from the air bath, place on a flat, non-absorbent surface and allow them to cool to room temperature.

6.3 Determine the Bulk Relative Densities of the briquettes using MTO Method LS-262. Group the six briquettes into two sets of three so that the average B.R.D. of each set is essentially the same.

6.4 Place one set of briquettes in the $25^\circ\text{C} \pm 0.3^\circ\text{C}$ water bath for one hour. Remove and quickly dry with a damp towel, then test for Marshall stability and flow. The time from removal from the water bath to completion of the stability test shall not exceed 30 seconds. After testing, break open the briquettes and allow them to sit overnight.

6.5 Place the other set in the vacuum cell(s) containing distilled water at $25 \pm 1^\circ\text{C}$. Place the top on the vacuum cell(s) conforming to details as shown in Figures 1, 2 and reduce the pressure to $30 \pm 1 \text{ mm Hg}$ for a period of one 1 h. Agitate the cell(s) periodically to release the air. At the end of the specified time release the pressure slowly. Remove the briquettes, place them in the metal holders and immerse them in the $60^\circ\text{C} \pm 1^\circ\text{C}$ water bath containing distilled water. Keep the briquettes in the bath for 24 h.

6.6 After 24 hours remove and place in the $25^\circ\text{C} \pm 0.3^\circ\text{C}$ water bath for one hour. Remove and quickly dry with a damp towel, then test for Marshall stability and flow. The time from removal from the water bath to completion of the stability test shall not exceed 30 seconds. After testing, break open the briquettes and allow them to sit overnight.

6.7 AIR CURED SPECIMENS: Using the illuminating-magnifying glass, examine the coating of the coarse aggregate (Ret. 4.75 mm, Pass 4.75 mm/Ret. 600 μ m and the Pass 600 μ m) of the broken faces of the specimens (briquettes). Assign a coating rating (heavy, medium or light, etc.) based on the following criteria:

Coating Rating	Description Of Film
Heavy	Thick shiny black film. Most of coarse aggregate particle surfaces covered with adhering fine aggregate visible.
Medium	Thinner film than above, opaque. Most of coarse aggregate particle surfaces are covered with adhering fine aggregate.
Light	Thin film. Still opaque. Coarse aggregate particle has very little fine aggregate adhering to surface due to thin film. Usually pass 300 μ m material is visible.
Heavy Stain	Dark brown translucent film. Some fine aggregate adhering to surface.
Medium Stain	Medium-dark brown translucent film. Little or no fine aggregate adhering to surface.
Light Stain	Light brown translucent film. No fine aggregate adhering to surface.

6.8 WATER CURED SPECIMENS: Using the illuminating-magnifying glass, examine the broken faces of the specimens (briquettes) for percentage of stripping for both coarse and fine aggregates.

6.9 Assign a stripping rating for each set of water-cured briquettes, using the following formula:

$$R = P_L + C + F$$

where:

P_L = 3 when no stripping is evident

P_L = 4 when some stripping is evident

C = coarse aggregate stripping factor

F = fine aggregate stripping factor

C	% STRIPPING
0	less than 10 %
1	10 % to 30 %
2	31 % to 60 %
3	greater than 60 %

F	% STRIPPING
0	less than 10 %
1	10 % to 30 %
2	greater than 30 %

7. CALCULATIONS

$$7.1 \quad \% \text{ Retained Stability} = \frac{\text{Marshall Stability (water samples)}}{\text{Marshall Stability (air samples)}} \times 100$$

8. REPORT

The report, (See Figure 5), shall include the following;

- 8.1 Percent retained stability.
- 8.2 All Flow values.
- 8.3 Coating rating.
- 8.4 Stripping rating factor and estimated % stripping. Note any swelling.

9. GENERAL NOTES

- 9.1 The Marshall flow values should be recorded because they may be used in further review of this test method.
- 9.2 If stripping in a salt solution is to be studied use a 0.5 percent solution (by mass) of NaCl in distilled water.
- 9.3 Perforated circular shelves with legs, placed one on top of the other, will allow several briquettes to be placed in the vacuum cell at one time.
- 9.4 When briquettes are in the vacuum cell gently shake the cell two or three times at intervals to help dislodge the air bubbles from the briquettes.
- 9.5 When determining stability and flow values, either the Marshall, Pine or the Rainhart testing apparatus may be used.
- 9.6 The asphalt content is normally set at the same percentage as designated in the approved mix design.
- 9.7 The fixed upper platen on the compression machine must be used.
- 9.8 If the retained stability is less than 70 %, repeat the complete test, with an additive (if no additive is used) or an increased dosage of additive (if an additive is used already).

10. PRECAUTIONS

- 10.1 Handle all hot equipment with heat resistant gloves.
- 10.2 When in an air bath, water bath or vacuum cell, each briquette must be placed on one of its flat surfaces. The briquettes must not touch each other.
- 10.3 Always place the briquettes in the metal holders before immersing in the 60°C bath as the briquettes are too fragile to remove from the water bath without support.

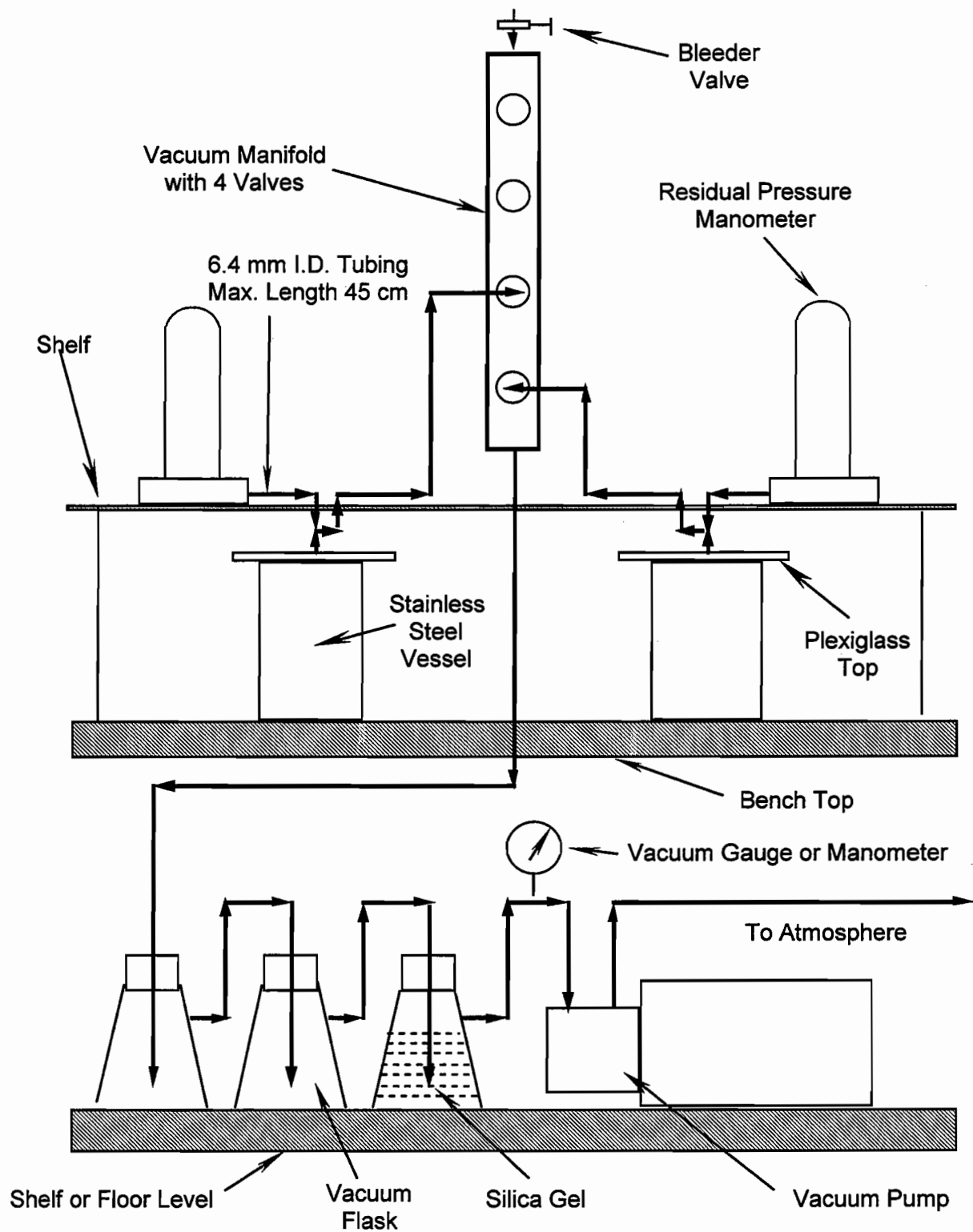
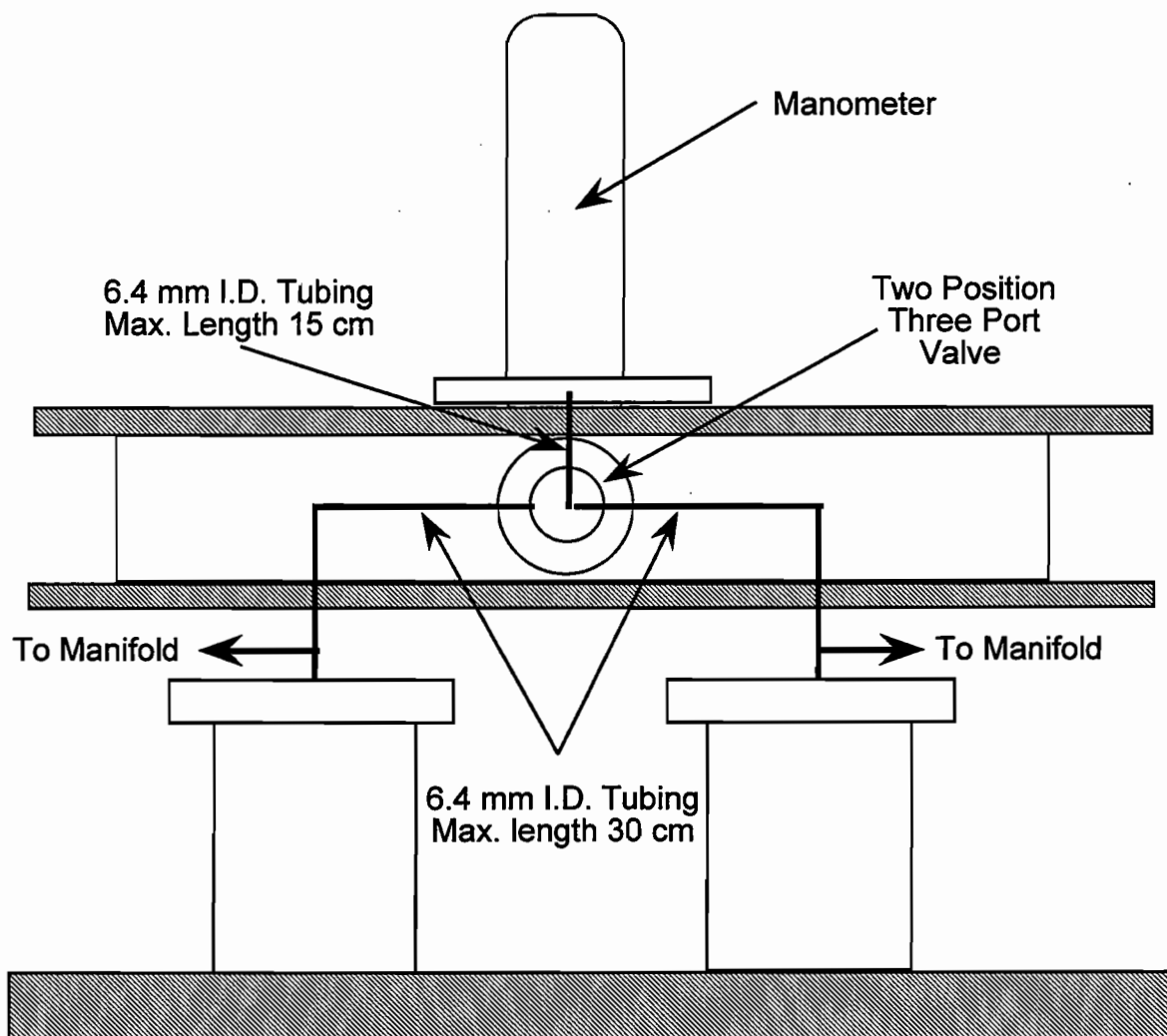


Figure 1
Vacuum Saturation System



MRD equipment using one manometer for two vessels

Note: Tubing between the manometer and the vessels must be kept as short as possible to enable accurate pressure readings.

Figure 2

Vacuum Saturation System - Alternative Setup

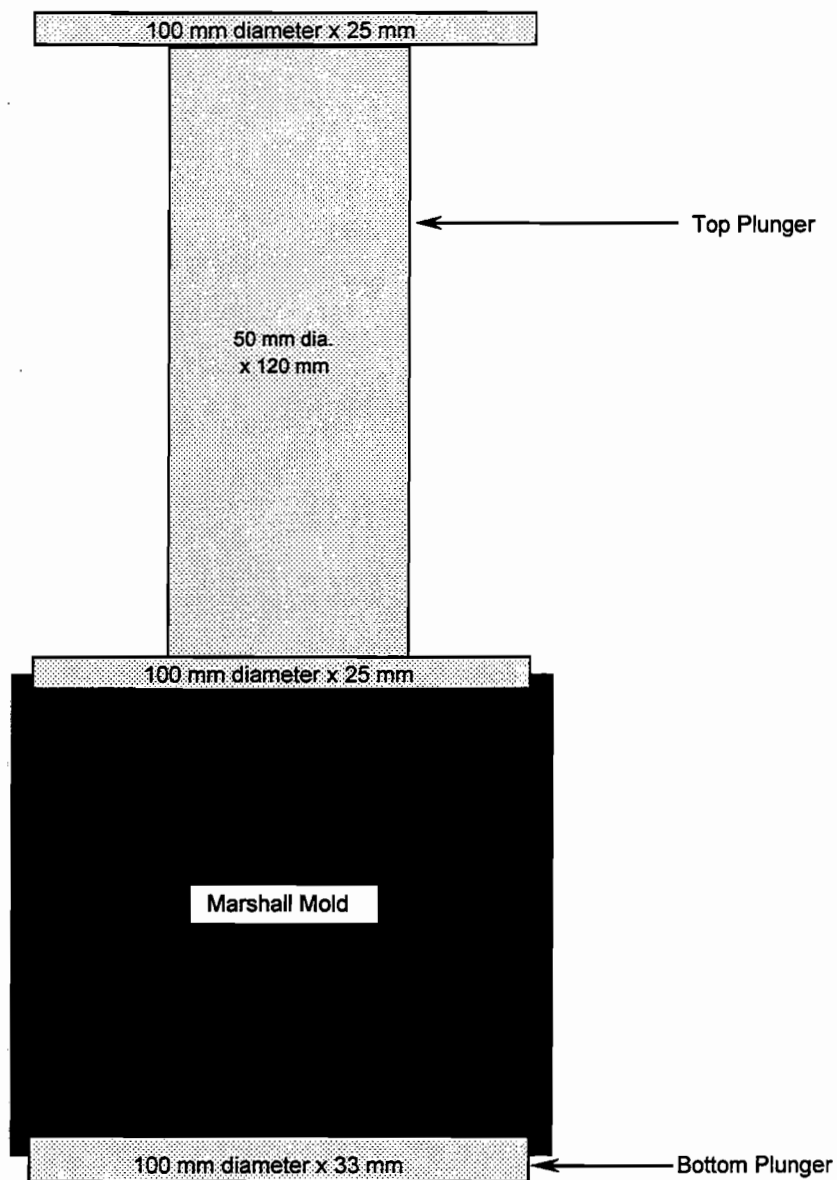


Figure 3
Double Plunger Apparatus

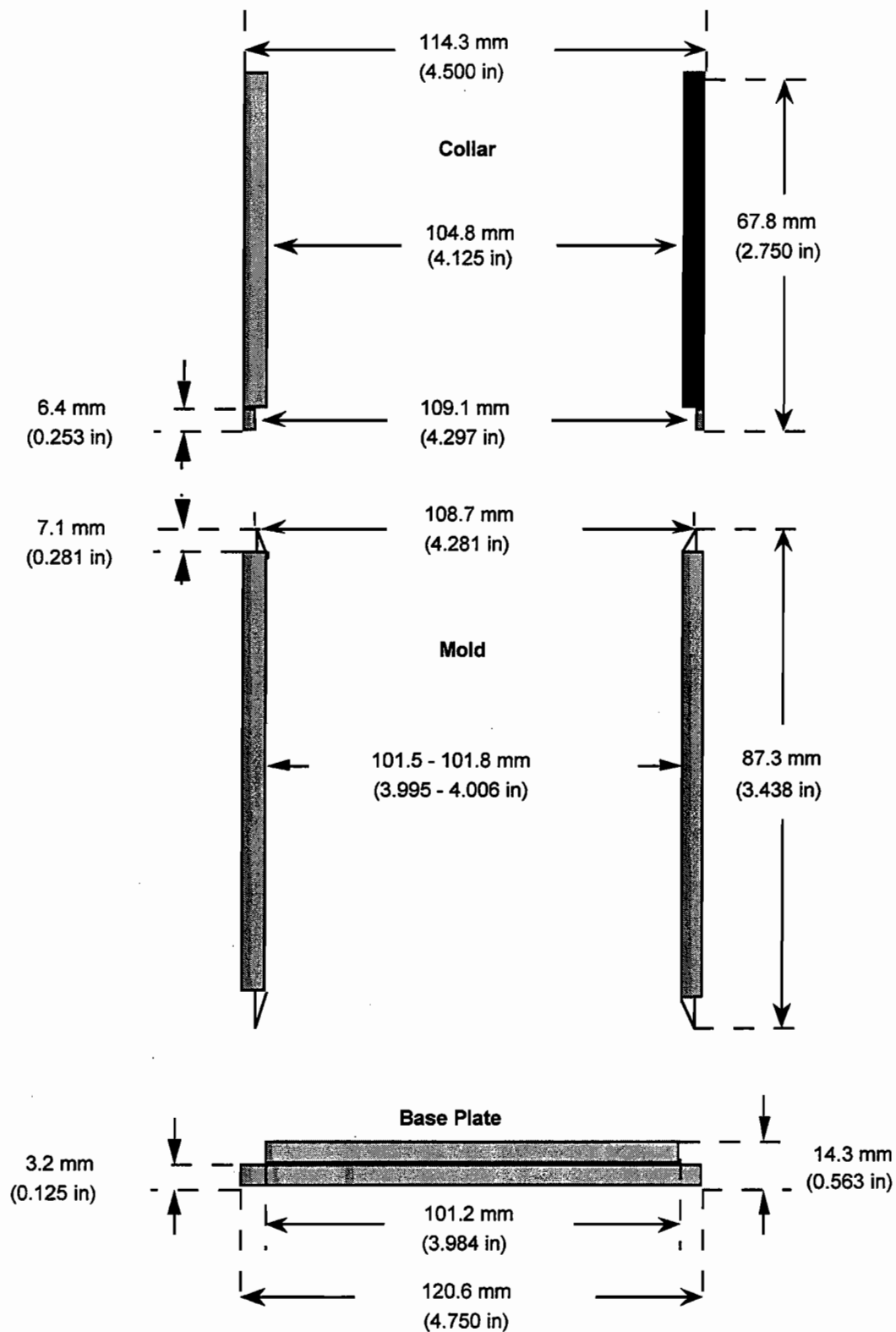


Figure 4

Dimensions for 4" Compaction Mold

Marshall Immersion Data Sheet											
Pressure (mm Hg)	Briquette #	BRD	Stability (C) (Cor'd)	Flow (.25mm)	Ret. 4.75	Coating Rating* Pass 4.75 /ret600	Pass 600	Estimated C/A	% Stripping F/A	Stripping Rating (R)	% Retained Stability
30	Air										
	Average										
	Water										
	Average										

*Coating rating

H - Heavy
M - Medium
L - Light
HS - Heavy Stain
MS - Medium Stain
LS - Light Stain

Pressure (mm Hg)
30

Swelling
Yes No

Contract : _____

Mix Type: _____

Antistripping Additive : _____

% Antistripping Additive : _____

Figure 5

MTO Marshall Immersion Form

METHOD OF TEST FOR RECOVERY OF ASPHALT FROM SOLUTION BY ABSON OR ROTAVAPOR

1. SCOPE

1.1 This method covers the recovery, by the Abson or Rotavapor Method, of bitumen from asphaltic mixtures with certified A.C.S. trichloroethylene.

1.2 This recovered bitumen has properties substantially the same as those it possessed in the asphaltic mixture, and is recovered in sufficient quantities for further testing.

2. RELEVANT DOCUMENTS

2.1 ASTM D 1856

2.2 ASTM D 2172

2.3 ASTM Rotavapor (Draft 5)

3. EXTRACTION APPARATUS

3.1 ROTAREX EXTRACTOR: Either hand or electrically operated, complete with a 1000 g capacity bowl.

3.2 TUBING: 10 mm inside diameter neoprene tubing to drain extractor.

3.3 TORQUE WRENCH: 9.5 mm drive, calibrated in N-m with a capacity of approximately 22 N-m.

3.4 SOCKET: 9.5 mm drive, 19.1 mm size with two slots milled out of the sides, to fit over the steel rod in the extractor unit funnel.

i) A 19.1 mm socket with two slots milled out of the sides to fit over the steel rod in the extractor unit funnel, or

ii) A fitted socket and socket head each of 1 cm (3/8 in) size.

3.5 OVEN: A gravity convection oven of suitable capacity and capable of maintaining the temperature at 93 to 105°C.

3.6 CENTRIFUGE

3.6.1 Batch Unit: capable of exerting a minimum centrifugal force of 770 times gravity. This unit must be capable of handling a minimum of two 250 ml capacity glass bottles.

3.6.2 Continuous Unit: high speed centrifuge as described in ASTM D-2172 Section 11.6.2.1.

4. ABSON RECOVERY APPARATUS

4.1 CYLINDER: Carbon dioxide gas with pressure reducing valve.

4.2 VARIABLE ELECTRICAL TRANSFORMERS

- 4.3 ELECTRIC HEATING MANTLE: 2000 ml capacity.
- 4.4 ELECTRICAL HEATING MANTLE: 500 ml capacity.
- 4.5 BOILING FLASK: 2000 ml capacity, round bottom with standard taper joints 24/40.
- 4.6 DISTILLING FLASK: 500 ml capacity, 2 neck with standard taper joints (24/40 and 34/45 sizes).
- 4.7 SUPPORT STAND: Large.
- 4.8 RING SUPPORT: For 2000 ml capacity heating mantle with clamp.
- 4.9 RING SUPPORT: For 500 ml capacity heating mantle with clamp.
- 4.10 GAS FLOWMETER: 10-1900 ml/min air flow capacity.
- 4.11 GAS FLOWMETER SHIELD: For above.
- 4.12 FIBREGLASS MUFFLERS: To fit over distilling flasks, (i) 500 ml size, (ii) 2000 ml size. Made from 50 mm thick fibreglass.
- 4.13 TRICHLOROETHYLENE: Certified A.C.S. grade.
- 4.14 GAS MANIFOLD: With regulating valves for CO₂ gas control, for multiple secondary distillations or use individual valves as required.
- 4.15 CONDENSER: Graham, jacket length 200 mm minimum.
- 4.16 GRADUATED CYLINDERS: Capacity of 500 ml used to measure the rate of flow of the extract during the removal of mineral fines. Use 2000 ml cylinders if they are being used as receivers for the total volume of extract.
- 4.17 FLASKS: Flat bottom, long neck, 2000 ml capacity for (i) recovery of bitumen solution from extraction, (ii) recovery of trichloroethylene from the primary distillation, (iii) 250 ml capacity for recovery of trichloroethylene from the secondary distillation.
- 4.18 BOILING CHIPS
- 4.19 GLASS CONNECTING TUBES: 6.4 mm inside diameter formed as shown in Figures 1 and 2.
- 4.20 RUBBER TUBING: 6 mm inside diameter for condensers.
- 4.21 CENTRIFUGE BOTTLES: 250 ml capacity.
- 4.22 GLASS OR PLASTIC FUNNEL: 100 mm in diameter.
- 4.23 AERATION TUBE: Copper - 4 mm inside diameter and 200 mm in length with one end cut at a 45° angle.
- 4.24 PLASTIC TUBING: 6.4 mm inside diameter for CO₂ gas distribution.
- 4.25 CORK STOPPERS: For distilling flasks - 500 ml and 2000 ml capacity flasks.
- 4.26 THERMOMETER: An ASTM thermometer 7C with a range of -2 to 300°C conforming to the requirements of ASTM Designation E 1.

5. ROTAVAPOR RECOVERY APPARATUS

5.1 ROTAVAPOR: Equipped with distillation flask, variable speed motor capable of rotating the flask at the rate of at least 50 rpm, condenser, solvent recovery flask and a heated oil bath. The angle of the distillation flask from the horizontal to the bath is set at approximately 15°. The distillation flask, when fully immersed, should be at a depth of approximately 38 mm (1.5 in.). See Figure 3, 4, and 5 for basic and optional equipment installations. See Note 1.

5.2 WATER BATH: Ice in water bath for cooling of the solvent recovery flask.

5.3 COLD TRAP: A vacuum flask in ice water is satisfactory.

5.4 MANOMETER, GAUGE OR PRESSURE CONTROLLER: Suitable for measuring the specified pressure (vacuum), (See Note 2).

5.5 WOLFE BOTTLE: Used only if pressure controller is included in the system (see Figure 5).

5.6 GAS FLOWMETER: Capable of indicating a gas flow of up to 1000 ml/min.

5.7 VACUUM SYSTEM: Capable of maintaining a vacuum to within ± 0.5 mm (± 0.02 in.) of the desired level up to and including 600 mm (23.6 in.) Hg.

5.8 NITROGEN GAS: Cylinder of nitrogen gas fitted with a pressure reducing valve.

5.9 TRICHLOROETHYLENE: Certified A.C.S. grade.

Note 1: The Buchi Rotavapor RE-121A has been found to be satisfactory for this purpose.

Note 2: The Buchi B-161 digital vacuum controller has been found to be satisfactory for this purpose.

6. RECOVERED ASPHALT CEMENT APPARATUS

3.4.1 BEAKER: Glass, 30 ml capacity, to pour recovered bitumen for kinematic viscosity testing.

3.4.2 PENETRATION CANS

3.4.3 SCREEN: 1.18 mm, 120 mm square.

3.4.4 SCREEN: 150 μ m, 120 mm square.

7. EXTRACTION PROCEDURE

7.1 Place a 2000 g sample into a large flat pan, and heat in an oven maintained at a temperature of 93 to 105°C for a period of 15 minutes.

7.2 Remove the sample from the oven. Using a large spike or a stiff spatula, break down the mix as much as possible.

7.3 Return the sample to the oven for an additional 30 minutes of heating.

7.4 After 30 minutes, remove the sample from the oven, and break down the mix as much as possible.

7.5 Transfer about 1000 g of the sample to a balance pan and measure the mass of the mix to 0.1 g

- 7.6 Clean and flush the extractor bowl, the inside of the extractor and the drain tube with fresh trichloroethylene.
- 7.7 Place the measured mass of mix in the bowl and distribute evenly. Add 350 ml of certified trichloroethylene and break up the mix further until all the particles are submerged.
- 7.8 Place the dried filter paper and the lid on the extractor bowl and tighten the lid to 11.3 N·m of torque. Allow the sample to soak for 15 minutes either in the stand or in the extractor.
- 7.9 At the end of the 15 minute period, with the bowl in the extractor and the lid in place, and a 2000 ml flat bottom flask to collect the asphalt solution, start the extractor slowly.
- 7.9.1 With the hand-operated extractor, turn the handle slowly, gradually increasing the handle speed to 50 rpm. Maintain this rate until the solvent ceases to flow from the drain tube.
- 7.9.2 With the electrically-powered extractor, calibrate and set the speed control for a speed of 1800 rpm. Start the machine, slowly letting it increase speed to a maximum of 1800 rpm. until the solvent ceases to flow.
- 7.10 Add 200 ml of certified trichloroethylene to the mix, allowing it to stand for 10 minutes, and repeat steps 4.9.1 or 4.9.2.
- 7.11 Add 200 ml of certified trichloroethylene to the mix. Allow to stand for 5 minutes, and repeat steps 4.9.1 or 4.9.2.
- 7.12 Repeat sections 4.5 through 4.11 with the second batch of 1000 g of mix.
- 7.13 Removal of Mineral Fines - Alternative 1
- 7.13.1 Transfer the asphalt solution to the 250 ml glass bottles, adjusting the amount of solution so that each bottle of solution weighs the same. Place the bottles in the centrifuge, and centrifuge at the maximum rate for 10 minutes.
- 7.14 Removal of Mineral Fines - Alternative 2
- 7.14.1 The following procedure is appropriate when using the SMM high speed centrifuge. Place a clean, previously tared, centrifuge cup in the high speed centrifuge.
- 7.14.2 Start the centrifuge and allow it to reach constant operational speed (at least 9000 r.p.m.). Close the feed funnel control valve and place a suitable receiver at the effluent drain to collect the solvent. Fill the feed funnel with extract. Open the control valve at the bottom of the funnel to allow a flow of 100 to 150 ml/min using a graduated cylinder to measure the centrifuge effluent flow rate. Continue to top up the feed funnel until all the extract has been transferred. Wash the container with several small volumes of fresh solvent and transfer each to the feed funnel. Wash the funnel with fresh solvent. Allow each increment of solvent from these washings to run through the centrifuge until the effluent is essentially colourless. Allow the centrifuge to run several more minutes to evaporate the remaining solvent.

8. ABSON RECOVERY PROCEDURE

8.1 PRIMARY DISTILLATION, (See Figure 1)

8.1.1 After centrifuging, decant the solutions from both extracted portions into a 2000 ml round bottom flask, add a few boiling chips, and assemble the apparatus. Place the fibreglass cover on the flask, and commence the primary distillation.

8.1.2 Adjust the variable electric transformer so that the distillate comes off in a slow, steady stream into a flask. When the asphalt solution is reduced to a volume of approximately 200 ml, transfer the solution and boiling chips into the secondary distillation flask.

8.2 SECONDARY DISTILLATION, (See Figure 2)

8.2.1 Preheat the secondary flask. Assemble the apparatus. Insert the copper tube and thermometer through a cork in the centre neck of the flask. The thermometer is set 6.4 mm from the bottom of the flask. The CO₂ tube is set above the surface of the solution temporarily. Place the fibreglass cover over the flask.

8.2.2 Adjust the variable electric transformer so that the distillate barely comes off in a steady stream. Collect the distillate in a suitable container. When the temperature of the solution reaches 115°C, lower the copper tube until the tapered end touches the bottom of the flask with the open end facing away from the thermometer. Introduce the CO₂ gas at a rate of 100 ml per minute, and maintain a distillation rate of 50 to 70 drops per minute. Increase the CO₂ gas flow rate to maintain the 50 to 70 drops per minute of distillation until the maximum gas flow rate of 900 ml/minute is attained. Increase the temperature of the solution to a maximum of 150°C at a rate to maintain the desired distillate flow of 50 to 70 drops per minute. Maintain a temperature of 150°C and the CO₂ gas flow rate of 900 ml/minute for a period of 20 minutes.

8.2.3 After the distillation is stopped, disassemble the apparatus and pour the residue through a 1.18 mm mesh sieve into a 236 ml container placed on its lid.

Note 3: This sample may be transferred immediately to the proper size can for the penetration determination. If kinematic viscosity is to be determined pour approximately 20 ml through a 150 µm mesh sieve into a 30 ml beaker and transfer to the appropriate viscosity tube. If reheating is required, heat the sample to the lowest temperature which will result in a consistency which will just allow the asphalt to be poured without the inclusion of air bubbles. Stir carefully in a horizontal fashion. In no case should the temperature be raised to more than 90°C above the softening point of the specimen. Approximately 20 ml is poured through a 150 µm mesh sieve into a 30 ml beaker for kinematic viscosity testing.

9. ROTAVAPOR RECOVERY PROCEDURE

9.1 Heat the oil bath to a temperature of 138°C ± 2.8°C

9.2 Circulate cold water through the condenser

9.3 Apply a vacuum of 40 ± 0.5 mm Hg below atmospheric pressure and draw approximately 600 ml of asphalt solution from the sample container into the distillation flask via the sample line. (for configurations in Figures 4 and 5 transfer all of the extract, normally about 1500 ml, to the 2000 ml distillation flask and fit the flask to the rotator assembly prior the applying the vacuum).

9.4 Begin a nitrogen flow of approximately 500 ml/min through the system. (Note 3). Begin rotating the distillation flask at approximately 40 rpm and lower flask into the oil bath. Initially the immersion depth of the flask will be determined by the need to achieve a controlled solvent evaporation rate. The correct evaporation rate can be observed as a steady controlled stream of condensed solvent being collected in the recovery flask.

Note 4: Vacuum and nitrogen flow valves may require adjusting depending on location. Also, low flow values are recommended at the beginning of the rotary process when sample volume is large because of the possibility of back flow into the vacuum system. The possibility of back flow can be minimized by regulating the depth of immersion of the flask in the oil bath.

9.5 When the amount of asphalt solution within the distillation flask appears low enough so that more solution may be added, (Figure 1) discontinue the nitrogen flow. Draw the remaining asphalt solution from the sample container into the distillation flask and readjust the nitrogen flow (Note 4).

Note 5: The equipment may be modified to allow a continuous flow of solution from the sample container into the distillation flask such that the volume in the distillation flask is maintained at approximately 600 ml. The nitrogen flow is not started until all the solution has entered the distillation flask.

9.6 When the bulk of the solvent has been distilled from the asphalt and no obvious condensation is occurring on the condenser, immerse the distillation flask to the recommended maximum immersion depth of 38 mm (1.5 in). A one to two minute delay before applying the vacuum is recommended. Slowly apply a vacuum of 600 ± 0.5 mm Hg below atmospheric pressure. Increase the nitrogen flow to approximately 600 ml/min and the spin rate to about 45 rpm (Note 5). Hold or reduce the vacuum if foaming or a bubbly formation occurs. When foaming subsides apply maximum vacuum. Maintain this condition for 15 ± 1 minute.

Note 5: A faster spin rate exposes more surface area of the asphalt and hence dislodges more traces of solvent from the asphalt. The rotation speed of the flask may also be varied of the flask rotation may be stopped to enhance the removal of solvent. Due to the cooling effect of the nitrogen flow, an increase in the temperature of the oil bath is generally needed to maintain a constant sample temperature. Experience has shown that a typical bath temperature range of 149 - 157°C (300 - 315°F) is satisfactory for this purpose.

9.7 At the end of the 15 minute period, remove the distillation flask from the apparatus and cover the neck loosely with aluminium foil.

CAUTION: Nitrogen flow should always be discontinued and system opened to atmosphere before vacuum pump is turned off to ensure that a positive pressure is not built up in the system.

Place the flask in an oven at 163°C (325°F) for 30 ±1 min (Note 6). After 30 minutes in the oven remove the flask, wipe the neck clean of any oily residue and pour into the containers prepared for subsequent testing of the asphalt as indicated in section 5.2.3.

Note 6: Experience has shown that for samples having penetration in excess of about 80 penetration a heating period in the oven at 163°C of fifteen minutes is sufficient to facilitate pouring of the asphalt.

10. SAFETY

10.1 The use of trichloroethylene requires that testing be carried out under vapour evacuation conditions (i.e. fume hood), because the solvent is toxic to some degree.

10.2 Neoprene gloves and safety goggles must be worn when handling trichloroethylene.

10.3 In case of spills of trichloroethylene appropriate respirators must be worn. (Occupational Health and Safety Act: R.R.O. 1980, Reg. 692, S. 134-C). See also the manufacturer MSDS.

10.4 Eating, drinking or smoking is not allowed in the working area of the laboratory.

11. GENERAL NOTES

11.1 The test must be completed within 8 h.

11.2 It may be necessary to calibrate the gas flow meter to determine the correction for the gas flow rate of 900 ml/minute for CO₂ gas.

11.3 Perform all operations under a fume hood, and avoid inhaling trichloroethylene fumes when transferring solution from the primary to the secondary distillation.

11.4 Wear heat resistant gloves when handling hot equipment.

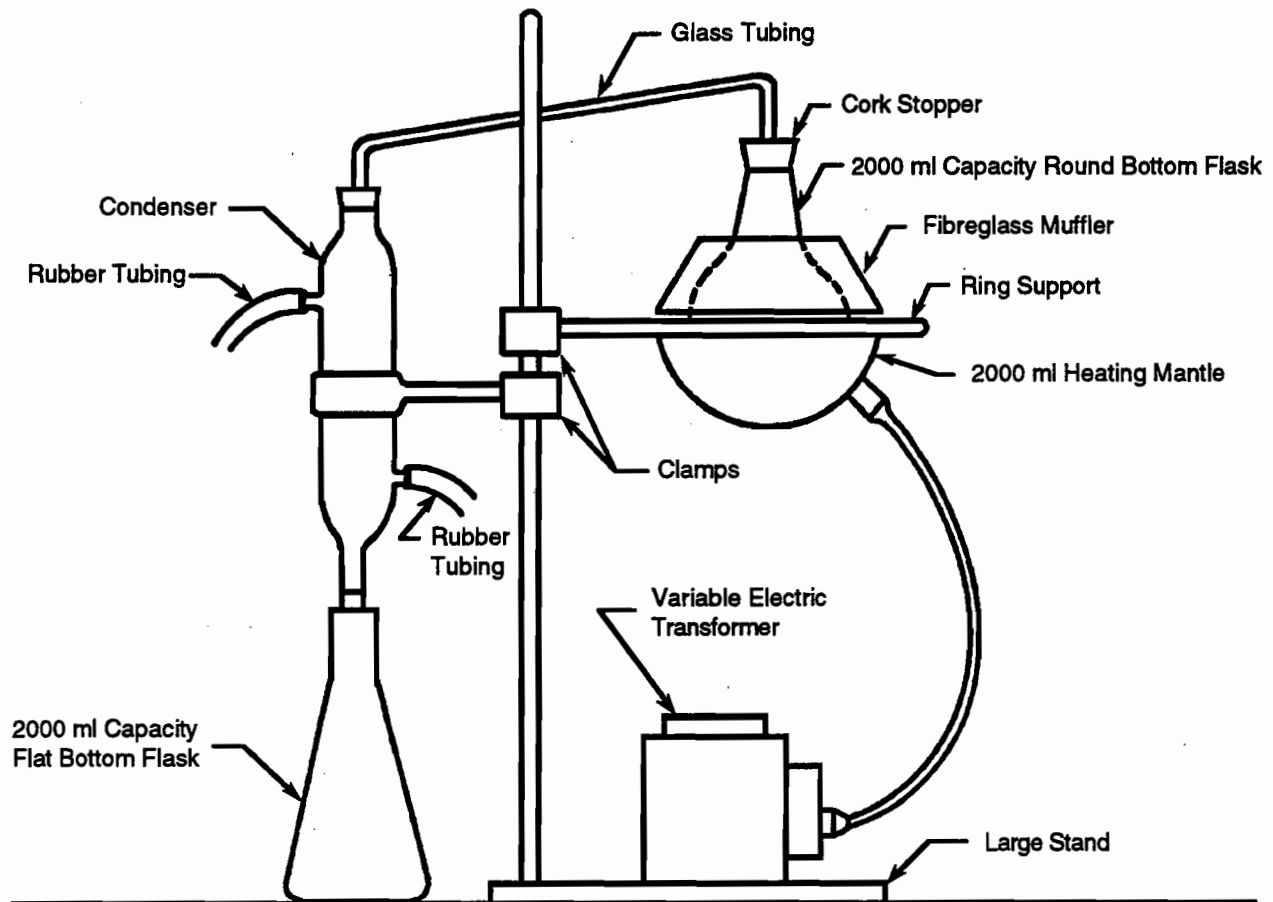


Figure 1
Abson Primary Distillation System

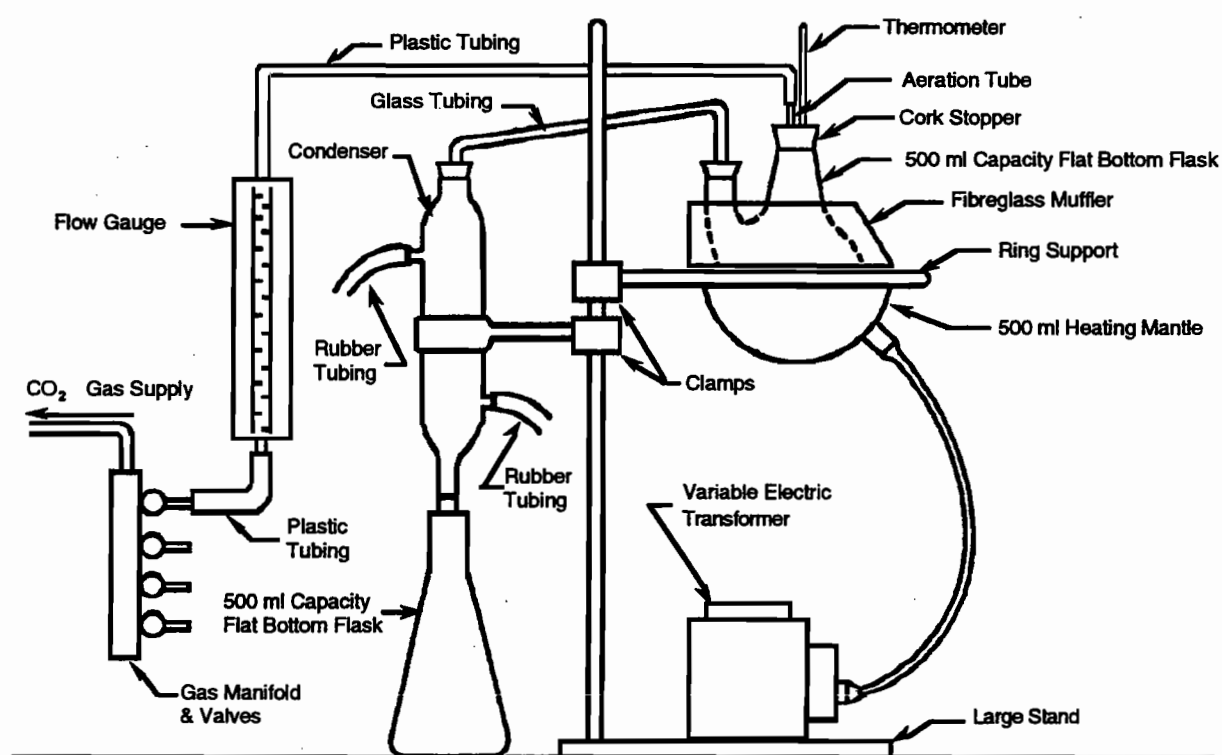
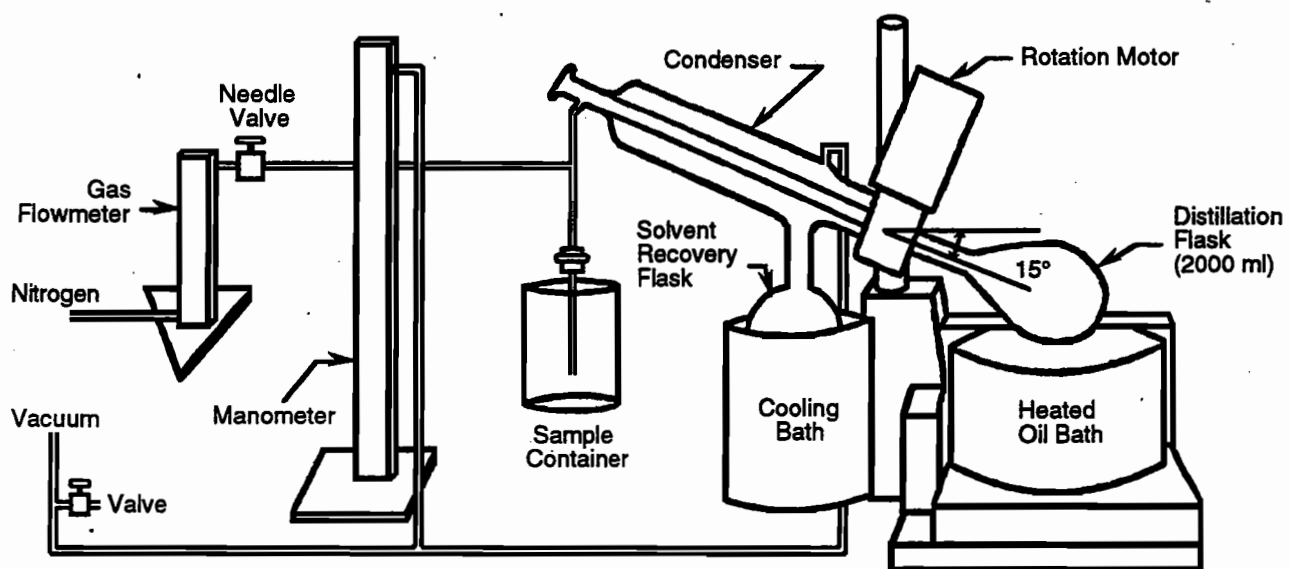
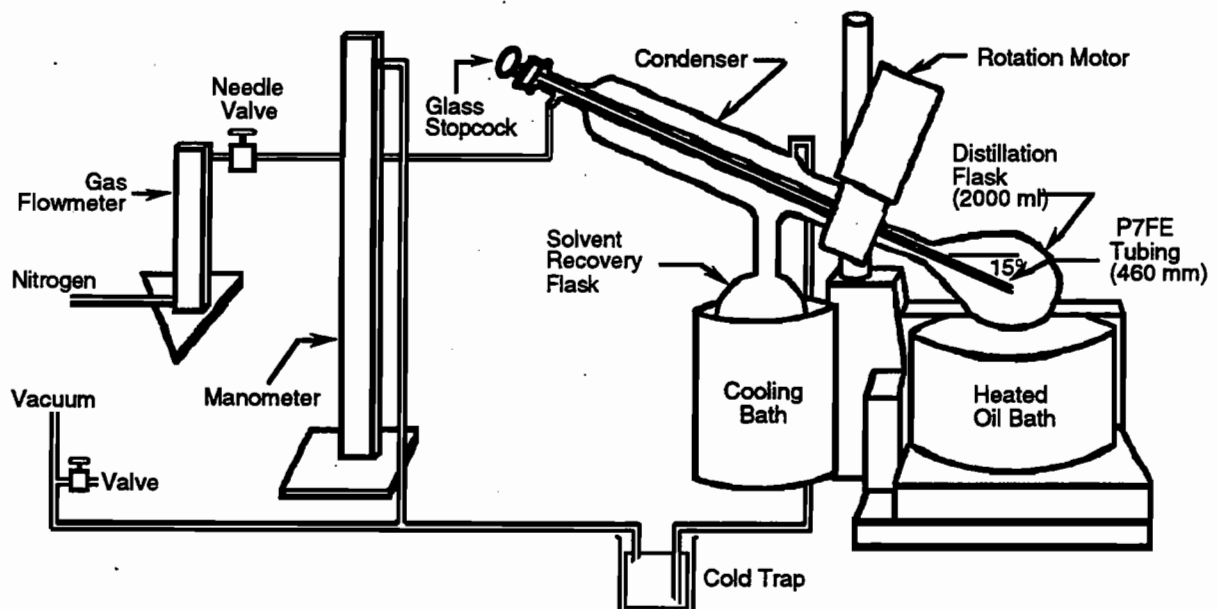


Figure 2
Abson Secondary Distillation System



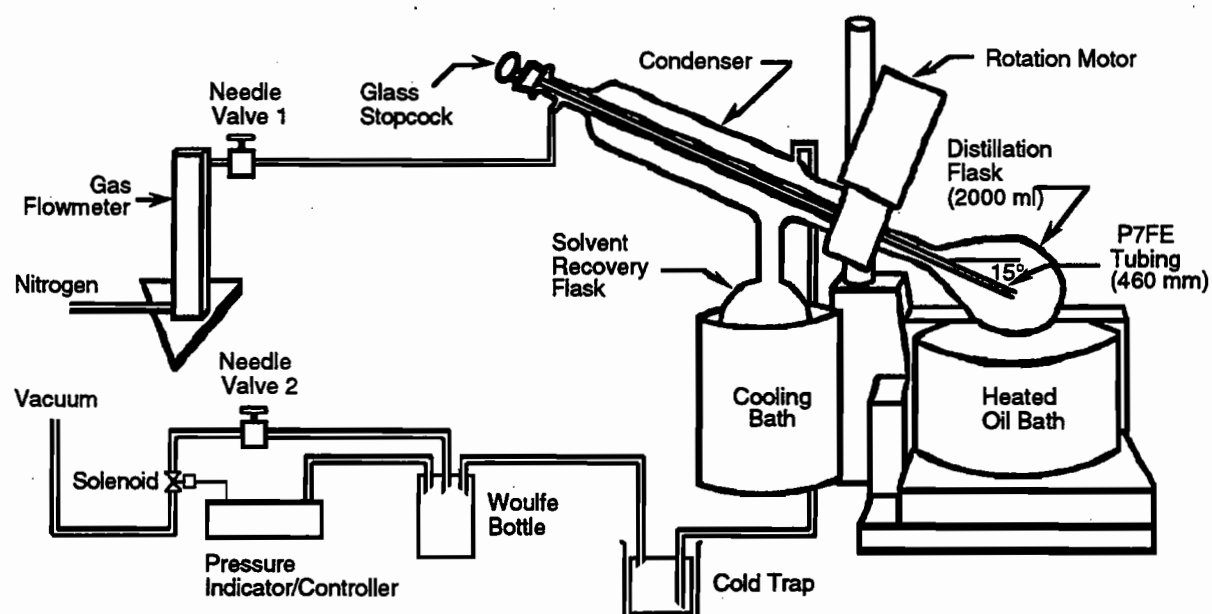
Note: It is important that the needle valve is at location shown; not ahead of the flowmeter

Figure 3
Rotavapor Apparatus And Recovery System
(Option A)



Note: It is important that the needle valve is at location shown; not ahead of the flowmeter

Figure 4
Rotavapor Apparatus And Recovery System
(Option B)



Note: It is important that Needle Valve 1 is at location shown; not ahead of the flowmeter; and that Needle Valve 2 is at the location shown; not ahead of the solenoid

Figure 5
Rotavapor Apparatus And Recovery System
(Option C)

METHOD OF TEST FOR STRIPPING BY STATIC IMMERSION

1. SCOPE

1.1 Aggregate is prepared and coated with asphalt that has been combined with an anti-stripping additive. Various percentages of the additive are compared. The samples are immersed in distilled water and the retained coating is visually evaluated.

2. RELEVANT DOCUMENTS

2.1 ASTM Designation D 1664

3. APPARATUS

3.1 **BALANCE:** Capable of weighing 1000 g to within 0.1 g accuracy.

3.2 **CONTAINER FOR MIXING:** An enamelled ware dish, approximately 140 mm in diameter and 70 mm in depth, must be suitable to withstand heat. Used to hold aggregate and asphalt cement with anti-stripping additive for thorough mixing.

3.3 **SPATULA:** With a metal blade approximately 100 mm long and 20 mm wide. Used for mixing aggregate and anti-stripping additive together to achieve a complete coating.

3.4 **OVEN:** Capable of maintaining temperatures between 121 and 177°C to within 2°C.

3.5 **WATER BATH:** Capable of maintaining a temperature of 49°C to within 0.5°C accuracy.

3.6 **QUICK HEAT OVEN:** Capable of rapidly heating aggregate to high temperatures.

3.7 **FLAT METAL PAN:** Suitable for containing aggregate to be quick heated. A thin film oven dish that can no longer be used for testing is convenient.

3.8 **BEAKER:** 600 ml, Pyrex.

3.9 **SQUARES:** (Approximately 200 mm) of polyethylene paper.

3.10 **POLYETHYLENE DISH:** Approximately 120 mm square by 40 mm deep.

- 3.11 CONTAINER (1 - Litre): Triple tight lid, screw cap, to hold 800 grams of asphalt cement with different percentages of anti-stripping additives in them.
- 3.12 HOT PLATE: To heat asphalt cement before anti-stripping additive has been added, then to heat 8oz cans with asphalt cement and various percentages of anti-stripping additives to 143°C.
- 3.13 CONTAINER (8oz ointment cans): Used to pour asphalt cement and various percentages of anti-stripping additive into bowls of aggregate and also to hold 100 grams of aggregate, that has been mixed in proportions.
- 3.14 BATH (ultrasonic): Used for cleaning of beakers and enamelled ware dishes.
- 3.15 LIGHT (with magnifier): Used to illuminate the surface of the water, to aid in the evaluation of the percentage retained coating.
- 3.16 THERMOMETER: Needed to read temperature of asphalt cements and anti-stripping additives being heated to 143°C for addition to the aggregate.
- 3.17 SIEVES: Standard, woven-wire, square-hole of 6.3 mm and 9.5 mm size, in accordance with Specification E11.
- 3.18 DISTILLED WATER: Used to cover the coated aggregate in the beaker.

4. PREPARATION

- 4.1 The aggregate is dried for 24 h in an oven maintained at about 141°C. The cooled aggregate is sieved and its gradation determined. The material passing the 13.2 mm sieve and retained on the 4.75 mm (No. 4) sieve is used with asphalt cements. The aggregate passing the 9.5 mm sieve and retained on the 4.75 mm (No. 4) sieve is used for cut-back asphalts. Each sieve size is stored in a separate container until ready for use.
- 4.2 If washed aggregate is to be used, the aggregate is dried and sieved as in 4.1. The aggregate is then washed thoroughly with tap water and rinsed with distilled water. (It is convenient to wash each sieve size to be used separately). The aggregate is surfaced dried and placed in an oven maintained at 141°C for a period of 24 h.
- 4.3 After the 24 h drying period, the cooled aggregate is stored (according to sieve size) in suitable containers. The container must have a lid and be air tight, in order to protect the aggregate from the surrounding air conditions until ready to be used.

4.4 It is often convenient for the aggregate to be prepared and weighed before the test is started. Each sample to be tested requires 100 grams of aggregate, composed of 50 grams of the 9.5 mm sieve designation, 35 grams of the 6.7 mm sieve designation and 15 grams of the 4.75 mm sieve designation. Once the aggregate has been weighed, it may be stored in 8 oz penetration cans with lids. The penetration cans will hold the pre-weighed, proportioned aggregate until ready for use.

4.5 For a single grade of asphalt cement being tested and a single anti-stripping additive, ten cans of aggregate will be required each day. It is important to remember all tests must be done in duplicate and thus 2 cans are required for each percentage of additive, as well as two cans for a control sample. Any subsequent days of testing may be completed without the control and thus will only require 8 cans of aggregate.

5. PROCEDURE

A. ASPHALT CEMENTS

5.1.0 If an anti-stripping additive is being tested, please refer to part D for the asphalt/additive preparation procedures. Otherwise proceed with step 5.1.1.

5.1.1 The oven is adjusted to a temperature of $143 \pm 2^{\circ}\text{C}$. The enamelled ware dishes are preheated in this oven and the quick heat oven is allowed to come back up to temperature.

5.1.2 100 g of the pre-weighed aggregate is placed into the flat metal pan. The pan and its contents are placed into the quick heat oven for 10 minutes. Upon completion of the ten minute heating period, the surface temperature of the aggregate should be between 149 to 177°C .

5.1.3 The aggregate is transferred from the flat metal pan to the preheated enamelled ware dish in the oven. The heating process is continued at 143°C for an additional 15 minutes to stabilize the temperature of the aggregate.

5.1.4 At the completion of this 15 minutes, the dish and contents are removed from the oven. 4.0 ± 0.1 g of asphalt heated to a temperature of 143°C , is quickly added to the aggregate. Using the metal spatula, the aggregate is mixed until completely coated. The coated aggregate is immediately transferred to a 600 ml beaker. The beaker may be shaken to keep the mixture even. The mixture is allowed to cool to room temperature.

5.1.5 Once cooled, the aggregate is submersed in distilled water, filling the beaker to about the 3/4 full mark. The beaker is covered with a square of polyethylene, which is secured with an elastic band. This is to prevent evaporation of the water. The beaker and its contents are placed into the water bath at $49 \pm 0.5^{\circ}\text{C}$ for 24 h.

5.1.6 After the 24 h period, the beaker and its contents are removed from the water bath. Do not pour out the water from the beaker. The surface of the water is illuminated by means of a shaded lamp and the percentage of total visible area of aggregate that has remained coated is evaluated.

5.1.7 If the retained coating is less than 65%, proceed with Part "C".

B. CUT-BACK ASPHALTS

5.2.1 100 g of the aggregate (as per grading) is placed into a 600 ml beaker. 6.0 ± 0.1 g of the asphalt which has been brought to the minimum mixing temperature as recommended in MTO Specification No. 1102 - Table V is added. Using the metal spatula, the asphalt and aggregate are mixed for 3 minutes.

5.2.2 The coated aggregate is transferred to the polyethylene dish. The spatula is used with this procedure. The mix is allowed to cure for 1 h at room temperature.

5.2.3 At the end of the curing period, the percent coated is visually evaluated. The dish is filled with distilled water and allowed to stand for 24 h at room temperature.

5.2.4 After 24 h, without disturbing the coated aggregate, any film floating on the surface of the water is removed. The percent coating, using the lamp to illuminate the water surface, is evaluated. Any thin, brownish, translucent areas are to be considered as coated.

5.2.5 If the retained coating is less than 65%, proceed with Part "C", except aggregate is not heated.

C. AGGREGATE EVALUATION

5.3.1 The oven is adjusted to a temperature of $143 \pm 2^{\circ}\text{C}$, the mixing pan is preheated in this oven and the quick heat oven allowed to come back up to temperature.

5.3.2 100 g of the test aggregate is weighed using the standard gradation of;

Ministry Sieve Designation (mm)	% Passing
13.2	100
9.5	50
6.7	15
4.75	0

5.3.3 The aggregate is put into a flat metal pan and the pan and contents placed into the quick heat oven for 10 minutes. After the ten minutes has elapsed, the surface temperature of the aggregate should be between 149 and 171°C.

5.3.4 At the end of this 10 minute heating period the aggregate is transferred from the flat metal pan to the preheated enamelled ware dish and placed in the conventional oven. The heating is continued at 143°C for an additional 15 minutes to stabilize the temperatures of the aggregate.

5.3.5 Asphalt cements and additives are selected in the following manner:

- (a) An asphalt that is representative of the bituminous material to be used on a contract with the aggregate in question is selected.
- (b) A source and grade of asphalt(s) that is representative of the area where the aggregate may be used is selected.
- (c) The MTO Designated Sources List #3.05.10 for the current listing of approved anti-stripping additives may be referred to, or a pre-selected additive may be used.

5.3.6 Additives are usually added to the asphalt in the following increments, 0.5%, 0.75%, 1.00% and 1.25% by weight of asphalt.

5.3.7 A minimum of 100 g of asphalt is heated in a suitable metal container and the required amount of additive is weighed to 0.1 g accuracy and added into the heated asphalt. Using a spatula, the additive is stirred thoroughly into the asphalt. The test procedure is continued as in 5.1.4 to 5.1.6.

D. ADDITIVE EVALUATION

5.4.1 A standard aggregate, freshly crushed from boulders and with known stripping characteristics is normally used. The composition of the aggregate by petrographic analysis, as currently used by the MTO is as follows:

GOOD AGGREGATE TYPE	%
Carbonates (Hard)	1.2
Carbonates Crystalline (Hard)	34.5
Gneiss-Schist (Hard)	10.5
Granite-Gneiss	15.2
Granite-Diorite-Gabbro	14.2
TOTAL	75.9

FAIR AGGREGATE TYPE	%
Carbonates Crystalline (Slightly Weathered)	17.5
Gneiss (Soft)	1.4
TOTAL	19.1

POOR AGGREGATE TYPE	%
Carbonates Crystalline (Soft)	3.8
Miscellaneous	1.2
TOTAL	5.0

The petrographic number for this aggregate when used for hot mix and concrete is 161.7

5.4.2 The aggregate is prepared according to 5.3.1 to 5.3.4.

5.4.3 The asphalt cement and additives are selected in the following manner:

- (a) Asphalt cements that are representative of the grades and sources used in the province are selected.

e.g. Penetration Grade

85/100	Southern Ontario
150/200	Mid Northern
300/400	Far North, Northwestern

Any of the above grades could be used in recycling asphalt pavements.

- (b) The additive evaluation test is normally performed to evaluate or re-evaluate an additive for approval for the MTO Designated Sources List #3.05.10.

5.4.4 Additives are usually added to the asphalt in the following increments; 0.5%, 0.75%, 1.0% and 1.25% by weight of asphalt.

5.4.5 Approximately 800 g of asphalt are heated in a suitable metal container (1 L capacity, triple tight lid with screw cap) and the required amount of additive is weighed to 0.1 g accuracy into the heated asphalt. Using a spatula, the additive is thoroughly stirred into the asphalt. 30 to 50 grams of the mixture is poured off. This asphalt/additive mixture is now ready for the initial day of testing. To coat aggregate, add asphalt binder as per 5.1.4 to 5.1.6.

5.4.6 When a heat stability cycle is included in the elevations, the additive-asphalt mixtures are placed in an oven at 177°C for a period of 1 day (24 hours), 2 days, 3 days, and 4 days (or other specified periods). After each 24 h period has elapsed, another 30 to 50 grams of asphalt is poured off for the completion of that particular day of testing.

When required for use, the additive-asphalt mixtures are brought up to mixing temperature (143°C).

It is suggested that a form sheet be used to record the data. Please refer to attached sheet for Static Immersion Stripping Results (Additive Evaluation).

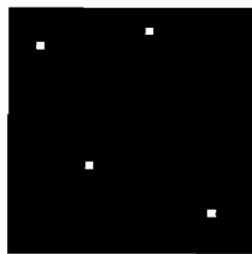
6. REPORT

6.1 The sample number and the initial and final coverages are reported on the appropriate forms.

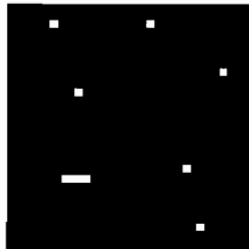
7. NOTES

- 7.1 If the initial coating of aggregate is much less than 90%, seldom will that combination of additive/asphalt meet the minimum coating requirements of 65% after four days of exposure in the oven.
- 7.2 The aggregate may also be immersed in a 0.5 percent solution of NaCl in distilled water.
- 7.3 All tests are to be performed in duplicate.
- 7.4 Never pour the distilled water or salt solution directly onto the aggregate.
- 7.5 With some very angular aggregates, it may be necessary to add more than 4.0 g of asphalt cement to obtain complete initial coating.
- 7.6 Use heat resistant gloves when handling hot aggregate and equipment.
- 7.7 If it is necessary to remove the mixing dish from the oven in order to add the aggregate from the quick heat oven, this operation must be quickly performed to keep heat loss to a minimum.
- 7.8 Refer to the attached chart for visual percentage estimation.

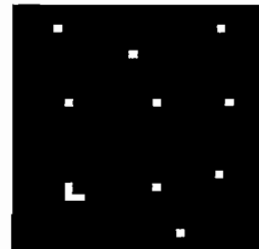
CHART FOR VISUAL PERCENTAGE ESTIMATION



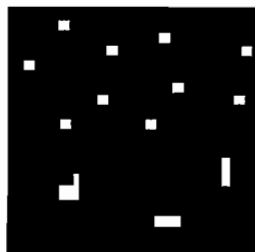
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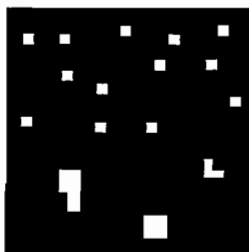
2%



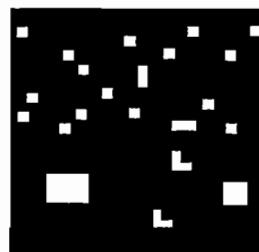
3%



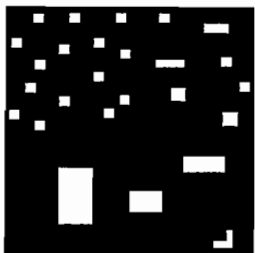
5%



7%



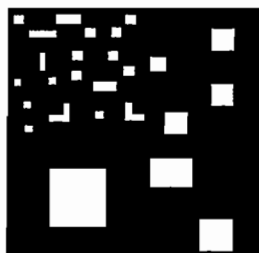
10%



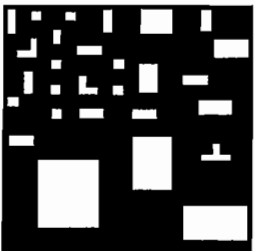
15%



20%



25%



30%



40%



50%



Static Immersion Stripping Results (Additive Evaluation)

Project: _____ Additive Used: _____
Date: _____ Aggregate Used: _____

		% Retained Coating											
		Heat Stability at 177°C											
		Initial						1 Day					
		Control	0.50%	0.75%	1.00%	1.25%		Control	0.50%	0.75%	1.00%	1.25%	
1													
2													
3													
		Source and Grade of Asphalt Binder						3 Day					
		Control	0.50%	0.75%	1.00%	1.25%		Control	0.50%	0.75%	1.00%	1.25%	
1	1.												
2	2.												
3	3.												

Remarks: _____

METHOD OF TEST TO MEASURE RESISTIVITY OF CONDUCTIVE ASPHALT MIXTURES

1. SCOPE

1.1 This method describes the procedure for the measurement of electrical resistance of an asphalt briquette prepared by the MTO Method of Mix Design using Marshall compaction and testing apparatus.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D 1664
- 2.2 MTO LS-261
- 2.3 MTO LS-262
- 2.4 MTO LS-263
- 2.5 MTO LS-264
- 2.6 MTO LS-265
- 2.8 OPSS 1149

3. APPARATUS

3.1 AC or DC OHMETER: Capable of measuring to .01 ohms is acceptable for both laboratory measurements and testing at field lab installations..

Note: Two models which have demonstrated satisfactory performance are;

- (1) Vibroground, Associated Research Inc., and*
- (2) Neilson 400.*

- 3.2 "C" CLAMP: 100 mm size, one required.
- 3.3 PLEXIGLASS DISCS: 98 mm diameter by 6.35 mm thick, two required.
- 3.4 COPPER SHEET: 101 mm diameter by 0.8 mm thick, as required.
- 3.5 VERNIER CALIPER: With 0.025 mm accuracy, one required.

4. PROCEDURE

- 4.1 Use MTO Test Method LS-261 for the preparation of the Marshall specimens.
 - 4.1.1 Determine the mass and the thickness of the two copper plates being used.
 - 4.1.2 Place one copper plate in the bottom of the compaction mold.
 - 4.1.3 Weigh in a mass of approximately 900 g of mixture to produce a briquette with a desired compacted volume ranging from 510 to 520 mL.

4.1.4 Rod the mixture as outlined in MTO Test Method LS-261, place the other copper plate on the rodded mixture, and compact in the normal manner.

4.2 Using the Vernier calipers, measure the diameter and the height of the briquettes at four different locations. An average value for each is then computed. If the copper plates are attached to the briquettes, subtract the thickness of the plates from the height dimensions.

4.3 Subtract the mass of both copper plates, and calculate the bulk relative densities of the briquettes.

4.4 Place a plexiglass disc against each of the copper plates leaving sufficient area of the copper plates exposed so that the ohmmeter lead terminals can contact each copper plate.

4.5 Centre the "C" clamp on each plastic disc, and apply a small compressive force to hold the discs on the copper plates. Place an ohmmeter lead terminal on each copper plate.

4.6 After each 1/8 turn of the "C" clamp, measure the resistance of the sample between the copper plates and record the value. The resistance value should decrease as the applied compressive force is increased. Apply pressure in increments by means of the 1/8 turn of the "C" clamp until the resistance no longer decreases. The lowest resistance achieved is recorded for the final calculations, and should be obtained before the sample has noticeably deformed.

5. REPORT

5.1 The resistivity for each sample is determined using the following formula:

$$P = \frac{R \times A}{L}$$

where: P	=	resistivity	-	ohm cm
R	=	resistance	-	ohm
A	=	area of briquette	-	cm ²
L	=	length of briquette between copper plates	-	cm

5.2 Maximum allowable resistivity is 3 ohm cm.

6. GENERAL NOTES

6.1 If the resistivity is greater than 3 ohm cm, alter the mix proportions by replacing a portion of the sand with a maximum of 5 percent by mass of additional coke breeze.

**METHOD OF TEST FOR
THE DETERMINATION OF PERCENT COMPACTION
OF COMPACTED BITUMINOUS PAVING MIXTURE
(MRD METHOD)**

1. SCOPE

1.1 This method covers the determination of the percent compaction of a sample of compacted bituminous pavement. The percent compaction is given by the bulk relative density expressed as a percentage of the theoretical maximum relative density. A correction is applied when the thickness is less than 40 mm.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D-3549
- 2.2 MTO LS-262
- 2.3 MTO LS-264

3. TEST PROCEDURE

- 3.1 Determine the thickness of the test specimen according to the procedure outlined in ASTM D-3549 and record the average of four measurements.
- 3.2 Determine the bulk relative density of the pavement sample according to the test procedure outlined in LS-262.
- 3.3 Determine the theoretical maximum relative density of the pavement sample according to the test procedure outlined in LS-264.

4. CALCULATION

- 4.1 The percent compaction is given by the equation:

$$\text{Compaction, \%} = \left(\frac{\text{BRD}}{\text{MRD}} \times 100 \right) + C$$

Where: BRD = Bulk Relative Density of the pavement sample

MRD = Theoretical Maximum Relative Density of the pavement sample

C = Thickness correction factor (0.1% for each whole millimetre that the pavement course thickness is less than 40 mm)

5. REPORTING OF RESULTS

5.1 Calculate the results to one decimal place.

6. GENERAL NOTES

6.1 The pavement sample taken for establishing the thickness and bulk relative density must be free from distortion or cracks or foreign material, and must consist of a minimum of a 150 mm diameter core with a minimum mass of 1000 g, or a sawn sample of the same minimum mass.

6.2 Where desirable, specimens may be separated from other layers by shearing or other means provided a well defined construction plane is achieved.

**METHOD OF TEST FOR
QUANTITATIVE DETERMINATION OF
ASPHALT CEMENT CONTENT OF BITUMINOUS MIXTURE
USING THE NUCLEAR ASPHALT CONTENT (AC) GAUGE**

1. SCOPE

1.1 This method covers the quantitative determination of asphalt cement in a bituminous paving mixture using the nuclear asphalt content gauge.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D-4125-92
- 2.2 MTO Method LS-261
- 2.3 MTO Method LS-282
- 2.4 AI Mix Design MS-2

3. APPARATUS

- 3.1 **NUCLEAR AC GAUGE:** Consisting of (a) Neutron Source - an encapsulated and sealed radioactive source of americium/beryllium and (b) Detectors - thermal neutron detectors such as helium - 3.
- 3.2 **STAINLESS STEEL SAMPLE PANS:** Of uniform size and mass (minimum of five recommended).
- 3.3 **PLUG FIXTURE (optional):** When testing with briquettes, the plug fixture is used to position the compacted sample briquettes in the sample chamber for testing.
- 3.4 **CONTROL CONSOLE/READOUT INSTRUMENT:** The operator interface to the system. It consists of a keypad, scalar display providing a direct digital reading device calibrated in percent asphalt and the microprocessor that is used to process the sample data.
- 3.5 **SERIAL PRINTER (optional):** Capable of interfacing with the nuclear gauge.
- 3.6 **BALANCE OR SCALE:** 10000 g capacity with an accuracy of ± 0.1 g.
- 3.7 **OVEN:** Of suitable capacity and capable of maintaining a temperature in the range 100 to $180^{\circ}\text{C} \pm 3^{\circ}\text{C}$.
- 3.8 **HOT PLATE/OVEN:** Thermostatically controlled and capable of heating asphalt cement to a temperature of 100 to $180^{\circ}\text{C} \pm 3^{\circ}\text{C}$.
- 3.9 **MARSHALL MOLDS/MECHANICAL COMPACTOR/MANUAL COMPACTION HAMMER:** In accordance with LS-261.
- 3.10 **STRAIGHT EDGE:** Steel, approximately 450 mm in length.

- 3.11 LEVELING PLATE: Plywood 19 mm or heavier, 13 mm plexiglas, or metal plate 10 mm or heavier, having an area slightly larger than the sample pans.
- 3.12 MECHANICAL MIXER: 19 L Hobart or similar equipment.
- 3.13 Assorted spoons and mixing bowls.
- 3.14 THERMOMETER/TEMPERATURE PROBE: Suitable for measuring temperature of aggregates, asphalt and bituminous mixtures in the range of 10 to 250°C with sensitivity of $\pm 3^{\circ}\text{C}$.
- 3.15 KETTLE OR CONTAINER: Of sufficient capacity to hold approximately 4.5 L of asphalt cement.
- 3.16 GLOVES: Heat resistant for handling hot equipment.
- 3.17 BRIQUETTE EXTRACTOR: Steel, in the form of a disk with a diameter not less than 100 mm and 13 mm thickness. The extractor shall be any device, either electrical or hand operated that will force the briquette from the mold into the extension collar at a uniform rate without causing any deformation to the specimen.

4. PREPARATION OF CALIBRATION SAMPLES

- 4.1 Prepare specimens for specific % AC yielding 5 data points with the middle point being the proposed JMF target % and the remaining 4 points being two below and two above the target % AC in 0.5 % increments.
- 4.2 Dry aggregates to a constant weight at 110°C and separate the aggregates by dry sieving into the desired size fractions according to the JMF.
- 4.3 Arrange the individually sized coarse aggregate(s) and fine aggregate(s) in bags or in suitable containers on a bench, in order of decreasing sieve sizes. See weigh card for the particular mix.
- 4.4 PREPARATION OF PAN CALIBRATION SAMPLES.
 - 4.4.1 Blank Sample Preparation for Pan Calibration - If for the JMF the asphalt sample size (mass - kg) to be placed in the pans for calibration and testing is not available from historical records, a blank sample of aggregate should be prepared to estimate the asphalt sample size.
 - 4.4.2 Select an empty sample pan and obtain the weight (tare weight).
 - 4.4.3 Blend the aggregate(s) in the proper proportions (at least 10 kg total).
 - 4.4.4 Fill the sample pan with the blended aggregate in two or three layers, avoiding segregation. Using a scoop or spatula, distribute the aggregate to reduce voids and segregation. For each layer, raise the pan approximately 20 to 50 mm from the working surface and let it drop two or three times to settle the contents. Fill the pan to a point slightly above the top edge. Slide a straightedge along the top of the pan until the aggregate is absolutely flush with the top edge of the pan.
Note 1: Caution - Do not compact the sample.
 - 4.4.5 Determine the mass of the blank sample to the nearest gram and record to the nearest 10 grams. Use this mass for all calibration and plant mix test samples for that particular JMF.

Note 2: The mass of the blank sample may not be sufficient to completely fill the calibration and plant mix test sample pans for all mixes. The asphalt cement may act as a lubricant allowing additional consolidation of the aggregate particles. An adjusted blank sample mass may be determined by preparing a calibration sample using these procedures and using the mass of this sample as the blank sample mass for this and all remaining samples for that particular JMF.

4.4.6 Preparation of the five calibration samples for the pan calibration will require each of the five mixtures to be prepared in duplicate 4000 g batches to provide sufficient material to fill the pans.

4.4.7 Using the flat bottom scoop, weigh up, into separate duplicate pans for each test specimen, a sufficient quantity of oven-dried sample of the selected aggregates, so that the total mass will result in 4000 g with the specified AC content.

4.4.8 Use the pans accompanying the nuclear gauge. Weigh each pan and mark the pans with the tare weight to the nearest 0.1 g.

4.4.9 Place the aggregates in an oven maintained at a temperature not exceeding 30°C above the temperature that will yield a viscosity of $170 \pm 20 \text{ mm}^2/\text{s}$ for the asphalt used. Heating time shall be a minimum of 16 hours, normally overnight.

4.4.10 Preheat the mixing bowl in the same oven as the aggregate. Preheat the metal trowel and spatula on the hot plate.

4.4.11 Heat the asphalt to a temperature which will give a viscosity of $170 \pm 20 \text{ mm}^2/\text{s}$ (Mixing Temperature). Refer to the temperature/viscosity chart for the particular asphalt cement in use. The asphalt cement should not be held at mixing temperatures for more than 2 hours. Suitable shields, baffle plates or sand pads shall be used on the surface of the hot plate to prevent localized overheating.

4.4.12 When the asphalt cement has reached the desired temperature, remove the container of aggregate from the oven (for one 4000 g batch only), and quickly place it in the mixing bowl that has been previously buttered and tared. Using the mixer, dry mix the aggregate for 15 seconds.

4.4.13 After dry mixing, form a crater in the centre of the aggregate in the bowl, quickly add in the required amount of asphalt cement, and mix 45 seconds or until the aggregate is coated. Do not mix longer than 1.5 minutes.

4.4.14 At the end of the wet mixing cycle, using the pre-heated spatula, scrape as much of the mix as possible from the mixing paddle and scraper blade.

4.4.15 Spread the mixture into a tray using a back and forth motion. Scrape all the loose mixture in the bowl into the tray. Cover the top of the tray (e.g. plywood cover).

4.4.16 Repeat steps 4.4.10 to 4.4.14.

4.4.17 Combine the duplicate mix with the mix in the tray and stir to produce a uniform blend.

4.4.18 For all mixes with a permeability of $K/L = 10^{-10} \text{ cm}^2$ or greater (i.e. DFC, HDBC, OFC, OGD, etc.), the calibration bituminous mix for the pan calibrations must be left in the tray and

allowed to cool overnight to room temperature. On the following work day, reheat the calibration mixes in the trays to 150°C before placing in the pans.

4.4.19 Fill the sample pan in three layers. After placing each layer in the sample pan, using a scoop or spatula, distribute the layer of material evenly in the pan to reduce voids and segregation. Place the sample pan on the scales and add or remove material until the mass equals the mass of the blank aggregate sample or other predetermined mass within ± 1 g.

4.4.20 Level the mixture on the top of the sample pan, spreading the mixture out to the edge of the pan.

4.4.21 Place wax paper over the pan to prevent the asphalt from sticking to the plate. The asphalt mix may be compressed with a piece of flat plywood or flat metal plate to ensure that the asphalt is level with the top of the pan. (This is accomplished by laying the leveling plate on top of the sample and then standing on it and using a twisting motion while standing on it to screed it off even with the top of the pan). Sight across the top of the sample pan to ensure that the mixture does not protrude above the pan.

Note 3: Do not compact with a press or compaction tool.

4.4.22 Reweigh the sample pan with sample and if necessary adjust the mass to within ± 1 g of the target by adding fines from the leftover mix in the tray.

4.4.23 Repeat steps 4.4.7 to 4.4.21 for each of the remaining calibration samples.

4.5 PREPARATION OF MARSHALL BRIQUETTE SAMPLES

4.5.1 The gauge calibration shall be performed using two compacted specimens at five known asphalt contents.

4.5.2 Dry aggregate to constant mass at 110°C and separate the aggregates by dry sieving into the desired size fractions.

4.5.3 Arrange the individually sized coarse aggregate(s) and fine aggregate(s) in bags or in suitable containers on a bench, in order of decreasing sieve sizes. See weigh card for the particular mix.

4.5.4 Preparation of the five sets of calibration briquettes will require each of the five mixtures to be prepared in 4000 g batches to provide sufficient material in order to prepare three Marshall briquettes. The mass of each briquette shall be determined to the nearest 0.1 g and recorded. The two briquettes with mass approximating each other the closest shall be selected and used to calibrate the nuclear gauge to the known % AC.

4.5.5 Using the flat-bottom scoop, weigh up a sufficient quantity of oven-dried sample of the selected aggregates, so that the total mass will result in 4000 g with the specified AC content.

4.5.6 Repeat steps 4.4.9 to 4.4.14.

4.5.7 Spread the mixture into a tray using a back and forth motion. Scrape all the loose mixture in the bowl into the tray.

Note 4: For all mixtures with AC content equal to the JMF + 0.5 % or lower, allow the material in the tray to cool overnight to room temperature. For the mixture with AC content equal to the JMF +1.0 %, reheat the mixture the following day to 150°C and allow to cool overnight to room temperature a second time.

Note 5 As an option, the briquette calibrations may be prepared using only the mixes prepared with an AC content of JMF mixes 1.0 % to JMF plus 0.5 % thereby foregoing the mix with an AC content of JMF + 1.0 %. Electing this option will eliminate the requirement for a second reheat of the mix with an AC content greater than the JMF plus 0.5 %.

4.5.8 After the cooling period(s), place all trays in the oven and heat to a temperature of 150°C (approximately 2 hours).

4.5.9 Scoop out and place in a heated compaction mold enough mixture that will result in a compacted specimen 63.5 ± 1.25 mm in height (approximately 1200-1300 g). Alternatively, if for field samples the laboratory doing the AC testing for the associated contract has established a predetermined or historical mass for the respective HL mix for compacting field samples, then the calibration briquettes shall be prepared to that same mass.

4.5.10 Compaction procedure for the briquettes shall be in accordance with LS-261. It is recommended that all briquettes (both calibration and field) associated with testing with the nuclear AC gauge be prepared using mechanical compaction to reduce time and improve consistency.

5. GAUGE START-UP AND STANDARDIZATION

5.1 The nuclear AC gauge should be set up on a level sturdy surface in a location with a minimum clearance of 1 metre from any large standing object and at least 2 metres from any object containing moisture. Do not store samples of hot mix asphalt or asphalt cement within 2 metres of the gauge location.

5.2 The gauge must be installed at least 10 metres from any other nuclear gauge.

5.3 To begin a gauge calibration sequence complete the following steps (refer to the gauge operation manual for specific instructions to accomplish each step in the start-up, standardization and calibration procedures).

5.3.1 Turn the gauge on and set the measure time to 16 minutes and take a Background count: for pan calibration, the chamber must be empty; for briquette sample calibration, the plug fixture (without asphalt briquettes) must be placed in the chamber before taking the Background count.

5.3.2 Compare the new Background count to the previous 4 Background counts. If the new count is not within 1 % of the average of the previous 4 counts, inspect the gauge surroundings, remove any large source of hydrogen (water, asphalt cement, etc.) and repeat the Background count.

5.3.1 Record the new Background count on the calibration data sheet.

6. ASPHALT MIXTURE CALIBRATION

6.1 PAN SAMPLES

6.1.1 Set the measure time to 16 minutes and initiate a new calibration by pressing the CALIB key. Press the key sequence for "New Calibration" following the manufacturer's instructions and enter "5" as the number of samples for the calibration.

6.1.2 Enter the % AC, place the prepared sample pan in the chamber, close the chamber door and press the "START/ENTER" key to begin the count.

6.1.3 At the end of the count, record the count, remove the pan sample, place the second pan in the chamber and start a new count.

6.1.4 Repeat step 6.1.3 for the remaining 4 pan samples.

6.1.5 At the completion of measuring all specimens, the gauge display will show the Fit Coefficient. The Calibration Constants and the % Difference for each data point should be reviewed and recorded or printed out.

6.1.6 Calculate and record the incremental differences and the mean of the incremental differences amongst the five calibration counts.

6.1.7 The Calibration shall be accepted if:

- 1) The fit coefficient is greater than 0.995.
- 2) No incremental difference varies from the mean of the incremental differences by more than 15 %.

6.1.8 If the calibration is not accepted, review the results to identify the outlier sample(s). If a recount does not correct the discrepancy, prepare new replacement samples until an acceptable fit is achieved.

6.1.9 The calibration is then stored in the unit.

6.2 BRIQUETTE SAMPLES

6.2.1 Set the measure time to 4 minutes and initiate a new calibration by pressing the CALIB key. Press the key sequence for "New Calibration" following the manufacturer's instructions and enter "5" as the number of samples for this calibration. Where the control console is so programmed, enter to the nearest 0.1 g the total mass of the set of the two calibration briquettes. Enter the % AC.

6.2.2 Place the two selected compacted briquettes corresponding to this % AC in the plug fixture, and place a keel or chalk mark (arrow) on one face of each briquette for reference and orientation. Place the plug fixture in the chamber, close the chamber door and press the "START/ENTER" key to begin the measure count.

6.2.3 At the end of the count, record the count, rotate the asphalt briquettes in the plug fixture 180°, replace the plug fixture in the chamber and start a new count.

6.2.4 At the end of the count, record the count, remove the asphalt briquettes, turnover and repeat steps 6.2.2 to 6.2.3.

6.2.5 After the four minute readings for the set of briquettes are completed, record the average count.

6.2.6 Repeat steps 6.2.1 to 6.2.5 for the remaining four sets of calibration briquettes.

6.2.7 At the completion of measuring all specimens, the gauge display will show the Fit Coefficient. The Calibration Constants and the % Difference for each data point should be reviewed and recorded or printed out.

6.2.8 Calculate and record the incremental difference and the mean of the incremental differences amongst the five calibration counts.

6.2.9 The Calibration shall be accepted if:

- 1) The fit coefficient is greater than 0.995
- 2) No incremental difference varies from the mean of the incremental differences by more than 20 %.

6.2.10 If the calibration is not accepted, review the results to identify the outlier sample(s). If a recount does not correct the discrepancy, prepare new replacement samples until an acceptable fit is achieved.

6.2.11 The calibration is then stored in the unit.

7. TESTING OF PRODUCTION MIXTURE (FIELD SAMPLES)

7.1 PREPARING PAN SAMPLES

7.1.1 The field sample shall be a minimum of 8.0 kg and be obtained according to approved methods.

7.1.2 In order to be consistent, any material received in the laboratory from the paving site in a hot condition, i.e. $>50^{\circ}\text{C}$, shall be allowed to cool to room temperature. Fans are permitted.

7.1.3 Warm the entire sample until it can be separated without causing any breakdown of the aggregates.

7.1.4 Spread the mixture in a tray and heat in an oven (microwave not permitted) to a temperature of $150^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

7.1.5 After heating, stir the mixture with a trowel to ensure it is uniform and begin to transfer the mixture from the tray to the pan. The total mass of the mixture transferred to the pan shall be within ± 1 g of the mass of the mixture selected for the corresponding calibration pan samples.

7.1.6 Fill the sample pan in three layers. After placing each layer in the sample pan, using a scoop or spatula, distribute the layer of material evenly in the pan to reduce voids and segregation. Do not pack the material with a press or compaction tool. Place the sample pan on the scales and add or remove material until the desired sample mass is obtained.

7.1.7 Level the mixture on the top of the sample pan, spreading the mixture out to the edges of the pan. Place a piece of wax paper over the asphalt and press down on the asphalt with a piece of flat plywood or flat metal plate. (This is accomplished by laying the leveling plate on top of the sample

and then standing on it, and using a twisting motion while still standing on it.) Sight across the top of the sample pan to ensure that the mixture does not protrude above the pan.

7.1.8 Place the full sample pan on the scale and obtain the mass of the mixture. Record the value. It should equal the mass of the calibration sample reference mass ± 1 g.

7.1.9 Repeat Steps 7.1.1 to 7.1.8 for each sample.

7.1.10 After the measurements with the nuclear gauge are completed, the asphalt can be removed from the sample pan by placing the filled pan in an oven set to a temperature of 180°C. Leave the pan in the oven for a period of 10 to 15 minutes (at a lower temperature, a longer time may be required). Turn the pan upside down and lightly tap on the bottom. Do not dent the bottom of the pan.

7.2 TAKING A MEASUREMENT (PAN SAMPLES)

7.2.1 Ensure that the background count is current.

7.2.2 Place the sample pan into the sample chamber and close the door.

7.2.3 Select the correct calibration.

7.2.4 Perform a 4 minute count according to the operator's manual. Optionally a longer time period may be selected but it is not required.

7.2.5 After the count time has elapsed, the results will be displayed on the screen. Where equipped, a printed copy may also be obtained.

7.2.6 Transfer results to the appropriate forms.

7.2.7 Repeat Steps 7.2.2 to 7.2.6 for each sample.

7.3 PREPARING BRIQUETTE SAMPLES

7.3.1 Prepare 3 briquettes for each sample of asphaltic concrete.

7.3.2 The field sample shall have a minimum mass of 4000 g and be obtained according to approved methods.

7.3.3 In order to be consistent, any material received in the laboratory from the paving site in a hot condition, i.e. $>50^{\circ}\text{C}$, shall be allowed to cool to room temperature. Fans are permitted.

7.3.4 Warm the entire sample until it can be quartered down without causing any breakdown of the aggregates.

7.3.5 Obtain from the sample by the splitting/quartering method, sufficient material in order to prepare three Marshall briquettes.

7.3.6 Spread the mixture in a pan and heat in an oven (microwave not permitted) to a temperature of $150^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

7.3.7 Scoop out and place in a heated compaction mold the same mass (± 1 g) of mixture that was used when preparing the corresponding calibration briquettes.

7.3.8 Compaction procedure for the briquettes shall be in accordance with LS-261. It is recommended that all briquettes (both calibration and field) associated with testing with the nuclear AC gauge be prepared using mechanical compaction to reduce time and improve consistency. If the

field briquettes are compacted on a different mechanical hammer than the corresponding calibration briquettes, an "equivalency factor" should be established in order that the compactive effort for the type of mix being compacted is the same for both units.

7.3.9 After compaction, allow the briquettes to cool until warm to touch (approximately 40°C). Fans may be used. Cooling by submerging in water is not permitted.

7.3.10 Remove the specimens from the molds by means of an extrusion jack or other compression device. The mass of each briquette shall be determined to the nearest 0.1 g. Record the mass of each briquette. For each set of three briquettes, the two briquettes with mass approximating each other the closest shall be used to determine the AC content in the gauge. Place the briquettes on a smooth level surface until ready for testing.

7.4 TAKING A MEASUREMENT (BRIQUETTE SAMPLES)

7.4.1 Ensure that the background count is current.

7.4.2 Using a piece of keel or chalk, make a mark on the top and bottom edge of each briquette. This mark will be used as a reference when the briquettes are rotated in the fixture.

7.4.3 Place the sample briquettes (2 required) into the Sample Plug Fixture. Place the fixture into the sample chamber and close the door.

7.4.4 Select the correct calibration.

7.4.5 Perform a 4 minute count according to the operator's manual. After the first count, rotate the briquettes 180° and take a second 4 minute count.

7.4.6 After the second count, turn the briquettes over and take a third 4 minute count. After the third count, rotate the briquettes 180° and take a fourth and final 4 minute count.

7.4.7 After the count time has elapsed, the results will be displayed on the screen. Where equipped a printed copy may also be obtained.

7.4.8 Transfer the results to the appropriate forms.

7.4.9 Repeat steps 7.4.2 to 7.4.8 for each sample.

8. CROSS CALIBRATION

8.1 Operations involving testing the AC content using the nuclear gauge permit the calibrations to be carried out in a laboratory independent of the location of the laboratory testing the field contract samples. This can be accomplished by employing the procedures of Cross Calibration and JMF Transfer Calibration. A master gauge is located at the main or Regional laboratory while other nuclear gauges are located in field laboratories.

8.2 Prepare five calibration samples according to Section 4 to obtain an initial relational curve (or correlation) between the master and field gauges. The five calibration samples must be prepared such that they all can be measured on both gauges on the same day. (It is recommended that a pan calibration be prepared).

8.3 Starting with the master gauge press CALIB to perform a new calibration. Take a new Background count and record the value.

Note 6: The gauge which is currently active and measurements are being taken on must be a minimum of 10 m away from any and all other nuclear gauges while the calibration measurements are being taken.

8.4 Run each sample in the master gauge in the normal calibration mode (16 minutes). Record the counts obtained on each of the samples. The coefficient of fit should be at least 0.995 or better.

8.5 On the field gauge, select CROSS CALIBRATION (Refer to gauge manual). Perform a Background count and record the value.

8.6 Using the same five calibration samples, perform a Cross Calibration on the "Field" gauge.

- 1) input the number of samples
- 2) measure the samples (16 minute counts)
- 3) keypad input "Master" gauge background count
- 4) keypad input the five sample counts taken with the "Master" gauge.

The master gauge and the field gauge are now cross calibrated.

8.7 Repeat steps 8.5 to 8.6 for each "Field" gauge. If this is not done on the same day, repeat steps 8.3 and 8.4 first.

9. CALIBRATION TRANSFER

9.1 After the cross calibration is complete, calibrations performed on the "master" gauge can be transferred to the "field" gauge(s) without additional "field" gauge calibration.

9.2 Perform a calibration on the "master" gauge. Record the sample weights, the "master" gauge background count and calibration constants A1, A2 and A3

9.3 Input the calibration information (Step 9.2) from the "Master" gauge into the "Field" gauge. The "Field" gauge is now ready to measure unknown field asphalt samples produced from the related job mix formula.

10. GENERAL NOTES AND PRECAUTIONS

10.1 Perform background counts at least once per day and whenever there is a change in the environment around the gauge. Any hydrogen sources such as water, asphalt samples, people etc. should be kept at least 2 m away from the gauge. If the gauge environment has not changed, the daily background count should not vary by more than $\pm 0.5\%$.

10.2 During operation of the nuclear asphalt content gauge, the gauge must be located at least 10 m from any other nuclear gauge.

10.3 The room where the gauge is to be located should be well ventilated and should not experience abrupt temperature changes or humidity changes.

10.4 To ensure measurement consistency, mark the sample pans so they are inserted into the chamber the same way each time the pan is used.

10.5 The presence of moisture in the asphalt sample and its effect on the readings taken with the nuclear AC gauge can be considered non existent for the following reasons:

(a) Historical records reported by Mobile lab foremen indicate the moisture content determined from field samples of hot mix asphalt to be generally 0.05 % or less.

(b) Spreading out the sample in the tray and reheating to 150°C to allow placement in the pan or the manufacture of Marshall briquettes removes the remaining moisture.

10.6 The reheating of the asphalt samples for the calibration briquettes is essential in order for the calibration briquettes to match the characteristics (i.e. mass loss during briquette fabrication as well as void characteristics) of the briquettes fabricated from the field samples of the respective mix.

10.7 For the calibration pan samples, the incremental difference in counts between successive 0.5 % AC increments should not vary by more than 15 % of the mean of the increment values over the range of the calibration. If the above criteria is not satisfied, review the readings and repeat the counts for any suspected specimens. If the criteria remains unsatisfied, prepare new calibration samples for any suspected specimens and repeat the calibration.

18.8 The effect of changes in gradation of the aggregates and changes in proportions of coarse and fine aggregates on the % AC measured with the nuclear gauge are negligible provided the gradations and proportions are within the acceptable tolerances that are specified by the MTO for the respective mix type.

10.9 Users of this equipment must become familiar with possible safety hazards and with all applicable regulations concerning the handling and use of radioactive materials. Effective user instructions together with routine safety procedures are a required part of the operation of this apparatus.

10.10 A new calibration curve shall be developed whenever there is a change in the source of asphalt or aggregates; or a change in the job mix formula resulting in a change in the proportions of the coarse and fine aggregates where the fine and coarse aggregates differ petrographically.

10.11 When preparing calibration samples for mixes containing recycled asphalt pavement (RAP) materials, determine the AC content of the RAP material from extractions on three random 1 kg samples taken from the same sample of the RAP material being utilized to prepare the calibration samples. Since the extractions generally do not recover all the asphalt cement contained in the RAP, the resultant % AC in the RAP should be increased to properly define the % AC in the calibration samples. For each 10 % RAP fraction in the JMF, increase the predetermined % AC by 0.05 %. (E.g. If the extraction of the RAP samples indicate that the RAP has an AC content of 4.18 % and the JMF specifies 30 % RAP, the % AC assigned to the 30 % RAP fraction of the calibration samples shall be $4.18 + (\frac{30}{10} \times 0.05) = 4.33$ %.

10.12 Do not reheat prefabricated calibration or production samples at high temperatures for long periods of time. (If reheating is necessary, use a low heat setting).

10.13 Do not use damaged (severely bent or cracked) sample pans.

10.14 Do not move the gauge to a new location without taking a new background count.

10.15 Do not place large sources of liquids near the gauge after taking the background count.

METHOD OF TEST FOR WORKABILITY OF COLD BITUMINOUS PATCHING MATERIAL BY BLADE RESISTANCE METHOD

1. SCOPE

1.1 This test method covers the determination of the workability property of cold patching material (CPM) in cold temperatures (e.g. at -10°C). The handling property of CPM is duplicated in this method by the action of a blade penetrating a mixture.

2. RELEVANT DOCUMENTS

2.1 MTO Form 1153-1 Material Specification for Emulsified Asphalt Patching Material

2.2 MTO Method LS-261 Preparation of Marshall Specimens

2.3 MTO Method LS-263 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.

2.4 MTO Engineering Materials Office Report EM-85 - New Method for Testing Workability and Cohesion of Cold Patching Material ISBN 0-7729-3825-3, 1987.

3. SUMMARY OF METHOD

3.1 This test measures the workability of CPM in cold temperatures by using a modified Marshall tester holding a metal blade onto a proving ring. The blade is used to penetrate a compacted sample. The resistance to the blade penetration in Newtons (N) after 30 seconds of loading is a measure of the workability of a CPM, and is called the workability index (W.I.); the higher W.I. is, the poorer the workability.

3.2 The consolidation of CPM in the stockpile is simulated by compacting a CPM sample, at room temperature in a wooden box, with a modified flat foot square hand held Marshall hammer. The sample is then conditioned in a cold room or a freezer before testing. Duplicate samples are prepared for each mix.

4. SIGNIFICANCE AND USE

4.1 CPM is commonly used for patching minor surface defects in routine asphalt pavement maintenance in the winter. The ease of handling and application, compaction and performance of CPM are all affected by workability. It is, therefore, important to have some means of measuring this property.

4.2 The method enables the mix workability, as indicated by the ease of shovelling a mix in a stockpile, to be quantitative measured rather than by the subjective judgement of an operator. The

measurement will allow the operator to assess the effort required for removing a mix from a stockpile or truckbox by shovelling or scooping.

5. APPARATUS

- 5.1 **WOODEN BOXES:** Two boxes measuring 265 mm x 165 mm x 50 mm deep inside dimensions, and sufficiently rigid for forming and testing of cold mix specimen.
- 5.2 **COMPACTION HAMMER:** A hand held hammer (to LS-261) with a modified flat tamping foot of 150 mm x 150 mm x 6 mm thick attached to the bottom of the hammer.
- 5.3 **FREEZER OR COLD ROOM:** Capable of maintaining temperature at $-10 \pm 2^{\circ}\text{C}$.
- 5.4 **MARSHALL TESTING MACHINE:** A breaking head modified to hold a steel blade measuring 130 mm wide, 50 mm height and 3 mm thick to the adapter at the bottom of the proving ring.
- 5.5 **STAND:** Any stand of suitable height and configuration for supporting the wooden box.
- 5.6 **METAL SCOOP:** Flat bottom type for transferring mixes.
- 5.7 **THERMOMETER:** A type suitable for measuring a range of mix temperature from $+25$ to -25°C with sensitivity of $\pm 2^{\circ}\text{C}$. Suitable for measuring mix temperature in the range of -25° to $+25^{\circ}\text{C}$ with a sensitivity of $\pm 2^{\circ}\text{C}$.
- 5.8 **BALANCE:** 5 kg capacity, with sensitivity of 1 g.
- 5.9 **METAL PANS OR BOWLS**
- 5.10 **STOP WATCH**
- 5.11 **RUBBER GLOVES**
- 5.12 **MARKING CRAYONS**

6. PREPARATION OF TEST SPECIMENS

- 6.1 Prepare two specimens using the material to be tested.
- 6.2 **MIX PREPARATION**
 - 6.2.1 Bring samples of cold patching material (about 5 kg) to room temperature ($21 \pm 3^{\circ}\text{C}$).
 - 6.2.2 Weigh into two separate wooden boxes the amount (about 2 kg) that will result in a compacted specimen height of 48 or 50 mm.
 - 6.2.3 Spread the mix uniformly over the box and level the mix, avoiding any segregation. Discard any excess material.
- 6.3 **COMPACTION OF SPECIMENS**
 - 6.3.1 Place the box (Figure 1) with the material on any hard and level surface, and place the compaction hammer with the modified foot close to one side of the box and apply two blows with the hammer. Then apply another two blows to the material on the other side of the box.
- 6.4 Mark three locations along the length of the box, approximately at 1/4 points, to indicate the position for the blade penetration (Figure 1).

6.5 Place the compacted material and the box in a freezer or cold room for a minimum of 12 hours (e.g. overnight) at -10°C .

7. PROCEDURE

7.1 Attach the penetration blade to the adapter at the bottom of proving ring of the Marshall apparatus with the blade parallel to the front of the machine (Figure 1).

7.2 Adjust the dial indicator to zero.

7.3 Transfer the box with the compacted material from the freezer or cold room to the Marshall apparatus. Place it under the blade and on the support stand, ensuring that it is level and firmly seated on the support stand (Figure 1).

7.4 Switch on the motor and bring the specimen close to the blade. Position the specimen at the marked location.

7.5 Continue the upward movement of the jack head and start the stop watch when the dial indicator begins to move. Watch the dial carefully and record the reading after 30 seconds of penetration.

7.6 Stop the motor, lower the jack head and move the specimen to the next testing position. Clean the blade if necessary. Repeat the blade penetration procedure for the remaining two locations. Record the readings on the dial indicator.

7.7 Repeat the above procedure on the second specimen.

8. CALCULATION

8.1 Multiply each of the three dial readings by the proving ring calibration factor to calculate the blade resistance values.

8.2 Calculate the average of the three values.

8.3 Repeat the same for the second specimen.

9. REPORT

The report shall include the following information

9.1 Identification and description of the mix or sample.

9.2 The W.I. by averaging of the two calculated values from the two specimens.

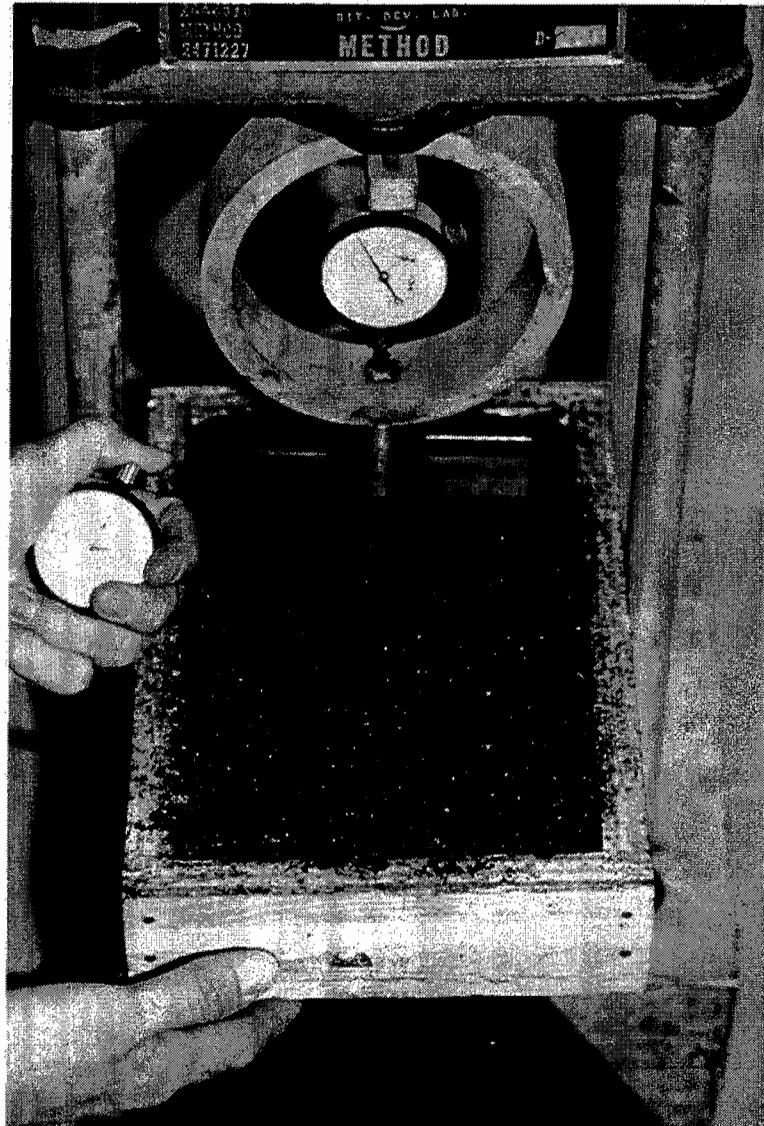


Figure 1
Blade Resistance Workability Test

TEST METHOD FOR COHESION OF COLD BITUMINOUS PATCHING MATERIAL BY ROLLING SIEVE METHOD

1. SCOPE

1.1 This test method covers the determination of the cohesive property of cold patching material (CPM) in cold temperatures (e.g. at -10°C). This property of CPM is evaluated in this method by rolling a compacted briquette in a sieve simulating the wearing of traffic on a mix patch.

2. REFERENCED DOCUMENTS

2.1 MTO Method LS-261 Preparation of Marshall Specimens

2.2 MTO Engineering Materials Office Report EM-85 - New Method for Testing Workability and Cohesion of Cold Patching Material ISBN 0-7729-3825-3, 1987.

3. SUMMARY OF METHOD

3.1 The bonding or cohesive property of a CPM is evaluated by subjecting a compacted mix to the disturbance and attrition action of a rolling sieve back and forth twenty times on a standardized tray. The abrasion between the surfaces of the sieve and the briquette simulates the wearing action of traffic. The percentage of material retained on the sieve to the total mass of the briquette is a measure of the cohesion and is called the cohesion index (C.I.); the higher the C.I., the better is the cohesion.

3.2 The compaction of CPM sample is carried out at -10°C using a 100 mm (4 in) diameter Marshall mold and handheld hammer.

4. SIGNIFICANCE AND USE

4.1 Since field performance of all asphalt mixes relates to a great extent on the material's cohesive characteristic, it is therefore important that the cohesion property be determined in the laboratory prior to application of the materials in the field. This method quantifies the cold patching material cohesiveness and its potential to resist ravelling due to traffic wear.

5. APPARATUS

5.1 MARSHALL COMPACTION APPARATUS:

5.1.1 Marshall mold assembly

5.1.2 Compaction hammer, hand type

5.1.3 Pedestal, for handheld compaction

- 5.1.4 Flat bottomed metal scoop
- 5.2 FREEZER/COLD ROOM: Capable of maintaining temperature at $-10 \pm 2^{\circ}\text{C}$
- 5.3 BALANCE : 200 g capacity, with sensitivity of ± 1 g
- 5.4 THERMOMETER: Suitable for measuring mix temperature in the range of -25 to $+25^{\circ}\text{C}$, with sensitivity of $\pm 2^{\circ}\text{C}$.
- 5.5 METAL PANS OR BOWLS
 - 5.5.1 One pan, 400 mm square x 100 mm deep
 - 5.5.2 Four pans or bowls with 1000 g holding capacity
- 5.6 METAL TRAY: With an inside dimension of 550 mm length, 445 mm width and 105 mm height.
- 5.7 SPECIMEN EXTRUDER: Hand type, suitable for extruding a compacted specimen from the mold with the use of a mold collar
- 5.8 STANDARD SIEVE: 19 mm square openings, 305 mm diameter and 82.6 mm height, with a sieve cover sufficiently tight fit to keep the specimen inside during the test.
- 5.9 RUBBER GLOVES
- 5.10 STOP WATCH OR TIMER

6. PREPARATION OF TEST SPECIMENS

- 6.1 Prepare three specimens using the material to be tested.
- 6.2 Weigh into the separate pans the amount of cold patching mixture (about 1100 g) that will result in a compacted specimen height of 63 ± 2 mm.
- 6.3 Place the pans and mix in a freezer and store for at least 12 hours at -10°C .
- 6.4 Place the specimen mold assembly and hammer head in the freezer for at least 2 hours.
- 6.5 Remove the mixture and compaction devices from the freezer and immediately place a piece of filter paper at the bottom of the mold before the mixture is introduced. Level the surface before placing another piece of filter paper on top.
- 6.6 Place the mold assembly on the compaction pedestal in the mold holder and apply five (5) blows with the compaction hammer with a free fall of 457 mm (18"). Reverse the mold and mix assembly and apply another five (5) blows of compaction to the specimen.

7. PROCEDURE

- 7.1 After compaction, carefully extrude the specimen into an extension collar and transfer the specimen to a diametrically positioned test sieve in a metal tray on a level surface (Figure 1).
- 7.2 Place the compacted briquette diametrically on the lowest point of the sieve with the flat face facing the wire mesh.

7.3 Immediately place the sieve cover tightly on the sieve and bring the sieve to one side of the metal tray. Roll the compacted briquette in the sieve back and forth twenty (20) times. The rolling should last about 20 seconds.

7.4 Lift the sieve from the pan and hold it in a horizontal position. Strike the side of the sieve slightly with a hand to allow all particles separated from the specimen to pass through the sieve openings.

7.5 Place the retained and passed portions of material in separate containers and determine the mass of both portions by weighing on a balance to the nearest gram.

8. CALCULATION

8.1 Calculate the cohesion index (C.I.) in percent as follows:

$$\text{C.I. (\%)} = \frac{r}{r + p} \times 100$$

where:-
C.I. = percent of cold patching mix retained on the 19 mm sieve
r = mass of mix retained on the 19 mm sieve
p = mass of mix passing the 19 mm sieve

9. REPORT

The report shall include the following information:

9.1 Identification and description of the sample

9.2 The C.I. calculated from averaging the triplicate test results for each of the samples.

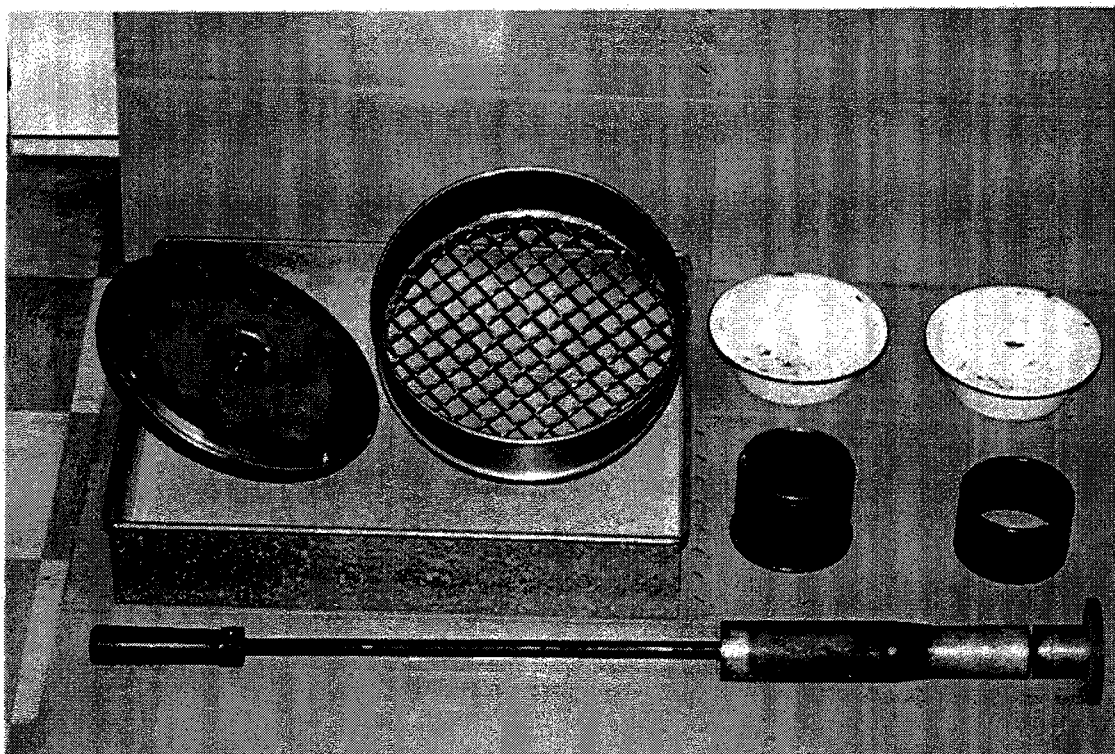


Figure 1

A 305 mm Diameter 19 mm Opening Sieve and Cover,
Metal Tray, Compaction Hammer and Mold, and Pans

**METHOD OF TEST FOR
QUANTITATIVE EXTRACTION OF ASPHALT CEMENT
AND MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE
FROM BITUMINOUS PAVING MIXTURES - ONTARIO PROCEDURE**

1. SCOPE

- 1.1 This method covers the quantitative determination of asphalt cement in a bituminous paving mixture using a solvent and ultrasonic bath equipment.
- 1.2 The mineral fines content (smaller than 75 μm) is determined by the use of a high speed centrifuge on the extract and by the washing of the extracted aggregate. The remaining aggregate is used for sieve analysis.

2. APPARATUS

- 2.1 DRYING OVENS: Capable of maintaining the required temperature $\pm 5^{\circ}\text{C}$.
- 2.2 BALANCE: Minimum 3 kg capacity, accurate to 0.1 g.
- 2.3 BALANCE PAN.
- 2.4 SIEVES: Sieves with a minimum diameter of 200 mm. The sieves shall conform to ASTM Specification E 11.
- 2.5 THERMOMETER: Capable of reading from 20°C to 250°C , accurate to 2°C .
- 2.6 DRYING PANS: Flat seamless enamel, stainless steel, or aluminum pans with a minimum of 10 square mm horizontal surface area per gram of sample, shall be used for drying of the washed aggregate. Rectangular metal pans of nominal size 250 x 400 x 50 mm have been suitable for the determination of moisture content.
- 2.7 ULTRASONIC BATH: Ultrasonic cleaner unit certified for ordinary (non-hazardous) locations to the requirements of CAN/CSA C22.2 No. 68-92, Motor-Operated Appliances (Household and Commercial). The specification requires the unit to be marked "USE A CLEANING FLUID HAVING A FLASH POINT HIGHER THAN 60°C ".

Approximate ultrasonic unit tank capacity - 12 L, approximate internal dimensions - L 300 mm x W 240 mm x H 200 mm.

Note 1: Engineering methods to control hazardous conditions are required. For engineering controls (mechanical ventilation, process enclosure) data, refer to the solvent MSDS and contact your local Occupational Health and Safety Office for assistance.

- 2.8 EXTRACTION SAMPLE CONTAINER: Stainless steel beaker, 4000 ml capacity.

2.9 POSITIONING TRAY: Metal tray, with the edges formed to fit over the ultrasonic bath tank and the opening to support sample container. The container shall be suspended on the positioning tray with approximately half its height submerged in the water. The clearance between the sample container bottom and the bath tank bottom shall be not less than 25 mm.

2.10 SIEVES: 1.18 mm and 75 μ m sieves with a minimum diameter of 200 mm. The sieves shall conform to ASTM Specification E 11.

2.11 EXTRACT AND RINSEWATER CONTAINERS: Containers of sufficient diameter and capacity to capture all solvent and water rinses passing through the 1.18 mm and 75 μ m sieves and which will permit the quantitative transfer of the liquids to the high-speed centrifuge.

2.12 CENTRIFUGE: High- speed as described in ASTM D-2172.

2.13 EFFLUENT RECEIVERS: Separate containers for solvent and water effluent, each of approximately 2 L capacity.

2.14 GRADUATED CYLINDER: 1000 mL capacity, with graduated intervals of 10 mL.

2.15 MISCELLANEOUS ITEMS: Metal stirring spoon or spatula 250 mm minimum length, 1 L plastic wash bottles, stopwatch.

2.16 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.

3. REAGENTS

3.1 Non-chlorinated solvents with a flash point (by Tag Closed Cup) above 60°C (140°F). For health and safety precautions see Section 11, HEALTH AND SAFETY AND ENVIRONMENTAL REQUIREMENTS, and/or consult with your local Occupational Health and Safety Office.

4. SAMPLE SIZE

4.1 The size of the test sample shall be governed by the 'Designated Large Sieve' size of the mix (see Note 2) and shall conform to the requirements as shown in Table 1.

Table 1 - Size Of Test Sample

Designated Large Sieve Size, MTO Sieve Designation, mm	Minimum Mass Of Sample, kg
2.36	0.5
9.5	1.5
13.2	1.5
16.0	2.0

Note 2: The Designated Large Sieve is a sieve size specifically designated for gradation testing with the following mixes:

2.36 mm for HL 2;

9.5 mm for HL 1, HL 3, HL 3A, Dense Friction Course or Open Friction Course;

13.2 mm for HL 4 Binder or Surface Course;

16.0 mm for HL 8, Medium Duty Binder Course, or Heavy Duty Binder Course.

4.2 For moisture content, a minimum sample size of 1000 g is required for all types of paving mix.

5. SAMPLE PREPARATION

5.1 PLATE OR LOOSE PAVING MIXTURES: Obtain the samples in accordance with specified procedures and reduce to proper size. Two methods of reducing the field sample to testing size are acceptable: quartering or splitting using a mechanical splitter. Both procedures are specified in ASTM C 702 Standard Practice for Reducing Field Samples of Aggregate to Testing Size.

5.1.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A conventional oven maintained at 110°C or a microwave oven (see Note 3) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 4). The sample shall be mixed until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the test portion is obtained.

*Note 3: **Caution:** Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metallic particles in some mixtures may render the microwave oven unsafe for the heating of those mixtures.*

Note 4: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

5.1.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A conventional oven maintained at 110°C or a microwave oven (see Note 3 above) may be used for this purpose. The mix may agglomerate if it is too cold or stick to the splitter if too hot. A temperature range of 90 to 110°C is satisfactory. Heat lamps may be used to keep the walls of the splitter box warm (see Note 4 above). Chutes shall be cleaned after each split. The use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found suitable.

5.2 COMPACTED PAVING MIXTURES: When testing core samples for asphalt cement content and sieve analysis, the core shall be warmed just sufficiently to enable the trimming of the curved face to remove particles which were cut during the coring process. The depth trimmed shall be equivalent to the 'Designated Large Sieve' size for the particular mix type, except for HL 2 mix for which the depth trimmed shall be 4.75 mm. Dry the trimmed core to a constant mass to remove moisture (see Section 6.1).

6. TEST PROCEDURES

6.1 MOISTURE CONTENT DETERMINATION

6.1.1 In extraction test calculations, asphalt cement content is obtained by subtracting the extracted aggregate mass from the original mass of the test sample. If moisture is present in the original sample, it will appear as asphalt cement in the final calculation unless a correction is made. This is done by determining the amount of moisture in a 1000 g portion and adjusting the mass of the extraction test portion or, if time permits, heating the extraction test portion to a constant dry mass. The first method has the advantage that the two procedures can be run concurrently. Either method is acceptable.

6.1.2 Weigh the test portion obtained for moisture content determination and record the mass to 0.1 g. Place in an oven maintained at $110 \pm 5^{\circ}\text{C}$ and dry to a constant mass.

Note 5: Constant mass is defined as no change in mass in excess of 0.1 % or 1 g, whichever is less, for each 30 minute drying period.

6.1.3 Reweigh the test portion and calculate its moisture content rounding off to the nearest 0.01 % as follows:

$$\% \text{ Moisture Content, } (Z) = \frac{(Ma - Md)}{Md} \times 100$$

where: Ma = Original mass of mix, g

Md = Oven dry mass of mix, g

Adjust the original mass of the test sample used for extraction. If the method of drying the test sample is followed, then use the dried mass as the original mass in the subsequent calculations.

6.2 ASPHALT CEMENT EXTRACTION

6.2.1 Fill the ultrasonic bath with water. Add a few drops of liquid detergent to improve cavitation. Turn on the bath heater to preheat water to 50°C .

Note 6: Under ultrasonic power the solvent will heat up gradually. The solvent's flash point determines the range of the process' working temperature. The maximum bath temperature must be a minimum of 16.7°C (30°F) below the solvent's flash point. The temperature given in this test method is based on a minimum solvent flash point of 67°C .

6.2.2 Measure and record the mass of the original test portion to the nearest 0.1 g (W1). Use the work sheet report form (WS1) found at the end of this test method and dedicated for the Ontario LS-291 procedure.

6.2.3 Carefully transfer the mix from the balance pan into the steel beaker. Monitor the mix temperature and allow to cool below the solvent's flash point. Pour approximately 1 L of solvent over the warm mix [see Section 11, HEALTH AND SAFETY AND ENVIRONMENTAL and/or contact your local Occupational Health and Safety Office for specific requirements for the approved solvent(s)] to completely cover the sample (see Note 7). Wash any of the mix remaining in the balance pan or on the

thermometer into the steel beaker using the solvent. Stir the sample with the metal spoon to uniformly distribute and break up the mix; leave the spoon in the beaker.

Note 7: The quantities of solvent or water used in this procedure are based on a mix mass of 1 kg and a 4 L beaker (approximately 160 mm diameter) as a sample container. If a larger mix mass is required and/or alternative container is used, adjust the quantities of solvent or water to completely cover the sample.

6.2.4 Suspend the beaker on the positioning tray placed over the ultrasonic bath. Adjust the bath water level such that it is above the level of solvent covering the mix in the beaker. Allow the mix to soak in solvent a minimum of 1 hour at 50°C.

Note 8: For a virgin mix, 1 hour is sufficient. For a RAP or RHM mix, a minimum soaking period of 4 hours is required to break up agglomerations. In no case shall a mix be allowed to soak for more than 24 hours.

Note 9: A water bath at 50°C may be used in lieu of the ultrasonic bath for the soaking period as required by Section 6.2.4.

6.2.5 After the soaking period, turn on the ultrasonic bath for a 20 minute cycle.

6.2.6 Turn off the ultrasonic bath after the 20 minute cycle and stir the sample with the spoon/spatula for 15 seconds to reorient the aggregate particles.

Note 10: While the bath is on, avoid any contact with the liquid and containers through which ultrasonic vibrations are being transmitted. For more information on preventive measures for operating ultrasonic equipment see Section 11, HEALTH AND SAFETY AND ENVIRONMENTAL.

6.2.7 Turn the bath on for another 20 minute ultrasonic cycle.

6.2.8 Turn off the ultrasonic bath. Carefully decant the sample solvent through the 1.18 mm and 75 µm sieves into an extract container.

6.2.9 Add a small portion of new solvent to the sample, stir the sample and again decant through the sieves into the extract container. Repeat the procedure approximately six to eight times until the solvent extract is essentially colourless, using a total of approximately 1.5 L of solvent (see Note 7 above). The last decant should leave the aggregate drip dry.

6.2.10 Use new solvent to wash through the sieves any asphalt residue remaining on the metal spoon/spatula and the sieves. Replace the extract container under the sieves with a rinse water container. Save the solvent in the extract container for SMM centrifuging.

6.2.11 In order to wash the solvent off the aggregate, add approximately 0.3 L of water and 10 mL of wetting agent solution at 50°C (see Notes 6, 7, and 11) to the aggregate sample. Stir the sample, then carefully decant the sample rinse water through the sieves into the rinse water container.

Note 11: Wetting agent solutions may be pre-mixed at the rate of 50 g of Calgon or Alconox per L of water.

6.2.12 Repeat Section 6.2.11 three more times. The last decant should leave the aggregate drip dry.

6.3 WASHING OF EXTRACTED AGGREGATE

6.3.1 Transfer the aggregate from the sample beaker into a clean metal pan. Cover the aggregate with water and 100 mL of wetting agent solution (see Notes 11 and 12). The contents of the pan shall be agitated vigorously taking care not to splash out any material (see Note 13), and then the water shall be immediately decanted through the 1.18 mm and 75 μ m sieves into the rinse water container.

Note 12: It has been found advantageous to allow the first wash to soak for five minutes after the addition of the wetting agent solution and preliminary agitation.

Note 13: The agitation shall be sufficiently vigorous to completely separate particles finer than the 75 μ m from the coarse particles and bring them into suspension, in order that they may be removed by decanting the wash water. The use of a hand or the metal spoon/spatula to stir and agitate the aggregate in the wash water has been found to be satisfactory. Care shall be taken to prevent decanting the aggregate coarse particles.

6.3.2 Repeat Section 6.3.1 until the wash water is clear. The last decant should leave the bulk aggregate drip dry.

6.4 MINERAL FINES IN EXTRACT

6.4.1 Determine at 90 to 100°C the mass of two clean empty high-speed centrifuge cups to the nearest 0.1 g. Place one of the cups in the high-speed centrifuge.

6.4.2 Start the centrifuge and allow it to reach a constant operational speed (9000 r.p.m. minimum). Close the feed funnel control valve and place an effluent receiver at the effluent drain to collect solvent. Fill the feed funnel with solvent from the extract container. Open the control valve at the bottom of the funnel to allow a flow rate of 100 to 150 mL/min, using the graduated cylinder to measure the centrifuge effluent flow rate. Continue to top up the feed funnel until all the solvent has been centrifuged. Wash any fines remaining in the extract container into the feed funnel using a solvent filled wash bottle.

6.4.3 Replace the receiver filled with solvent at the effluent drain with another effluent receiver to collect rinse water. Fill the feed funnel with water from the rinse water container. Continue to top up the feed funnel until all the rinse water has been transferred. Wash any fines remaining in the rinse water container into the feed funnel using a water filled wash bottle.

6.4.4 Stop the centrifuge, remove the cup containing the mineral fines, and place the second cup in the centrifuge. Recentrifuge all of the solvent collected in the effluent receivers followed by recentrifuging of all rinse water collected in the effluent receivers. Wash any fines remaining in the solvent and rinse water effluent receivers through the feed funnel, using a water filled wash bottle.

Note 14: Solvent waste and rinse water waste may be kept in separate containers for storage and/or disposal.

6.5 DRYING OF EXTRACTED AGGREGATE

6.5.1 Mineral fines: Stop the centrifuge and remove the second cup. Dry both cups containing mineral fines to constant mass in a drying oven at $110 \pm 5^{\circ}\text{C}$. Record the mass of mineral fines to the nearest 0.1 ± 0.05 g (W4).

Note 15: To avoid damage to the balance and because dry aggregate absorbs moisture when exposed to air, determine the mass of the extracted aggregate immediately after cooling to 90 to 100°C .

6.5.2 Calculate mineral fines in extract as follows:

Dry mass of mineral fines in high speed centrifuge cups, (W4) = $M_{cf} - M_c$

where: M_{cf} = mass of cups plus fines, g
 M_c = mass of cups, g

6.5.3 Remaining aggregates: Invert the 1.18 mm sieve onto a clean metal pan. Strike the rim of the inverted sieve gently with the wooden handle of a sieve brush to dislodge particles from the sieve cloth and evenly distribute the pan aggregate over the entire horizontal area. Reverse flush the 1.18 mm and 75 μm sieves with water onto a second clean metal pan to capture any retained particles. Dry the pans in an oven (see Note 16) to constant mass (see Note 15 above) to the nearest 0.1 g (W3).

Note 16: The pan drying of the aggregate should be done in temperature stages to avoid fracturing aggregate particles (first at 110°C for a minimum of one half hour, then at 10°C above the boiling point of the solvent until constant mass has been achieved).

6.5.4 Calculate the mass of dried aggregate as follows:

Dry mass of extracted aggregate after washing, (W3) = $M_{ba} - M_b$

where: M_{ba} = mass of balance pan plus dried aggregate, g
 M_b = mass of balance pan, g

6.6 ASPHALT CEMENT CONTENT CALCULATION: Calculate the asphalt cement content in the test portion to two decimal places making use of work sheet (WS1) as follows:

6.6.1 If moisture is present in the mix and the sample has not been dried to constant mass to eliminate the moisture, adjust the original mass of the mixture for the test portion as follows:

Dry mass of test portion, (W2) = $\frac{W1}{100 + Z} \times 100$

where: $W1$ = mass of original test portion, g
 Z = moisture content, %

6.6.2 For the test portion calculate the total mass of dry aggregate as follows:

Total mass of extracted aggregates, (W5) = $W3 + W4$

where: $W3$ = dry mass of extracted aggregates after washing, g
 $W4$ = dry mass of fines in high speed centrifuge cup(s), g

6.6.3 The mass of the asphalt cement can be determined for the test portion as follows:

Mass of asphalt cement, $(W6) = W2 - W5$

where: $W2 =$ dry mass of test portion, g

$W5 =$ total mass of extracted aggregates, g

6.6.4 The asphalt cement content expressed as a percentage of the moisture free mix is calculated as follows:

% Asphalt cement content, $(W7) = \frac{W6}{W2} \times 100$

where: $W6 =$ mass of asphalt cement, g

$W2 =$ dry mass of test portion, g

6.7 GRADATION OF THE AGGREGATE

6.7.1 Sieve analysis: Transfer cooled aggregate into the nest of coarse and fine sieves (see Note 17). Agitate on a mechanical shaker. A satisfactory end of sieving is considered to have been reached when an additional 1 minute of sieving by hand fails to change the mass on any sieve by more than 1 %. This is usually about twelve minutes. On completion of the sieving operation, separate the sieves. Each sieve shall be placed within a round stainless steel bowl and shaken manually, checking to see if additional material passes through. Any additional material should be transferred to the next smaller sieve size. When emptying the sieves, gently strike the rim of the inverted sieve with the wooden handle of the sieve brush. This helps to dislodge aggregate particles from the cloth. Individual particles stuck in coarser sieves may also require help. Following this, brush the bottom surface of the sieve cloth with a circular motion. In no case should the particles be turned or manipulated through the sieves by hand. Weigh and record cumulatively (e.g. each successive size is to be added to the previous total) on the appropriate work sheet, the mass of the fraction retained on each sieve.

Note 17: The transfer may require splitting the cooled aggregate into two approximately equal portions for sieving to prevent sieve overloading, and then recombining results on each of the sieve sizes to obtain the correct gradation.

6.7.2 Calculation of aggregate fractions: Calculate the percent passing on each sieve in the test portion as follows:

% passing on "x" sieve $= 100 - \frac{Wx \times 100}{W5}$

where: $Wx =$ cumulative mass retained on that sieve, g

$W5 =$ total mass of extracted aggregates, g

7. EXAMPLE CALCULATION

7.1 MOISTURE CONTENT

7.1.1 Percent moisture in the sample:

Mass of sample plus moisture (M_a) 1000.3 g

Mass of dried sample (M_d) 998.1 g

$$\% \text{ Moisture (Z)} = \frac{(1000.3 - 998.1)}{998.1} \times 100 = 0.22$$

7.1.2 Adjust original mass of test portion

Original mass of test portion (W1) 1020.4 g

$$\text{Dry mass of test portion (W2)} \quad (W2) = \frac{1020.4}{(100 + 0.22)} \times 100 = 1018.2 \text{ g}$$

7.2 ASPHALT CEMENT CONTENT

i) Dry mass of test portion (W2), 1018.2 g

ii) Dry mass of aggregate:

Dry mass of aggregate plus pan (Mba) 1160.8 g

Mass of pan (Mb) - 200.0 g

Dry mass of aggregate (W3) 960.8 g

iii) Dry mass of mineral fines in extract:

Dry mass of cup and fines after centrifuge (Mcf) 143.1 g

Mass of cup (Mc) - 141.1 g

Dry mass of mineral fines (W4) 2.0 g

iv) Total dry mass of aggregate:

Dry mass of aggregate (W3) 960.8 g

Dry mass of mineral fines (W4) + 2.0 g

Total dry mass of aggregate including fines (W5) 962.8 g

v) Mass of asphalt cement

Dry mass of test portion (W2) 1018.2 g

Dry mass of aggregate including fines (W5) - 962.8 g

Mass of asphalt cement (W6) 55.4 g

$$\% \text{ asphalt cement, } (W7) = \frac{55.4}{1018.2} \times 100 = 5.44$$

7.3 AGGREGATE FRACTIONS

Total mass of aggregate (W5) 962.8 g

Cumulative mass retained on 9.5 mm sieve 213.3 g

$$\% \text{ passing 9.5 mm sieve} = (100 - \frac{213.3}{962.8}) \times 100 \quad 77.8$$

Cumulative mass retained on 600 µm sieve 689.8 g

$$\% \text{ passing 600 µm sieve} = (100 - \frac{689.8}{962.8}) \times 100 \quad 28.4$$

7.4 SWING BACK GRADING (Optional): This is the grading of the coarse or fine aggregate when either fraction is considered to be the total sample.

For fine aggregate the calculation is as follows:

The percent passing the 4.75 mm sieve in the total grading, divided into the percent passing each subsequent sieve and the result multiplied by 100 will give the fine aggregate gradation expressed as a percent passing each sieve.

Example:

Given for the full gradation:

% passing the 4.75 mm sieve is 52.1

% passing the 2.36 mm sieve is 40.9

% passing the 1.18 mm sieve is 33.0

then for the fine gradation:

$$\% \text{ passing the 2.36 mm sieve} = \frac{40.9}{52.1} \times 100 = 78.5$$

$$\% \text{ passing the 1.18 mm sieve} = \frac{33.0}{52.1} \times 100 = 63.3$$

To "swing back" the grading of the coarse aggregate fraction of the extracted aggregate, the following procedure is used:

The percent retained on the 4.75 mm sieve in the total grading, is divided into the percent retained on each of the coarse aggregate sieves in the total gradation and the result is multiplied by 100, to give the coarse aggregate grading expressed as the percent retained on each sieve.

Example:

Given for the full gradation:

% passing the 13.2 mm sieve is 92.5

% passing the 9.5 mm sieve is 75.4

% passing the 4.75 mm sieve is 52.4

then for the coarse gradation:

$$\% \text{ ret'd on the 13.2 mm sieve} = \frac{(100 - 92.5)}{(100 - 52.4)} \times 100 = 15.8$$

$$\% \text{ ret'd on the 9.5 mm sieve} = \frac{(100 - 75.4)}{(100 - 52.4)} \times 100 = 51.7$$

8. REPORTING OF RESULTS

8.1 The asphalt cement content shall be reported as a percentage of the total mass of the mix to two decimal places.

8.2 For the aggregates, the cumulative mass and the cumulative percentages passing each sieve shall be reported to one decimal place.

8.3 The swing back grading, when required, shall be recorded as a percentage retained or passing for each sieve, accurate to one decimal place, and shall be reported as described in Section 7.4.

9. GENERAL NOTES

- 9.1 When testing Cold Mix such as SC 800, the sample must be dried at $110 \pm 5^{\circ}\text{C}$ to a constant mass to remove all solvents before testing.
- 9.2 Samples are weighed while still warm to avoid absorption of moisture. In order to avoid undue variation in this process it is recommended that on removal from the drying oven all samples be weighed at 90 to 100°C .
- 9.3 Extreme care must be exercised when transferring the aggregates from one container to another to avoid any loss of the particles.
- 9.4 Prior to using, check each sieve for the condition of the mesh, the soldered edges and the nest for correct order of descending sizes.
- 9.5 All balances should be calibrated at least once a year, at the start of the construction season. When the operator questions the accuracy/condition of the balance, it should be re-calibrated and/or inspected immediately.
- 9.6 Several important factors affect the operation of ultrasonic bath. In order to achieve the best results while extracting asphalt using ultrasonic cavitation the following should be considered:
- a) any weight on the tank bottom dampens sound energy and may cause damage to the transducer. Do not place any objects on the tank bottom. Always use a positioning tray to support the sample container.
 - b) closely monitor the time and temperature of the solvent during the extraction cycle by using ultrasonic bath controls backed by external thermometer and a stopwatch.
 - c) follow general rules of operating the ultrasonic bath as described in the operator's manual.
- 9.7 All equipment and testing for LS-291 including MINERAL FINES IN EXTRACT (Section 6.4) shall be located in one laboratory building only.

10. PRECISION AND BIAS

- 10.1 The statements of precision for asphalt cement content and aggregate sieve analysis have not been established yet. To determine precision and bias statements for single-operator and multilaboratory precision for the test method, a correlation program will be carried out.

11. GENERAL HEALTH AND SAFETY AND ENVIRONMENTAL REQUIREMENTS

The following are a number of general health, safety, and environmental requirements to be followed when conducting this method. Specific requirements for the approved reagent(s) can be obtained from your local Occupational Health and Safety Office.

- 11.1 TRAINING: Prior to conducting work, all employees must receive training on the hazards associated with the method and the solvent being used. This training should include: instruction on safe handling, storage, use, disposal and transport of the solvent; the required control measures (i.e. local

exhaust ventilation, personal protective equipment and devices etc.); and safe operating, handling and spill response procedures.

In addition, all employees must have WHMIS (Workplace Hazardous Materials Information System) training.

It is also recommended that all employees working in the laboratory receive first aid training.

11.2 WHMIS: A current MSDS (Material Safety Data Sheet) for the solvent being used must be maintained in the workplace in a location accessible to all employees. Employees should refer to the MSDS for specific information on the solvent.

All containers must be labelled with a supplier label or a workplace label if decanted from the original supplier container.

11.3 CONTROL MEASURES: In most cases the solvent should be used under local exhaust ventilation to control for potential exposure to the vapours and fire hazards. Information regarding the minimum recommended level of local exhaust ventilation specific to the solvent being used can be obtained from your local Occupational Health and Safety Office.

In most cases the personal protective equipment and devices required are specific to the solvent being used. Information regarding them can be obtained from your local Occupational Health and Safety Office. In all cases approved eye safety goggles should be worn when there is a danger of solvent splashing.

Eating or drinking is not allowed in the working area of the laboratory.

11.4 FIRE SAFETY: If the solvent is flammable or combustible the local Occupational Health and Safety Office and Fire Chief should be consulted where necessary to ensure the correct fire protection controls and facilities are in place.

11.5 ULTRASOUND SAFETY: The ultrasonic bath is a high power device that produces vibrations at a frequency above the audible range (i.e. the frequency of the vibration is too high to hear). The ultrasonic bath should not be touched while it is operating. There are risks associated with immersing fingers or hands in the bath, or handling objects that transmit ultrasound with wet or greasy hands. The known adverse health effects include dermatitis (i.e. skin irritation), and localized skin damage that resembles bruises. These effects are reversible.

11.6 TDGA: The transportation of some solvents and the waste generated from their use in asphalt extraction testing procedures, may be regulated under the Transportation of Dangerous Goods Act and Regulations due to their flammability or poisonous nature. Information can be obtained from your Regional Environmental Planner–Waste Management.

11.7 WASTE MANAGEMENT AND DISPOSAL: Waste solvents generated from asphalt extraction testing procedures will be classified as either hazardous or liquid industrial waste. They will require special management for disposal subject to Regulation 347 of the Environmental Protection Act which

may include a Certificate of Approval for waste management from MOEE, generator registration with MOEE, manifesting during transport and driver training for transport.

11.8 SPILLS: Spills of solvents and waste indoors must be contained and cleaned up in a healthy and safe manner. Spills to the natural environment during transfer may require certain notifications to be made as well as containment and clean up.

ONTARIO EXTRACTION TEST - WORK SHEET (WS1)
Hot Mix - Acceptance Test Result for Gradation and Asphalt Cement

Contract No.:		Highway No.:		Lot No.:	Sublot No.:	Date Sampled:		
						YR	MM	DD
Item No.:	Mix Type:		Job Mix Formula No.:			Date Tested:		
						YR	MM	DD

Note: All mass measurements below are to the accuracy requirements of MTO method LS - 291

MOISTURE CONTENT BY LS - 291 FOR EXTRACTION (WS1)	
Option #1 Determine amount of moisture in original test portion (W1) by drying to constant mass. W2 = M3 Option #2 Determine amount of moisture in a 1000 g portion by drying to constant mass and adjusting original test portion (W1).	$Z = \frac{(M1 - M2) - M3}{M3} \times 100$ $W2 = \frac{W1}{100 + Z} \times 100$

MOISTURE CONTENT			
Drying to Constant Mass	Option 1	Option 2	
Sample Mass with Moisture + Pan			M1
Mass at 30 min.			
Mass at 60 min.			
Mass at 90 min.			
Mass at 120 min.			
Mass at min.*			
Mass of Pan			M2
Constant Mass - Mass of Pan			M3

*Continue process until constant mass is obtained.

EXTRACTION (to nearest 0.1 g)		
Mass of original test portion (with moisture)		W1
Dry mass of test portion		W2
Dry mass of extracted aggregates after washing		W3
Dry mass of fines in high speed centrifuge cup(s)		W4
Total mass of extracted aggregates, [W3 + W4]		W5
Mass of asphalt cement, [W2 - W5]		W6
Asphalt cement, (to 0.01%) % = [(W6 / W2) x 100]		W7

WASHED SIEVE ANALYSIS														
Designated Sieve	26.5	19.0	16.0	13.2	9.5	4.75	2.36	1.18	600	300	150	75	Pan	
Cumulative Mass Retained, Wx														
% Passing 100 - (Wx / W5 x 100)														
% Swingback See LS-291														

Remarks: _____

METHOD OF TEST FOR QUANTITATIVE DETERMINATION OF ASPHALT CEMENT CONTENT BY IGNITION AND ANALYSIS OF REMAINING AGGREGATE FROM BITUMINOUS PAVING MIXTURES

1. SCOPE

1.1 This method covers the quantitative determination of asphalt cement in a bituminous paving mixture by ignition in a furnace. The method requires that the furnace be calibrated using original construction materials which are blended proportionally, in the laboratory to duplicate the paving mixture.

1.2 The gradation of the aggregate is determined by sieve analysis of the residual aggregate after washing to remove fines smaller than 75 μm .

2. RELEVANT DOCUMENTS

2.1 LS 282 and LS 291

2.2 ASTM D 6307-98

2.3 Furnace manufacturer's instruction manual

3. PROCEDURE

3.1 Provisional Test Methods for Asphalt Content of Hot Mix Asphalt by the Ignition Method (ASTM D 6307-98) shall be followed, except as noted below.

4. EXCEPTIONS TO PROCEDURE

4.1 APPARATUS

4.1.1 **FURNACE: that heats the sample by either the convection method or direct irradiation method. The convection type furnace shall have a minimum temperature capability of 580°C. For the direct irradiation type furnace, follow the operating instructions provided by the device manufacturer; including the setup of the burn profile for the type of Hot Mix Asphalt (HMA) being tested. The furnace chamber shall have an internal weighing system capable of measuring the mass of sample sizes of at least 2500 g. The furnace chamber shall be of sufficient size to accommodate sample sizes of at least 2500 g. A data collection system shall also be included so that the sample mass loss can be automatically determined to an accuracy of 0.1 g and displayed during a test. The equipment shall be capable of varying the test end point from 0.1 g to 1.0 g on a sample size of 1500 g (0.007% to 0.07% on 1500 g). After the testing end point criteria are met, the furnace shall be capable of alerting the operator and/or turning off the furnace heating elements. A system capable of reducing furnace emissions to a level meeting or exceeding all Health and Safety and environmental**

standards, shall also be incorporated in the furnace. The furnace shall be vented into a hood or to the atmosphere and when set up properly will have no noticeable odours escaping into the laboratory. The furnace will have a fan with capability to pull air through the furnace to expedite the test and to reduce escape of smoke into the laboratory. The furnace shall be equipped so that the door cannot be opened during the ignition test.

4.1.2 BALANCE: 3 kg capacity, accurate to 0.1 g.

4.1.3 DRYING PANS: Seamless enamel, stainless steel, or aluminum pans with a minimum of 10 square mm horizontal surface area per gram of sample, shall be used for drying the washed aggregate. (Rectangular metal pans of nominal size 250 x 400 x 50 mm have been found suitable for the determination of moisture content.)

4.1.4 RIFFLE SPLITTER: For splitting hot mix samples. Recommended width of the individual chutes is approximately 38 mm for all types of paving mix.

4.2 FURNACE CALIBRATION

4.2.1 A "calibration factor_{lab mix}" is the difference between an ignition furnace test result produced using raw materials which are blended in the laboratory, in accordance with the job mix formula (JMF) requirements *and* the asphalt content percent required by the JMF where:

$$\text{calibration factor}_{\text{lab mix}} = \text{ignition result}_{\text{using JMF \%AC}} - \%AC_{\text{JMF}}.$$

4.2.2 The furnace end point shall be set to 1.0 g for all sample sizes (0.2% by mass at 500 g sample size; 0.07% at 1500 g; 0.05% at 2000 g). The test shall be deemed to be complete when the difference between measured loss for three consecutive one-minute intervals does not exceed 1.0 g of the sample mass. The equipment shall provide a printout of the test data and results.

4.2.3 For a convection type furnace the testing temperature chosen shall be the highest of 430°C, 480°C or 540°C providing that individual "calibration factors_{lab mix}" are less than 1.0%. For a direct irradiation type furnace, follow the operating instructions provided by the device manufacturer; including setup of the burn profile for the type of mix being tested, providing that individual "calibration factors_{lab mix}" are less than 1.0%. To optimize accuracy, a "mean calibration factor_{lab mix}" must be obtained for each mix type. The "mean calibration factor_{lab mix}" shall be the average of three "calibration factors_{lab mix}" where the range for the three tests is less than or equal to 0.15%. If the range is greater than 0.15%, another two tests shall be done, and from the five tests, the highest and lowest results shall be discarded and the remaining three "calibration factors_{lab mix}" averaged. This procedure must be performed before any quality control, acceptance, or referee testing is completed.

4.3 PREPARATION OF SAMPLE

4.3.1 Use a sample obtained according to approved methods. Large field samples shall be reduced to the appropriate size for testing. Plate or loose mix samples shall be reduced to proper size. Two

methods of reducing the field sample to the testing size are acceptable: quartering or splitting using a riffle splitter.

4.3.1.1 Quartering: Warm the field sample to achieve sufficient workability for quartering. A conventional oven maintained at 110°C or a microwave oven (see Note 1) may be used for this purpose. The surface upon which the sample is to be reduced should be flat, non-abrasive, non-absorptive, and of sufficient area to provide for uniform quartering. Heat lamps may be used to keep the surface warm (see Note 2). The sample shall be mixed on the surface until uniform, then quartered, and opposite quarters removed. This process is to be repeated until the testing size is obtained.

*Note 1: **Caution:** Frequent mixing may be necessary to prevent localized overheating when using a microwave oven to heat paving mixtures. Also, the presence of metallic particles in some mixtures may render the microwave oven unsafe for the heating of these mixtures.*

Note 2: If required, 'Pam' or equivalent used in minimal quantities has been found suitable in preventing the sample from adhering to the surface. Motor oils must not be used for this purpose.

4.3.1.2 Riffle Splitter: Warm the field sample to achieve sufficient workability for splitting. A conventional oven maintained at 110°C or a microwave oven (see Note 1 above) may be used for this purpose. The mix may agglomerate if it is too cold, or stick to the splitter if too hot. A temperature range of 90°C to 110°C has been found to be generally satisfactory. Heat lamps may be used to keep the walls of the splitter box warm (see Note 2 above). Chutes shall be cleaned after each split. The use of a putty knife or a 25 mm diameter wire brush used to clean glassware has been found suitable.

4.3.2 When testing core samples for asphalt cement content and sieve analysis, the core shall be warmed just sufficiently to enable the trimming of the curved surface to remove particles which were cut during the coring process. The depth trimmed shall be equivalent to the 'Designated Large Sieve' size for the particular mix type, except for HL 2 mix for which the depth trimmed shall be approximately 4.75 mm. Dry the trimmed core to constant mass (see Section 4.4) to remove moisture.

4.3.3 A single test portion shall be used to determine the asphalt cement content. The sample size for testing is governed by the 'Designated Large Sieve' size of the mix (see Note 3) and shall conform to the requirements as shown in Table 1.

Table 1 - Size Of Test Sample

Designated Large Sieve Size, MTO Sieve Designation, mm	Minimum Mass Of Sample, kg
2.36	0.5
9.5	1.5
13.2	1.5
16.0	2.0

Note 3: The Designated Large Sieve is a sieve size specifically designated for the following mixes for gradation testing:

2.36 mm for HL 2;

9.5 mm for HL 1, HL 3, HL 3A, Dense Friction Course or Open Friction Course;

13.2 mm for HL 4 Binder or Surface Course;

16.0 mm for HL 8, Medium Duty Binder Course, or Heavy Duty Binder Course.

The gradation analysis shall be performed on the total test portion (see Section 4.7).

4.3.4 When splitting off a sample for determination of moisture content, a minimum sample size of 1000 g is required for all types of paving mix.

4.4 DETERMINATION OF MOISTURE CONTENT

4.4.1 If moisture is present in a sample, it will appear as asphalt cement after ignition testing and internal furnace software calculations are completed, unless a correction is made. This is done by determining the amount of moisture in a 1000 g portion and:

a) adjusting the asphalt cement content percent after ignition testing, or, if the percent moisture is known,

b) adjusting the mean calibration factor before ignition testing.

The first approach has the advantage that the two procedures can be run concurrently. Either way is acceptable.

The weighing and recording of the masses for both the moisture content determination and the ignition tests must be done at the same time - immediately before testing for ignition. In either case, weigh the test portion to be used and record the mass to 0.1 g. Place the test portion for moisture determination in an oven maintained at $110 \pm 5^{\circ}\text{C}$ and dry to constant mass.

Note 4: Constant mass is defined as no change in mass in excess of 0.1% or 1 g, whichever is less, for each 30 minute drying period.

4.4.2 Reweigh the test portion and calculate its moisture content rounding off to the nearest 0.01% as follows:

$$\% \text{ Moisture Content, (Z)} = \frac{(M_a - M_d)}{M_d} \times 100$$

where: M_a = Original mass of mix, g

M_d = Mass of oven dry mix, g

4.5 IGNITION PROCEDURE

4.5.1 **For the convection type** furnace, testing temperatures shall be one of $430 \pm 5^{\circ}\text{C}$, $480 \pm 5^{\circ}\text{C}$, or $540 \pm 5^{\circ}\text{C}$ as determined by Furnace Calibration (Section 4.2). **For the direct irradiation type furnace the burn profile for testing HMA samples shall be the same burn profile selected for testing mixture calibration samples (Section 4.2).**

4.5.2 The **convection furnace temperature or direct irradiation furnace burn profile** used for quality control, acceptance, or referee testing must be the same as that at which the "mean calibration factor_{lab mix}" is determined.

4.5.3 After loading the test portion into the furnace and during test initiation procedures, input the testing mass into the furnace software. Also input the mean calibration factor into the furnace software as given below.

4.5.3.1 For dry field samples, input the "mean calibration factor_{lab mix}" into the furnace software.

4.5.3.2 If a) of Section 4.4.1 is used, input the "mean calibration factor_{lab mix}" into the furnace software.

4.5.3.3 If b) of Section 4.4.1 is used, input the "mean calibration factor_{field mix}" into the furnace software where:

$$\text{Mean Calibration Factor}_{\text{field mix}} = \text{Mean Calibration Factor}_{\text{lab mix}} + \% \text{ Moisture Content}$$

Because of percent moisture content, this "mean calibration factor_{field mix}" may be greater than 1.0%.

4.6 ASPHALT CEMENT CONTENT CALCULATION

Calculate the asphalt cement content in the test portion to two decimal places making use of worksheets.

4.6.1 If the ignition furnace test sample is dry, the ignition furnace result will be the % AC_{correct}.

4.6.2 If a) of Section 4.4.1 was used, adjust the asphalt cement content for the test portion as follows:

$$\% \text{ AC}_{\text{correct}} = \% \text{ AC}_{\text{by ignition}} - \% \text{ Moisture}$$

4.6.3 If b) of Section 4.4.1 was used, the ignition furnace result will be the % AC_{correct}.

4.7 ANALYSIS OF RESIDUAL REMAINING AGGREGATE

4.7.1 **WASHING OF AGGREGATE:** After the mass (W_3) of the test portion of dried aggregate has been determined, return the sample to the drying pan and cover the sample with water. Add a sufficient amount of wetting agent (see Note 5) to ensure a thorough separation of materials finer than 75 μm from the coarser particles. The contents of the container shall be agitated vigorously taking care not to splash out any material, and then the wash water shall be immediately decanted over the nest of two sieves consisting of a 1.18 mm sieve superimposed on a 75 μm sieve. The use of a hand, a metal spoon or a spatula to stir and agitate the aggregate in the wash water has been found to be satisfactory (see Note 6).

Note 5: Wetting agents such as Calgon or Alconox may be pre-mixed with water at 50 g/L. 100 ml of this solution is then added to the first wash of each test. It has been found advantageous to allow the first wash to soak for five minutes after the addition of the wetting agent and preliminary agitation.

Note 6: The agitation shall be sufficiently vigorous to completely separate the particles finer than 75 μm from the coarser particles and bring them into suspension, in order that they may be removed by

decanting the wash water. Care shall be taken to avoid, as much as possible, decanting of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

4.7.2 Return all the material retained on the nested sieves by flushing into the washed sample in the drying pan. The washed aggregate shall be dried to a constant mass at a temperature of $110 \pm 5^{\circ}\text{C}$ and the mass determined to the nearest 0.1 g (W_7) (see Note 4 above).

4.7.3 SIEVE ANALYSIS: Transfer cooled aggregate into the nest of coarse and fine sieves. Agitate on a mechanical sieve shaker. A satisfactory end point in sieving is considered to have been reached when an additional 1 minute of sieving by hand fails to change the mass on any sieve by more than 1%. This is usually about twelve minutes. On completion of the sieving operation, separate the sieves. Each sieve shall be placed within a round stainless steel bowl and shaken manually, checking to see if additional material passes through. Any additional material should be transferred to the next smaller sieve size. When emptying the sieves, gently strike the rim of the inverted sieve with the wooden handle of the sieve brush. This helps to dislodge aggregate particles from the cloth. Individual particles stuck in coarser sieves may also require help. Following this, brush the bottom surface of the sieve cloth with a circular motion. In no case shall the particles be turned or manipulated through the sieve by hand. Weigh and record cumulatively (e.g. each successive size is to be added to the previous total) on the appropriate work sheet, the mass of the fraction retained on each sieve.

4.7.4 CALCULATION OF AGGREGATE FRACTIONS: Calculate the percent passing on each sieve in the test portion as follows:

$$\% \text{ passing on sieve } x = 100 - \frac{W_x \times 100}{W_3}$$

where W_x = cumulative mass retained on that sieve

W_3 = total mass of dry aggregate

5. EXAMPLE CALCULATIONS

5.1 MOISTURE CONTENT:

Percent moisture in sample of mix:

Mass of sample plus moisture (M_a)	1000.3 g	
Mass of dried sample (M_d)	998.1 g	
% Moisture (Z)	$= \frac{1000.3 - 998.1}{998.1} \times 100$	= 0.22 %

5.2 ASPHALT CEMENT CONTENT:

i) If the field sample used for ignition is dry, the % $AC_{\text{by ignition}}$ (the final value on ignition tape) will be correct.

ii) If a) of Section 4.4.1 is used, and % $AC_{\text{by ignition}}$ (the final value on ignition tape) = 5.66%,

$$\begin{aligned} \% AC_{\text{correct}} &= \% AC_{\text{by ignition}} - \% \text{ Moisture} \\ &= 5.66\% - 0.22\% \end{aligned}$$

$$= 5.44\%$$

iii) if b) of Section 4.4.1 is used, the % AC_{by ignition} (on tape) = % AC_{correct}.

5.3 AGGREGATE FRACTIONS:

$$\begin{aligned}\text{Total dry mass of aggregate (W}_6\text{)} &= 962.8 \text{ g} \\ \text{\% passing 9.5 mm sieve} &= 100 - \frac{213.3}{962.8} \times 100 = 77.8 \\ \text{\% passing 600 } \mu\text{m sieve} &= 100 - \frac{689.4}{962.8} \times 100 = 28.4\end{aligned}$$

5.4 SWING BACK GRADING (Optional): This is the grading of the coarse aggregate (plus 4.75 mm sieve fraction) when either fraction is considered to be the total sample. For the fine aggregate the calculation is as follows:

5.4.1 The percent passing the 4.75 mm sieve in the total grading, divided into the percent passing each subsequent sieve and the result multiplied by 100, will give the fine aggregate gradation expressed as a percent passing each sieve.

5.4.2 Example:

Given for the full gradation:

$$\begin{aligned}\text{\% passing the 4.75 mm sieve} &\text{ is } 52.1 \\ \text{\% passing the 2.36 mm sieve} &\text{ is } 40.9 \\ \text{\% passing the 1.18 mm sieve} &\text{ is } 33.0\end{aligned}$$

then for the fine gradation:

$$\begin{aligned}\text{\% passing the 2.36 mm sieve} &= \frac{40.9}{52.1} \times 100 = 78.5 \\ \text{\% passing the 1.18 mm sieve} &= \frac{33.0}{52.1} \times 100 = 63.3\end{aligned}$$

5.4.3 To "swing back" the grading of the coarse aggregate fraction of the extracted aggregate, the following procedure is used. The percent retained on the 4.75 mm sieve in the total grading, is divided into the percent retained on each of the coarse aggregate sieves in the total gradation and the result is multiplied by 100, to give the coarse aggregate grading expressed as the percent retained on each sieve.

5.4.4 Example:

Given for the full gradation:

$$\begin{aligned}\text{\% passing the 13.2 mm sieve} &\text{ is } 92.5 \\ \text{\% passing the 9.5 mm sieve} &\text{ is } 75.4 \\ \text{\% passing the 4.75 mm sieve} &\text{ is } 52.4\end{aligned}$$

then for the coarse gradation

$$\begin{aligned}\text{\% ret'd on the 13.2 mm sieve} &= \frac{100-92.5}{100-52.4} \times 100 = 15.8 \\ \text{\% ret'd on the 9.4 mm sieve} &= \frac{100-75.4}{100-52.4} \times 100 = 51.7\end{aligned}$$

6. REPORTING OF RESULTS

6.1 The report shall include the following:

6.1.1 Identification of aggregate and mix type and job mix formula,

6.1.2 Calibration temperature **for a convection furnace, or the burn profile setting for a direct irradiation furnace** and data using original materials and including mean calibration factor_{lab mix},

6.1.3 Testing date, laboratory log test number, physical condition of test sample,

6.1.4 Under which subsection of Section 4.5.3 testing was done; and the percent moisture determination if it was used,

6.1.5 Internal mass of test sample (nearest 0.1 g) before and after testing (via tape),

6.1.6 Ignition furnace end point setting of tests (1.0 g or 0.2% by mass @ 500 g sample size; 1.0 g or 0.07% @ 1500 g; 1.0 g or 0.05% @ 2000 g),

6.1.7 One test sample result measuring asphalt content (nearest 0.01%) along with test data,

6.1.8 The cumulative mass and the cumulative percentages passing for each sieve shall be reported to one decimal place. As well, the cumulative percentage may be recorded as a graph on the appropriate semi-log grading chart.

6.2 Where the residual aggregate sample requires splitting after ignition to determine gradation and two tests are carried out, the cumulative mass and the cumulative percentages passing each sieve shall be calculated as follows:

Example:

	<u>Portion A</u>	<u>Portion B</u>
Total Dry mass of Aggregate (W ₆)	962.7 g	968.3 g
Cumulative Dry Mass on 9.5 mm Sieve	213.3 g	214.4 g
$\% \text{ Passing the 9.5 mm Sieve} = 100 - \frac{213.3 + 214.4}{962.7 + 968.3} \times 100$		
$= 79.0$		

7. GENERAL NOTES

7.1 Aggregates in the pans are weighed while still warm to avoid absorption of moisture. In order to avoid undue variation in this process it is recommended that all samples be weighed at 90°C or higher on removal from the drying oven.

7.2 Extreme care must be exercised when transferring aggregates from one container to another to avoid any loss of particles.

7.3 Prior to using, check each sieve for the condition of the mesh, the soldered edges, and that the sieve nest is assembled as required in descending sizes.

7.4 All balances or load cells should be calibrated at the start of the construction season. When an operator questions the accuracy/condition of the balance, it should be recalibrated and/or inspected immediately.

7.5 All equipment and testing for LS-292 shall be located in one laboratory building only.

7.6 In Northern Ontario, gneiss/ migmatite aggregate was found to physically breakdown when burned in an ignition furnace. Aggregate gradations changed appreciably after burning, however no aggregate loss or burnoff occurred. The larger size aggregate would crumble when squeezed by hand. Aggregate gradation corrections could not be performed since the intensity of sieving determined the extent of aggregate breakdown. Lowering the burn temperature to the minimum specified in this LS did not correct the breakdown problem. Therefore for asphalt containing this type of aggregate, it is not possible to use the ignition oven for the determination of gradation from bituminous paving mixtures. The ignition furnace can still be used to determine the AC content.

8.0 Within Laboratory Precision

In a study involving 93 different laboratories, testing two specimens of two materials, the following statistical variations were obtained;

For AC%, Sample 1 Mean AC 5.10%, Std. Dev. 0.09

Sample 2 Mean AC 5.09%, Std. Dev. 0.10

Therefore when two laboratories test samples of the same material, the difference between the results should not exceed 0.283%, nineteen times in twenty.

METHOD OF TEST FOR CORRELATING PROFILE MEASURING DEVICES AND CONDUCTING SURFACE SMOOTHNESS MEASUREMENTS

1. SCOPE

1.1 This procedure covers the method which is used for approving Profile Measuring Devices (i.e. California profilographs) and for conducting surface smoothness measurements on Ministry contracts.

2. RELEVANT DOCUMENTS

2.1 ASTM E 1274 – Standard Test Method for Measuring Pavement Roughness Using a Profilograph.

2.2 MTO Method LS-101 – Method for Rounding-Off Test Data and Other Numbers.

3. DEFINITIONS

3.1 BLANKING BAND is a band of uniform height "B" in mm (0 mm for asphaltic concrete and 5 mm for concrete pavements) with a length equal to the subplot length, which is optimally positioned between the highs and the lows of the profile trace to "blank out" as much of the profile trace as possible.

3.2 The CORRELATION SITE is a location established by the Ministry to conduct PMD correlations.

3.3 A DATA FILTER FACTOR is an input parameter which is used to electronically modify the surface trace (2.0 for Ministry work).

3.3 PROFILE INDEX is the rate of smoothness averaged over both wheelpaths for any given subplot of surface course or a section of pavement.

3.4 An ODOMETER is a device for measuring longitudinal distance along a profile.

3.5 A PROFILE MEASURING DEVICE (PMD) is a device used for measuring the surface smoothness of a pavement.

3.6 RATE OF SMOOTHNESS is calculated by adding up all of the amplitudes for the individual bumps and depressions outside of a blanking band with heights which are greater than 0.8 mm and which also extend at least 0.6 m, as measured by a PMD along the profile length and then dividing that number by the subplot length or the length of any given pavement section; expressed in mm/km.

3.7 REDUCTION LENGTH is an input parameter equal to the subplot length (normally set at 100 m).

3.8 A SUBLOT is a continuous traffic lane of pavement; including partially-paved shoulder [up to 0.5 m in width, if present; which has been measured by PMD for purposes of repairs/price adjustments (normally 100 m in length).

3.9 A SCALLOP is a bump or depression in the pavement surface, which is at least "S" mm high (i.e. a bump height "S" of 10 mm will be the upper limit for acceptability for asphaltic concrete and concrete surface and an "S" of 15 mm for concrete base) above or below a 7.5 m long baseline (i.e. bump width) which is constantly changing in elevation due to the surrounding pavement.

4. APPARATUS

4.1 PROFILE MEASURING DEVICE

4.1.1 Hardware

All California Profilographs must conform to the requirements of ASTM E1274 for devices "With Non-Uniformly Spaced Wheels". A schematic diagram for a typical profilograph manufactured by McCracken Concrete Pipe Machinery Company is shown in Figure 1. Similar devices are also made by Cox Bros.

4.1.2 Software

The PMD's on-board computer must be programmed to read in metric units with all "bumps" used to determine profile index rounded to the nearest 0.2 mm (i.e. rate of smoothness to the nearest 2 mm/km) or better.

4.1.3 Profile Trace

All PMD's must be able to print a profile trace at the end of each 100 m subplot. The trace must have a 1:1 vertical scale and 1:300 longitudinal scale which begins with an automatically-printed header (i.e. stick-on labels or similar methods are not acceptable) listing all of the input parameters which were used for that run. The list of parameters must include, but not be limited to, the data filter factor settings, blanking band height/length, the bump height/width, date/time, lane, direction and wheelpath. Stations must be automatically marked every 10 m and amplitudes of individual bumps/depressions shown. The trace must also show the calculated rate of smoothness for each 100 m subplot in mm/km and clearly identify the locations of any scallop where the bump/width has been exceeded. At the end of each profile run, the computer must print a summary which lists of all of the measured sublots with their corresponding start/end stations, rates of smoothness and the locations of all scallops.

4.2 TIRE PRESSURE GAUGE: For checking the tire pressure of a PMD's measuring wheel.

4.2 AIR PUMP: For maintaining acceptable air pressure of a PMD's measuring wheel.

4.3 CALIBRATION BLOCKS: Finished steel blocks usually 12.7mm (1/2") and 38.1 mm (1.5") in height used for checking the vertical calibration of a PMD's measuring wheel.

4.4 THIN STEEL PLATE: Approximately 0.3X0.3 m square and 5-6 mm thick for use with the calibration blocks.

4.5 OFFSET BAR: A rigid metal bar, at least 2.5 m long, with a suitable weighted chain hanging from the end. The chain is dragged along a reference line, in order to ensure that the PMD is following a proper offset.

4.6 SMALL TAPE MEASURE: A metal tape, at least 5 m long, used to measure and establish offset distances from a reference line.

4.7 LARGE TAPE MEASURE: A metal or teflon-coated woven tape, at least 50 m long, used to establish and measure distances from fixed stations.

4.8 CHALK AND SPRAY PAINT: For temporary and permanent marking.

5. PROCEDURES

5.1 CORRELATING PROFILE MEASURING DEVICES

5.1.1 Checking Equipment

At the Correlation Site, a Ministry representative will check the PMD (and the equipment for power assist, if the operator intends to use power assist on Ministry contracts) to ensure that it is in suitable condition and that all appropriate accessories and peripherals are included with the device.

5.1.2 Checking Tire Pressure of Measuring Wheel

The PMD operator must demonstrate to the Ministry representative that the tire pressure of the measuring wheel meets ASTM requirements [i.e. 25 p.s.i. $\pm$ 1 p.s.i. (or 170 kPa)]. If the tire pressure is too low, then it must be slightly inflated using the air pump (i.e. with caution - since overinflation can permanently cause the measuring wheel to become out-of-round). However, if the tire pressure is too high, then the tire can be deflated slightly by pushing a small object such as a key into the tire valve.

5.1.3 Checking Height Sensor Calibration

The PMD operator must demonstrate to the Ministry representative that the height sensor is properly calibrated.

5.1.3.1 The PMD is moved to a relatively flat area and the measuring wheel is lowered onto a thin, flat steel plate sitting on the pavement surface.

5.1.3.2 The height measurement, M1, shown on the PMD's screen is then recorded (see Figure 2).

5.1.3.3 One of the metal calibration blocks of known height, H, is then placed on top of the thin plate and under the measuring wheel and the second height measurement, M2 shown on the PMD's screen, is recorded.

5.1.3.4 The PMD operator must check this with at least two blocks of differing heights [usually 12.7 mm (1/2") and 38.1 mm (1.5")].

5.1.3.5 The absolute value of the difference between M1 and M2 must be within 0.5 mm of the heights of both blocks, in order for the height sensor to be properly calibrated.

5.1.3.6 If the height sensor is not properly calibrated, then the correlation procedure will be terminated at that point and the sensor must be recalibrated by the manufacturer.

5.1.4 Checking Odometer Calibration

The PMD operator must demonstrate to the Ministry representative that the PMD's odometer is properly calibrated.

5.1.4.1 The longitudinal centreline of the PMD is aligned along a line, 100 m long, which has been established at the Correlation Site for this purpose.

5.1.4.2 The PMD's measuring wheel is lowered onto the pavement surface so that its geometric centre is sitting at the beginning of the line.

5.1.4.3 The station reading on the PMD's screen is set to 0 m and then the PMD is manually pushed 100 m using its internal odometer.

5.1.4.4 Once the PMD is about 90 m into the run, the PMD operator should begin to slow it down so that it is completely stopped just at the point where the odometer turns exactly 100 m.

5.1.4.5 The distance between the geometric centre of the PMD's measuring wheel and the end of the 100 m section is then measured using a small metal tape measure. This distance which must be no more than 1.0 m.

5.1.4.6 If distance between the geometric centre of the PMD's measuring wheel and the end of the 100 m section is more than 1.0 m, then the 100 m line must be rerun and the odometer of the PMD recalibrated using the manufacturer's procedure so that it exactly reads 100 m when the geometric centre of the measuring wheel has reached the end of the run (i.e. $\pm 1.0\%$).

5.1.5 Checking Tracking (Skewness)

While the PMD is being pushed during the odometer calibration check, a Ministry representative will also check to see if the PMD is tracking properly i.e. that the front and back bogey wheels are following one another in the same path.

5.1.5.1 If the horizontal tracking is deemed to be unacceptable, then the run will be terminated and the PMD operator will be asked to adjust the bogey wheels (usually by loosening a knurled knob on the back wheels) to improve tracking (i.e. to eliminate skewness).

5.1.5.2 Once the PMD is tracking properly, the operator may be required to wait until checks of several other PMD's have been made before his PMD is allowed to have a second calibration check of its odometer.

5.1.6 Conducting Correlation Runs

Once the Ministry's representative is satisfied that the PMD has been properly calibrated, the PMD will then be required to run along a line which has been established at the Correlation Site for this purpose.

5.1.6.1 The PMD must be perfectly aligned with the geometric centre of its measuring wheel sitting on the pavement and at the beginning of a 300 m long painted (dashed) Correlation line.

5.1.6.2 The operator must set the computer-generated blanking band at a height "B" of 0 mm (i.e. a Zero Blanking Band), the reduction length at 100 m and the data filter factor at 2.0.

5.1.6.3 The PMD will then run the measuring wheel a distance of 300 m, using the PMD's internal odometer at a speed of 3 to 4 km/hr.

5.1.6.4 Once the PMD has reached about 250 m, the operator must begin slowing the PMD down so that it comes to a complete stop when its odometer reads exactly 300 m.

5.1.6.5 The distance between the centreline of the measuring wheel and the end of the run is then measured using a small metal tape. That distance must be no more than 3.0 m (i.e. $\pm 1\%$).

5.1.6.6 The PMD must repeat the 300 m distance two more times for a total of three complete runs.

5.1.6.7 The PMD must repeat the 300 m run three times for each combination of mode of operation (manual or power-assist) and measuring wheel that the PMD operator intends to use on Ministry contracts during the construction season in which the correlation is being conducted. Also, if the PMD operator intends to measure concrete pavements on Ministry contracts, then at least one additional series of three runs must also be carried out while being manually pushed with the computer-generated blanking band set at a height of 5 mm.

5.2 SURFACE SMOOTHNESS MEASUREMENTS ON MINISTRY CONTRACTS

5.2.1 Taking Surface Smoothness Measurements

5.2.1.1 For California-type profilographs, smoothness testing must be carried out as per ASTM E 1274.

5.2.1.2 For all California profilographs, the height sensor, odometer and the tire pressure of the measuring wheel must always be within acceptable tolerances, as stated in Section 8.2 using the methods described in Section 5.1.

5.2.1.3 The computer-generated blanking band must be set at a height "B" of 0 mm (i.e. a Zero Blanking Band) for asphalt pavements and 5 mm for concrete pavements. The bump length must be

set at 7.5 m and the bump height set at 10 mm for asphalt surface course and concrete surface and 15 mm for concrete base. For profilographs manufactured by James Cox and Sons Inc., the panel switch must be set to the "Fixed Distance" mode at all times.

5.2.1.4 All surface smoothness testing must be done in the direction of traffic.

5.2.1.5 All individual profile runs must be less than or equal to 500 m in length.

5.2.1.6 Stations, areas that will not be measured, areas that will be measured but not price-reduced and all distances from such areas must all be referenced from the centreline of the PMD's measuring wheel.

5.2.1.7 The PMD operator must measure the heights of all scallops recorded on the profile trace. For McCracken profilographs this is done by measuring the maximum height above and perpendicular to the "excessive height" lines printed on profile traces using a millimetre scale and adding 10 mm. For traces produced by Cox Brothers profilographs, the PMD operator must measure the heights of all scallops by measuring the maximum height above and perpendicular to the lines shown on excessive height templates or so-called "bump" templates and by adding 10 mm (see Figure 3)

5.2.1.8 The amplitudes of all scallops identified by computer must be rounded to the nearest 0.5 mm.

5.2.2 Measuring Existing Pavements, Binder or Base Courses

5.2.2.1 Where either an existing pavement surface or asphalt binder course must be measured, then the pavement sections of the existing surface or the binder course, whichever is being measured, must have exactly the same stations and numbers as the sublots of the overlying asphalt surface course. Similarly where an existing pavement surface or concrete base must be measured, then the pavement sections of the existing pavement surface or concrete base, whichever is being measured, must have exactly the same stations and numbers as the sublots of overlying concrete surface.

5.2.2.2 However, if the stations for any subplot of asphalt surface course or concrete surface do not match the stations of the underlying measured existing surface, asphalt binder coarse or concrete base, then the Contractor will be required to either remeasure the asphalt surface course (or concrete surface) or to recalculate the profile indices for the affected subplot so that the stations for the asphalt surface course (or concrete surface) match the measured existing pavement surface, asphalt binder course or concrete base exactly.

6. CALCULATIONS

6.1 CORRELATION SITE

6.1.1 Means and Standard Deviations for Individual 100 m Sections

For each set of three runs of the 300 m Correlation Line, the PMD operator must calculate the mean, standard deviation and the coefficient of variation (i.e. ratio of standard deviation to the mean as a

percentage) of the rate of smoothness measurements for each 100 m section of pavement measured by the candidate PMD as follows:

$$(1) \quad \bar{X} = \frac{\sum x_i}{n}$$

$$(2) \quad s = \sqrt{\frac{\sum (x_i - \bar{X})^2}{n-1}}$$

$$(3) \quad \text{Coefficient of Variation (\%)} = \frac{s}{\bar{X}} \times 100$$

Where:

$\bar{X}$ = the mean rate of smoothness for each 100 m section

s = the sample standard deviation for each 100 m section

x_i = the individual rate of smoothness for each 100 m section

$n = 3$

6.1.2 Individual Average Rate of Smoothness for Entire 300 m Section

The profilograph operator must calculate the average rate of smoothness for all three runs of the 300 m Correlation line for the candidate PMD.

6.1.3 Average Coefficient of Variation

The profilograph operator must calculate the average coefficient of variation for the three individual coefficients of variation representing each 100 m pavement section measured by the candidate PMD.

6.1.4 Correlation Benchmark Mean

6.1.4.1 A Ministry representative will calculate a "Correlation Benchmark Mean" for the 300 m Correlation Line by averaging the individual average profile indices for all candidate profilographs which meet the Ministry's acceptance criteria on the first attempt during the first round of the season.

6.1.4.2 The individual average profile index determined for any PMD which does not meet the Ministry's acceptance requirements (based on the individual averages established by the other acceptable candidate PMD's) on the first attempt during the first round of the season will not be included in the calculation of the Correlation Benchmark Mean for that season.

6.1.5 Ratio of Individual Average to Correlation Benchmark Mean

Once the Correlation Benchmark Mean has been established for the season, a Ministry representative will calculate the ratio of individual average rate of smoothness to the Correlation Benchmark Mean, for each candidate PMD.

6.2 MINISTRY CONTRACTS

6.2.1 The PMD operator must calculate the profile index for each subplot by averaging the rate of smoothness which was measured for both wheelpaths.

6.2.2 The profile Index for a given subplot must always be rounded to the nearest whole number in accordance with LS 100.

7. REPORTING OF RESULTS

7.1 CORRELATION SITE

7.1.1 All calculations carried out during the PMD correlation must be entered on a PMD Correlation Sheet, such as the one shown in Figure 4

7.1.2 Separate forms must be filled out for each set of three runs taken of the 300 m correlation line for each combination of blanking band, mode of operation and measuring wheel.

7.1.3 All correlation forms should be handed to a Ministry representative on site along with the applicable profile traces. Once the "Correlation Benchmark" for the site has been established, the Ministry representative will complete the sheet.

7.2 MINISTRY CONTRACTS

7.2.1 Surface Smoothness Reporting Forms

7.2.1.1 All rate of smoothness measurements and profile index calculations carried out on Ministry contracts must be entered on forms similar to the Summary Sheet for PMD Measurements shown in Figure 5.

7.2.1.2 For measurements taken on asphalt surface course and concrete surface, the location and height of any scallop with an "S" value greater than 10 mm must be shown.

7.2.1.3 For measurements taken on concrete base, the location and height of any scallop with an "S" value greater than 15 mm must be shown.

7.2.1.4 Areas of special conditions, such as superelevations or curves, any additional information such as joints or major intersections and any areas which are being measured but will be exempt from surface smoothness-related price reductions/repairs must be clearly marked on all summary sheets

7.2.2. Continuous Daily Profile Record

One original, unbroken, continuous profile record representing all of the sublots and other pavement surfaces which were measured on a particular day must be produced at the end of that day or prior to the PMD leaving the site.

7.2.2.1 Before Each Individual Run

At the beginning of each different profile run within the daily profile record, the Contract number, mix type, pavement surface that was measured, the lane direction and wheelpath which was measured, the reference point that was used during measuring, the side of the lane that the reference point was on and the offset that was used, as well as any other relevant information must be automatically recorded.

7.2.2.3 Within Each Individual Run

Areas of special conditions, such as superelevations, curves, joints or major intersections and any areas which are being measured but will be exempt from surface smoothness-related price reductions/repairs within an individual profile run must be automatically printed or manually marked on the profile trace.

7.2.2.2 Documentation on Outside of Profile Record

The Contract number, mix types and pavement surfaces that were measured, the lanes, directions and stations covered, and whether the individual traces are the initial, subsequent or the final ones must be clearly shown.

8. CRITERIA FOR GAINING AND MAINTAINING PMD ACCEPTANCE

8.1 YEARLY CORRELATION ACCEPTANCE

8.1.1 The individual average rate of smoothness for the three sets of measurements taken of the 300 m correlation line by a candidate PMD, must be within 4% of the "Correlation Benchmark Mean".

8.1.2 The average coefficient of variation for the three sets of three individual 100 m pavement sections measured by a candidate PMD must be no more than 5%.

8.1.3 A candidate PMD which cannot be classified as a California Profilograph will not be fully approved for use on Ministry contracts, until that PMD has completed other surface smoothness measurements at one or more additional locations that the Ministry chooses and the Owner has been satisfied that such additional measurements compare favourably with similar measurements taken by the Ministry's own approved California Profilograph.

8.2 MAINTAINING ACCEPTANCE THROUGHOUT THE YEAR

8.2.1 The PMD operator must carry out regular inspections of the security of all bolts, wearing of the bogey and measuring wheels, roundness of the measuring wheel, tracking of the PMD etc. to ensure that the PMD is in suitable condition at all times.

8.2.2 Each PMD must be equipped with all necessary peripherals (printer etc.) in good working condition and all accessories such as suitable calibration blocks, a thin steel plate, tire pressure gauge, air pump, offset bar, tape measures, chalk, paints, wooden stakes etc.

8.2.3 The tire pressure of the PMD's measuring wheel must be maintained at 25 p.s.i. $\pm$ 1 p.s.i. (or 170 kPa $\pm$ 7 kPa) at all times.

8.2.4 The height calibration of the PMD's measuring wheel must be within acceptable limits at all times (i.e. the absolute value of M1-M2, shown in Figure 2, must be within 0.5 mm of the heights of both calibration blocks). The height calibration must be checked daily and each time the PMD is assembled, in accordance with the procedure stated in Section 5.1.3.

8.2.5 The PMD's odometer must measure within acceptable limits at all times (i.e. 1% of the true distance) and must be checked at least once a month, in accordance with the procedure stated in Section 5.1.4.

8.2.6 Any changes to the equipment (i.e. mode of operation, measuring wheel, printer etc.) and/or software from those that were demonstrated at the Correlation Site, during the initial yearly PMD approval, must be discussed with either the Ministry's Bituminous Section (for asphalt) or Concrete Section (for concrete) prior taking further measurements, respectively, on any of the Owner's contracts. Depending upon the nature of such changes, the Contractor's PMD may be required to repeat the correlation procedure at the Correlation Site.

Figure 1 – California Profilograph

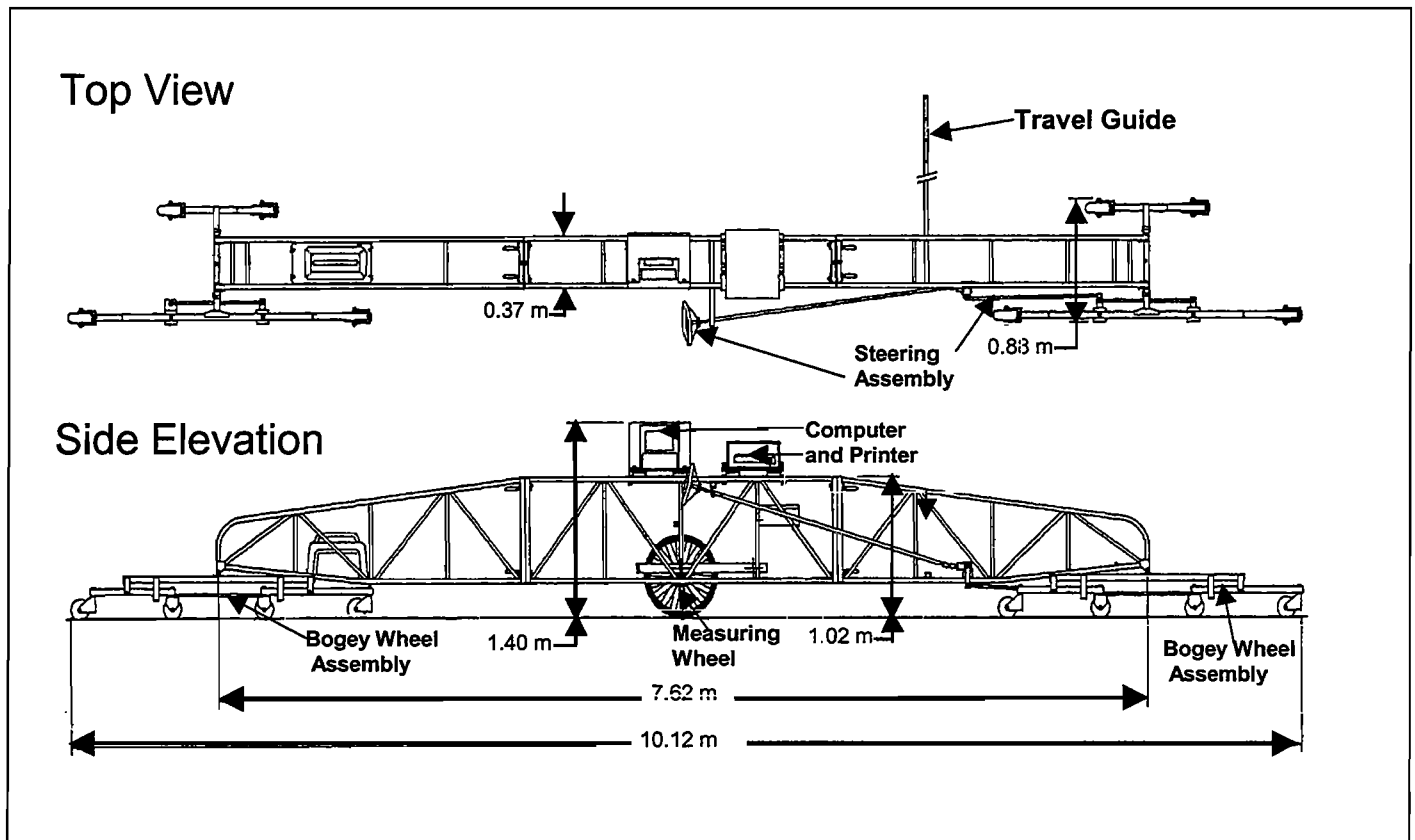


Figure 2 - Checking the Calibration of the Height Sensor

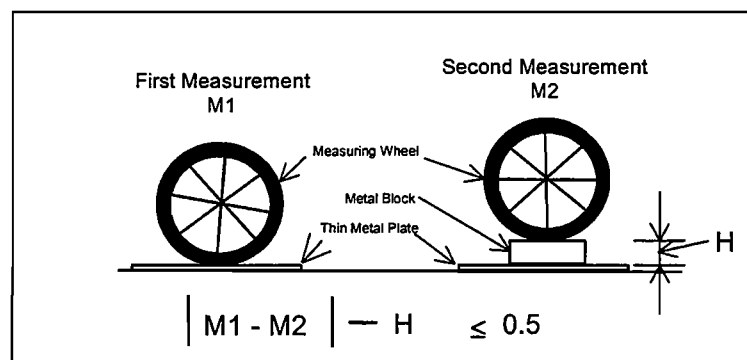


Figure 3 – Measuring Scallop Height Using a Bump Template

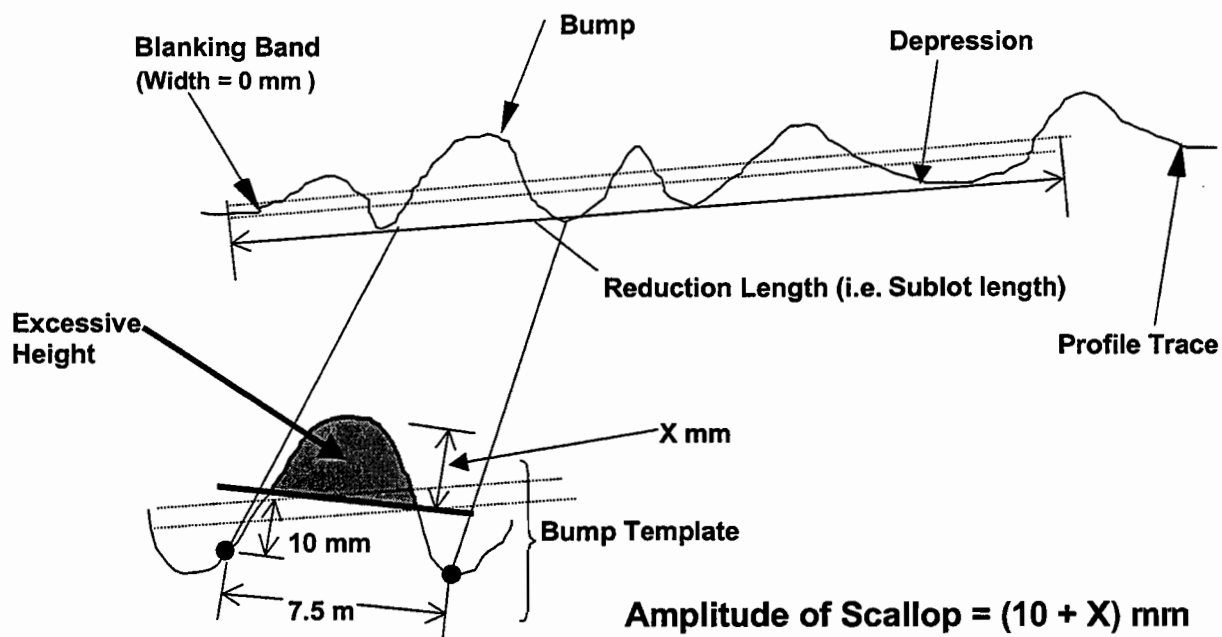


Figure 4 – Sheet For Correlation of Profilographs

Correlation of Profile Measuring Devices

Site: Trafalgar Weigh Scale

Date: _____

Name of Company: _____

PMD Manufacturer: _____

Serial #: _____

PMD Operator: _____

Measuring Wheel #: _____

Is the PMD Being Independently Powered?

Yes _____ No _____

If Answer to Above is Yes, How is it Powered? _____

Asphalt Correlation (Blanking Band = 0.0 mm)

Stations	Run #1	Run #2	Run #3	Average	Std. Dev.	Coeff. of Variation (%)
Average						

Correlation Benchmark Mean = _____ mm/km (Provided)

Average Coefficient of Variation = _____ %

Ratio of Company's Average to Correlation Benchmark = _____

Concrete Correlation (Blanking Band = 5.0 mm)

Stations	Run #1	Run #2	Run #3	Average	Std. Dev.	Coeff. of Variation (%)
Average						

Correlation Benchmark Mean = _____ mm/km (Provided)

Average Coefficient of Variation = _____ %

Ratio of Company's Average to Correlation Benchmark = _____

Smoothness Measurements For Asphalt / Concrete Pavements

[illegible]

Notes: * Areas that are superelevated or on curves should be designated as "(S)" or "(C)", respectively

† If a scallop is left unrepaired, write "(U)" after its height

METHOD FOR MEASURING PAVEMENT LIFT THICKNESS

1. SCOPE

1.1 This method describes the steps to follow when measuring lift thickness from cores of one or more lifts of pavement.

2. RELEVANT DOCUMENTS

MTO Laboratory LS – 100 Rounding-off of Test Data and Other Numbers

MTO Laboratory LS – 101 Calculation of Per Cent within Limits

3. DEFINITIONS

3.1 **Lift Thickness** – The thickness in millimetres of the placed and compacted surface course as determined through the measurement method specified in the Contract Documents.

4. APPARATUS

4.1 THICKNESS MEASURING APPARATUS

4.1.1 Plate

The base of the prefabricated device shall consist of a cold rolled aluminium plate, a minimum of 6 mm thick. The plate shall be rigid enough to provide a flat working surface. The plate shall have minimum surface dimensions of 350 mm by 300 mm, to allow both the core and the height gauge to sit perpendicularly on the plate. The plate surface shall be marked with a central axis running parallel across the centre of the longer axis of the plate, to coincide with the centre axis of the scribe and height gauge. A set of cross hairs running perpendicular to the central axis, offset 0 mm, 25 mm, 50 mm, and 75 mm from the tip of the scribe shall also be marked on the plate, along the axis and away from the height gauge to assist in positioning the cores for measurement. See Figure 1 for a detailed diagram of the plate markings and Figure 2 & 3 for the layout of the plate.

4.1.2 Height Gauge

The height gauge shall be equipped with a tipped scribe. The base of the gauge shall be securely fixed to the plate with the height gauge's scribe located at the 0 mm cross hair

mark, centred over the central axis, vertically perpendicular to the plate (see Figures 1, 2 & 4). The height gauge must be capable of measuring to an accuracy of 0.5 mm or 0.02 inches.

- 4.1.3 Spirit Level
- 4.1.4 Right Angle
- 4.1.5 Calibration Blocks
- 4.1.6 Marker

Writing implement capable of applying a permanently visible mark on the side of a hot mix asphalt core.

4.1.7 Test Core

The core sample should have a diameter of approximately 50 mm, 100 mm, or 150 mm and shall be representative of the hot mix asphalt lift being measured. The core may include additional lifts of pavement from which it was removed or the underlying lifts may be split off. A damaged core shall not be used for measurement. The core shall be clean and brushed to remove any loose subgrade aggregate that might be present.

5. PROCEDURES

5.1 MEASURING LIFT THICKNESS OF CORE SAMPLES

5.1.1 Setting Up Apparatus

5.1.1.1 Once a desired location for positioning the apparatus is found, a spirit level should be used to ensure that the surface of the plate is reasonably level and a right angle shall be used to confirm that the height gauge is measuring perpendicular to the plate's surface.

5.1.1.2 After setting up the equipment and prior to taking any measurement, the accuracy of the height gauge shall be verified using a combination of calibration blocks to match the lift thickness that is specified in the Contract. Any deviations in the accuracy shall be corrected prior to any readings being taken.

5.1.1.3 Ensure that the surface, markings and engravings on the plate are clean and free of debris.

5.1.2 Preparing The Core

5.1.2.1 Using the marker make a random mark on the side of the core, near the top of the surface course.

5.1.2.2 Place the core with the top of the surface course onto the plate (upside down), with the core centred over the main centre axis with the mark made in 5.1.2.1 located adjacent to the 0 mm cross hair (identified as #1) beside the scribe, so the scribe can move vertically up and down freely without rubbing against the core.

5.1.2.3 The core must sit freely upon the plate. The core should not be tilted to make contact with the height gauge as this will result in a false measurement. Height measurements will be taken approximately perpendicular to the upper plane of the surface course.

5.1.3 Measurement and Recording

5.1.3.1 Measure and record the distance between the upper plane of the lift to be measured and the lower plane of the lift being measured. This is done placing the scribe at the upper plane of the lift, zeroing the height gauge, raising the scribe to the lower plane of the lift or construction demarcation line between the lift being measured and the underlying lift. The technician may move the core along the central axis, so the scribe does not rub against the core as it is raised vertically to the construction demarcation. The lift height shall be read to the closest 0.5 mm or 0.02 inch. If the height gauge measures in inches, convert the reading to millimetres and record the Height Measurement on the "Lift Thickness Measurement Recording Form", Figure 5. Height measurements will be reported to one decimal place in millimetres. The core is not to be rotated when making a height measurement for a specific point on the core.

5.1.3.2 The first reading taken at position #1 is H_1 .

5.1.3.3 Once the first reading is taken, the core should be rotated counter clockwise, 90° at a time. Use the mark on the core, the cross-hairs, and #2, #3, and #4 marked on the plate as a guide to obtain three additional measurements H_2 , H_3 , and H_4 , as in 5.1.3.1 above, for a total of four height measurements located equal distance from each other around the core.

5.1.3.4 The core's lift thickness is determined by calculating the mean of the four height measurements (H_1 , H_2 , H_3 , and H_4) according to LS-101. The Lift Thickness measurements will be reported in millimetres and the rounding off of measurements and results will be in accordance with LS-100.

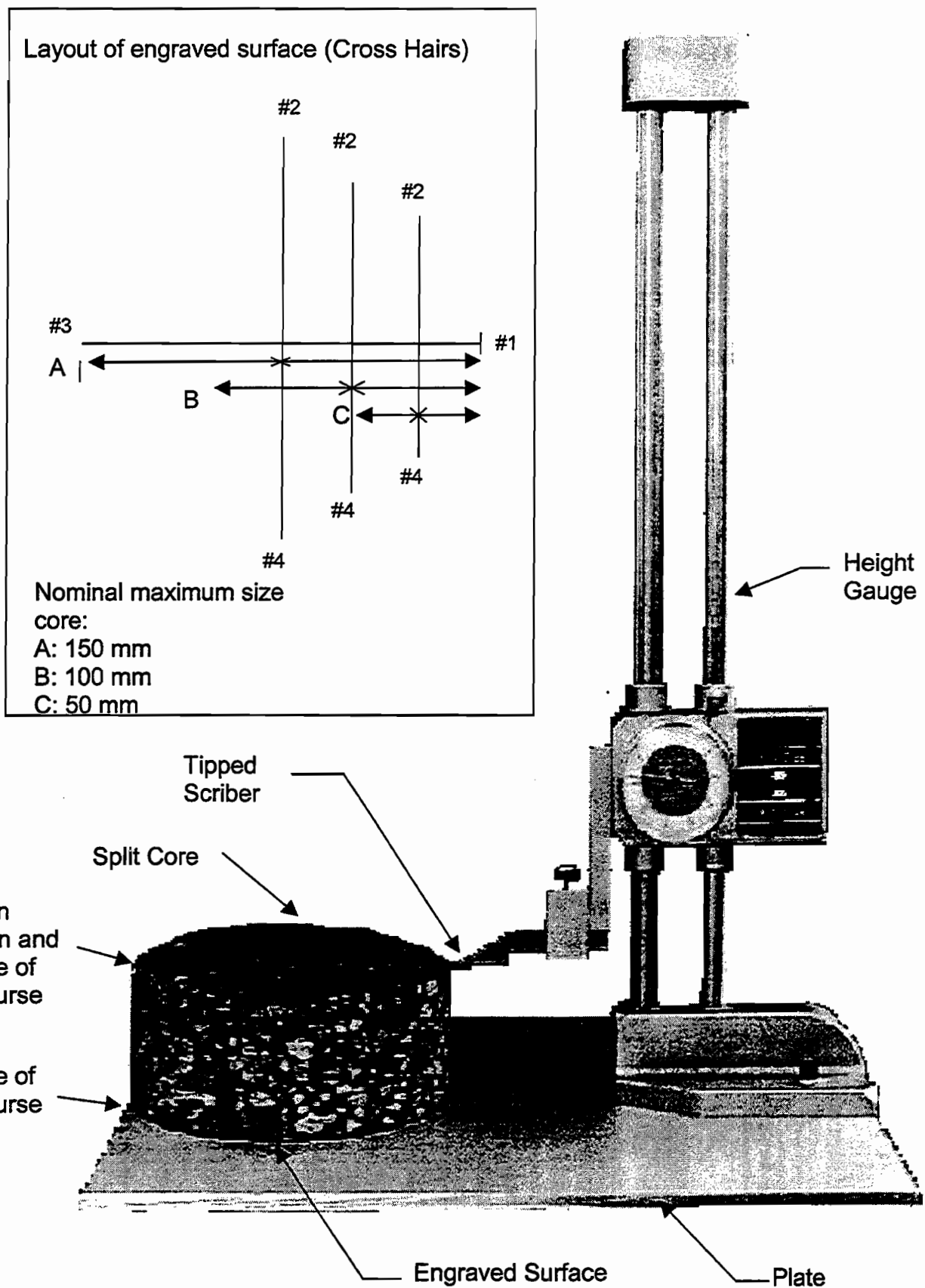


Figure 1: Detailed Side View of Thickness Measuring Apparatus with a Split Core

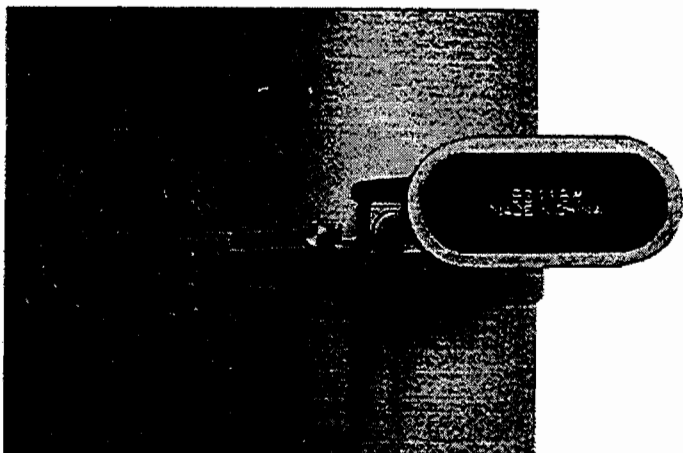


Figure 2: Top View of Plate and Height Gauge

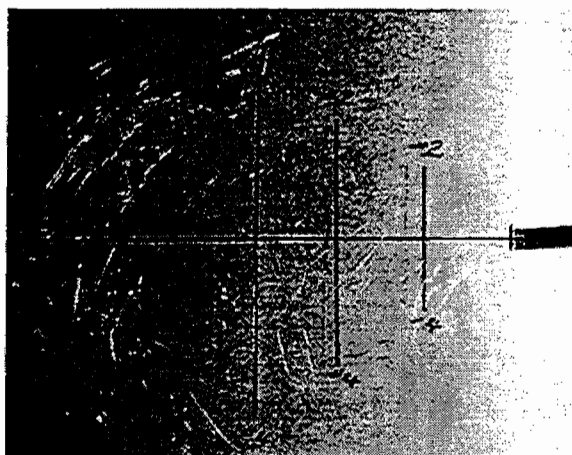


Figure 3: Top View Showing Cross Hairs and Tip of Scriber

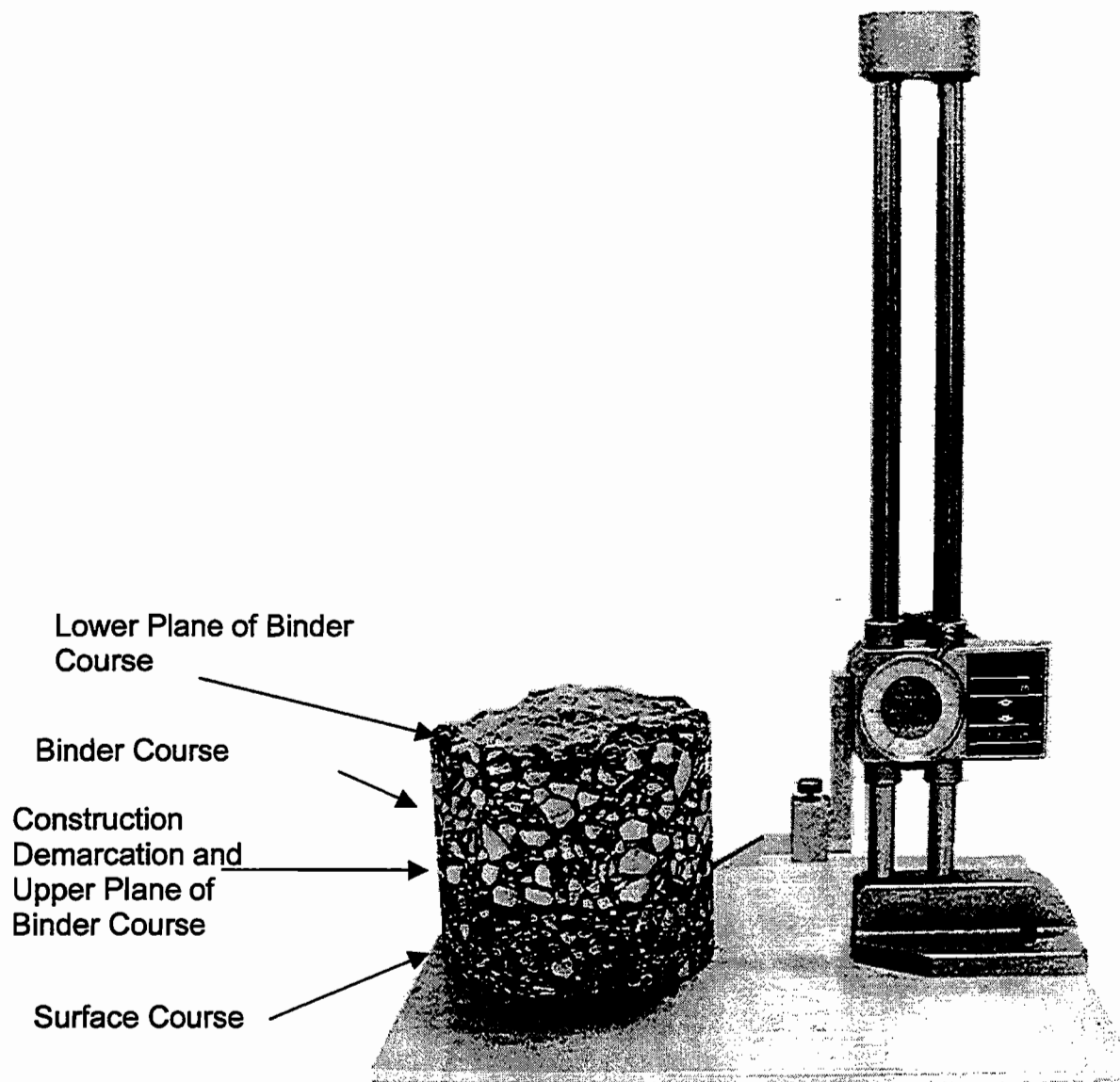


Figure 4: Side View of a Thickness Measuring Apparatus Measuring Binder Course

Lift Thickness Measurement Recording Form									
Contract No.		Region		Lot No.					
Item No.		Highway		Lot Size					
Lift		Core Diameter		Number of Sublots					
Mix Type									

Sublot #	Station	Offset from **	Date Sampled (dd/mm/yy)	Time Sampled	Height Measurements (mm)				*Lift Thickness Measurements (mm)
					H ₁	H ₂	H ₃	H ₄	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
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31									
32									
33									
34									
35									

*Where:

$$\text{Lift Thickness Measurement} = (H_1 + H_2 + H_3 + H_4) / 4$$

** Note: Fill in where offset is taken from, ie. centreline, left or right pavement edge.

The Contractor's representative was informed of the above, subplot numbers _____ to _____ on
 (Date) _____ at (time) _____

Ministry Rep. Signature _____ Contractor Rep. Signature _____

Comment: _____

METHOD OF DETERMINING LIFT THICKNESS USING CONCRETE COVER METER

1. SCOPE

1.1 This method covers the determination of lift thickness of a hot mix course using an electromagnetic concrete cover meter.

2. RELEVANT DOCUMENTS

2.1 Covermeter User's Guide for Concrete Cover Survey, Engineering Materials Office, Concrete Section, Ministry of Transportation, Ontario, March 1998.

3. DEFINITIONS

Concrete Cover Meter: means a measuring meter that utilizes Pulse Induction Eddy Current technology to determine the thickness of the lift thickness above a metal delineator.

Design Lift Thickness, T_D : means the thickness in millimetres of the hot mix course specified in the Contract Documents.

Lift Thickness, T : means the thickness in millimetres of the placed and compacted hot mix course as determined through the measurement method specified.

Metal Delineator: means a reflector that can be secured to the top of the underlying course in order to obtain a cover meter reading from which the lift thickness of the overlying course can be determined.

4. APPARATUS

4.1 Protovalle CM9 Microprocessor CoverMaster®: An electromagnetic concrete cover meter that uses Pulse-Induction Eddy Current technology to determine distance from the meter head through a non-reflective material to a reflector. The meter is equipped with a 24 character LCD screen, audio and visual signal to indicate a reading has been taken. Equipment is battery operated, equipped with the large Head 210 mm X 100 mm face, 52,710 g with a sensing area of 160 mm X 80 mm and a cover range of 20 mm to 180 mm.

5. CALIBRATION OF EQUIPMENT

5.1 Prior to taking any measurement the equipment shall be calibrated using a combination of non-conductive calibration blocks (i.e. wood or plastic) T_D , $T_D - 5$ mm, and $T_D - 10$ mm thick. Calibration measurements at a minimum shall be taken for these three thicknesses over a sample of the metal delineator, at bar diameter size settings 5, 5+, and 6 for a minimum of nine readings. Calibration at a minimum shall be carried out at the start of each day, after each battery charge or change (See Reference 2.1).

6. OPERATIONAL CONSTRAINTS

- 6.1 The unit shall only be used when it is fully charged.
- 6.2 Testing shall only occur when the pavement and air temperature range from 0°C to 45°C.
- 6.3 The cover meter head and pavement being tested shall be clean and dry.
- 6.4 Prior to any readings being taken, the equipment shall be set up and zeroed according to the equipment manual.

7. TEST PROCEDURE

- 7.1 All Cover Meter Readings shall be taken with the bar diameter size set at 5.
- 7.2 Place the cover meter over the hot mix course in the location of the metal delineator and locate it using the sensor.
- 7.3 Once the metal delineator is located, the operator shall take successive readings over the test location.
- 7.4 Readings shall be taken by moving the cover meter using a constant arm motion back and forth over the location in one direction and then at 90 degrees to the original direction until an intersection point is determined.
- 7.5 Readings shall be taken until two consecutive readings are the same, and they are not larger than any previous reading taken.
- 7.6 This reading is X, the cover meter reading.

8. CALCULATIONS

- 8.1 Calculate the lift thickness for the subplot, T

Where:

X = cover meter reading in millimetres

w = thickness of metal delineator (washer) measured in millimetres

$T = X + w$

9. REPORTING

9.1 Report all the calibration cover meter readings, X in millimetres and the thickness of the calibration block used in calibrating the equipment on a sheet such as Form A: Concrete Cover Meter Calibration Report shown in Figure 1.

9.2 Report the cover meter reading X , washer thickness, w and the calculated lift thickness, T in millimetres on a sheet such as Form B: Report on Lift Thickness as Determined from Concrete Cover Meter Readings shown in Figure 2.

Figure 1: Form A for Reporting Calibration of Concrete Cover Meter



Ministry of
Transportation

Ontario

Form A : Concrete Cover Meter Calibration Report						
Contract No.:			Description of Cover Meter:			
Highway:			Design Lift Thickness, T_D (mm):			
Date (dd/mm/yy)	Time	Thickness of Calibration Block (mm)	Cover Meter Reading, X (mm) at Bar Diameter Size #			Operator and Comments
			5	5+	6	

 Ministry of
Transportation
Ontario

Form B: Report on Lift Thickness as Determined from Concrete Cover Meter Readings						
Contract No.:		Design Lift Thickness, T_D (mm)				
Highway		Metal Delineator Thickness, w (mm)				
Station	Offset from	Date Tested (dd/mm/yy)	Time Tested	Cover Meter Reading, X (mm)	Lift Thickness $T = X + w$ (mm)	Operator and Comments

* Note: Fill in where offset is taken from, ie. Centreline, right or left pavement edge.

METHOD OF TEST FOR THE DETERMINATION OF INDIRECT TENSILE STRENGTH OF EXPANDED ASPHALT MIXES

1. SCOPE

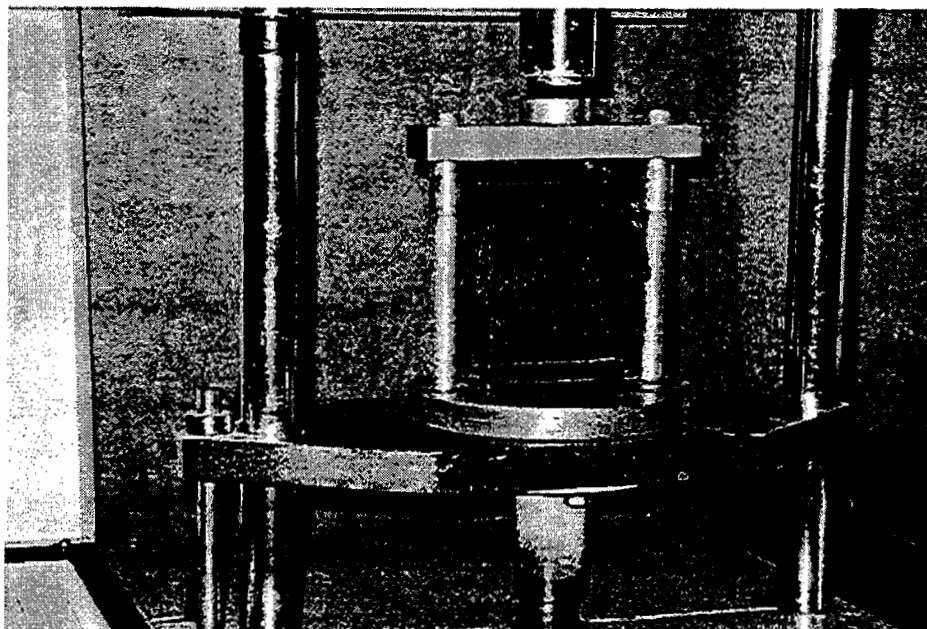
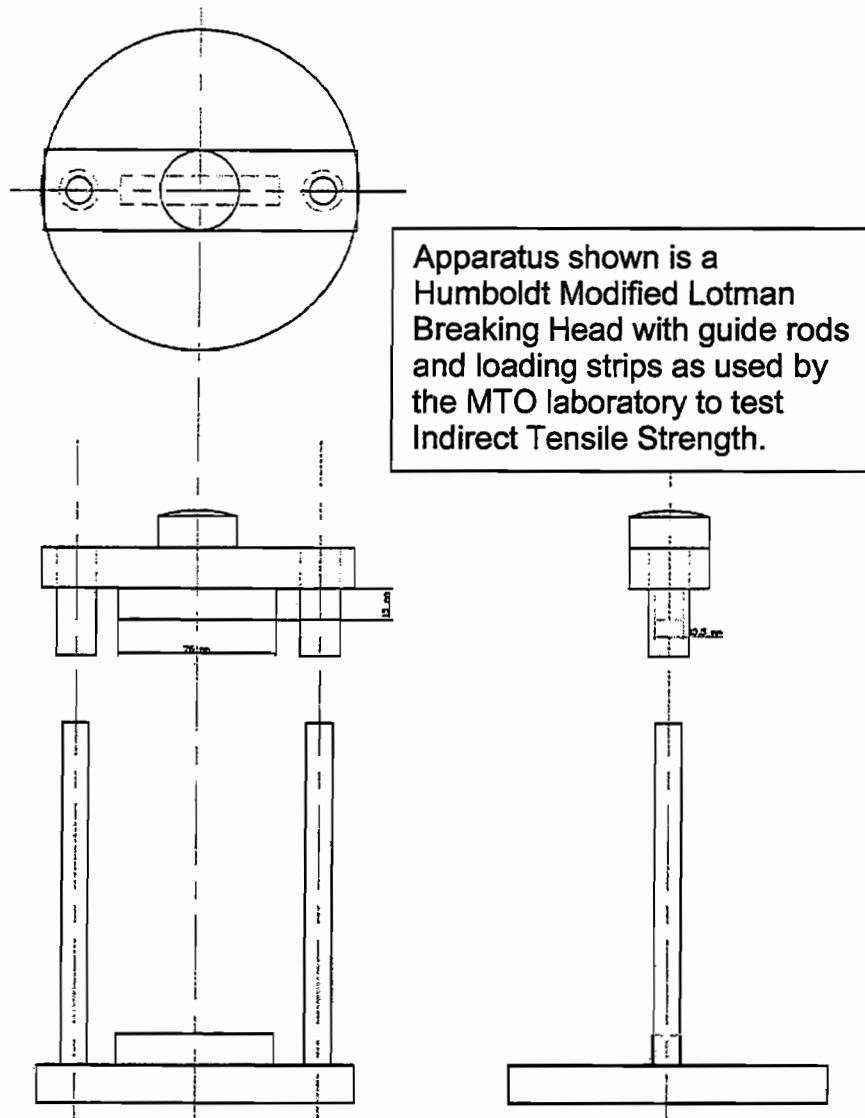
1.1 This method covers procedures for indirect tensile strength testing of field samples of expanded asphalt mix.

2. RELEVANT DOCUMENTS

- 2.1 MTO LS-261
- 2.2 ASTM E11
- 2.3 ASTM D4123
- 2.4 ASTM D2216
- 2.5 MTO LS-282
- 2.6 ASTM D4867 / D4867M -96
- 2.7 Wirtgen Cold Recycling Manual – Appendix A2.3

3. APPARATUS

- 3.1 Oven: of suitable capacity and capable of maintaining $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for drying samples
- 3.2 Marshall Molds: as per LS-261
- 3.3 Compaction Hammer: as per LS-261
- 3.4 Compaction Pedestal: as per LS-261
- 3.5 Filter Paper: paper disc as per LS-261
- 3.6 Weigh scale: as per LS-261
- 3.7 Sieve: 305 mm (12") diameter frame, 26.5 mm opening, meeting ASTM E11 specifications
- 3.8 Spatula: as per LS-261
- 3.9 Metal Trough: as per LS-261
- 3.10 Containers: as required for mixing and splitting samples
- 3.11 Extrusion jack: as per LS-261
- 3.12 Thermometer or Temperature Probe: capable of measuring specified temperatures with a precision of 0.2°C
- 3.13 Forced Draft Oven: capable of maintaining 60°C
- 3.14 Air Cabinet: capable of maintaining $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$
- 3.15 Compression loading apparatus and breaking head: able to uniformly load the specimen with a constant deformation rate of 50.8 mm/minute
- 3.16 Loading Strips: as per ASTM D4123



4 PROCEDURE FOR ACHIEVING FIELD MOISTURE CONTENT IN THE LAB SAMPLE

- 4.1 The field moisture content should be determined at the time the samples are collected in the field. This moisture content should be written on the sample bag.
- 4.2 Samples of expanded asphalt mix shall be moisture conditioned to the field moisture content.
- 4.2.1 Determine the percentage of moisture in the sample ($w_{lab\ sample}$) by following the procedure outlined in ASTM D2216, with the following exceptions: use 1000g portion, record the mass to the nearest 0.1g, constant mass is defined as no change in mass in excess of 0.1% for each 30 min. drying period.
- 4.2.2 Weigh the lab sample to be conditioned, $m_{lab\ sample}$ in g, in a tared flat pan.
- 4.2.3 The difference between the lab sample moisture content ($w_{lab\ sample}$ as determined in step 4.2.1) and the field moisture content (w_{field} as given in step 4.1) determines the percentage of water that will need to be either added to or subtracted from the lab sample. The mass of water is calculated by the following equation:
- $$m_{water} = (w_{lab\ sample} - w_{field}) \times m_{lab\ sample}$$
- 4.2.4 The lab samples need to be conditioned to the field moisture content by adding or removing water with the mass of m_{water} as calculated above. This can be done by either drying in an $110 \pm 5^{\circ}\text{C}$ oven or by spraying the sample with a spray bottle filled with distilled water and mixing the moisture into the sample.
- Note 1: If the samples were properly sealed and promptly tested the sample moisture content should not be significantly different from the field moisture content.*
- 4.3 The samples should be compacted into briquettes as soon as the field moisture content is achieved.

5 PROCEDURE FOR THE COMPACTION OF SPECIMENS (BRIQUETTE MANUFACTURE)

- 5.1 Prepare the Marshall mold and hammer by cleaning the mold, collar, base-plate and face of the compaction hammer. Use 100 mm (4") Marshall molds for the briquettes.
- 5.2 Reduce field sample to testing size in accordance with LS-282.
- 5.3 Obtain from the sample by the splitting/quartering method, sufficient material (approximately 6,600 g) in order to prepare six (6) Marshall briquettes. The six (6) briquettes will be divided into two (2) sets of three (3) briquettes each. One set of three (3) briquettes will be tested as dry specimens and the other set of three (3) briquettes will be tested as wet specimens.
- 5.4 Some particles may be stuck together with the asphalt cement that is in the mix. It may be necessary to separate these particles by hand so that they are not larger than 26.5 mm. Do not crush the particles.

- 5.5 Screen the sample over a 26.5 mm sieve. The material retained on the 26.5 mm sieve shall be discarded, because the size is too large for the 100 mm diameter molds.
- 5.6 Weigh enough material to achieve a compacted height of 63.5 ± 2.5 mm (usually 1,100 g is sufficient).
- 5.7 Place a filter paper at the bottom of the Marshall mold.
- 5.8 Using the metal trowel for removing the mix from the trough, place approximately 1,100g into each of the tared molds. Make certain that the bottom of the trowel is in contact with the bottom of the trough so that the mixture is not removed in layers.
- 5.9 Using the spatula, rod the mixture in the mold 25 times – 15 around the outside, 10 around the center. When rodding around the outside, keep the spatula blade flat against the inside the mold. When rodding around the inside, do not change direction of the blade, and finish by leaving a small cone of mix in the center of the mold.
- 5.10 Place another filter paper at the top of the Marshall mold.
- 5.11 The briquettes shall be compacted at room temperature. Each briquette shall receive 75 blows per side. Make sure the hammer is kept as vertical as possible and ensure free fall of the hammer during compaction.

6 PROCEDURE FOR CURING THE SPECIMENS

- 6.1 After compaction, remove the mold from the base-plate, remove the top and bottom filter papers, and allow the specimen to cure for 24 hours in the mold in a force draft oven at 60°C.
- 6.2 Allow the molds to cool until warm to the touch, and extrude the briquettes by means of an extrusion jack.
- 6.3 Place the samples on their faces on a smooth flat tray and cure in a forced draft oven for a further 48 ± 4 hours at 60 °C.
- 6.4 Remove the briquettes from the oven, and immediately determine each briquette mass (g) and record the mass in air.
- 6.5 Allow the briquettes to cool in air. Faster cooling is achieved by using a fan(s). Do not cool in water. When sufficient cooling is achieved measure the diameter, d (cm) and the height, h (cm) of each briquette. Measure the height of each briquette at four (4) evenly spaced places around the circumference and calculate the average height. Use these measurements to calculate the volume of each briquette with the following formula:

$$V = \pi r^2 h$$

Where V = volume in cm^3

r = radius of specimen in cm ($r = d/2$)

h = average height of specimen in cm

7 DETERMINATION OF SPECIMEN DENSITY

- 7.1 Calculate the Density of the compacted specimens using the following formula:

$$D = \frac{M}{V}$$

Where D = density in g/cm³

M = Mass of briquette in g

V = Volume of briquette in cm³

- 7.2 If the density of any one briquette is more than ± 0.015 g/cm³ from the average density of all the specimens, recheck the calculations.
- 7.3 Group the six (6) briquettes into two (2) sets of three (3) so that the average density of each set is essentially the same.

Note 2: Indirect Tensile Strength (ITS) requires three briquettes for dry conditioning and another three briquettes for wet (soak) conditioning.

8 DETERMINATION OF INDIRECT TENSILE STRENGTH (ITS)

- 8.1 The standard ITS test is used to test the briquettes under both dry and soaked conditions. The ITS is determined by measuring the ultimate load to failure of a specimen which is subjected to a constant deformation rate of 50.8 mm/minute on its diametrical axis.
- 8.2 The dry specimen procedure is as follows:**
- 8.2.1 Bring the specimens to the test temperature by placing the briquettes in the air cabinet at 25 °C $\pm$ 1°C for at least 1 hour, but not for longer than 2 hours before testing.
- 8.2.2 Remove a specimen from the air cabinet and place it into the loading apparatus.
- 8.2.3 Center the briquette on edge on the lower loading strip. Position the upper loading strip. Take note of the alignment marks on the loading apparatus and position accordingly.
- 8.2.4 Position the assembly centrally under the loading ram of the compression testing device.
- 8.2.5 Apply the load to the specimen, without shock, at a rate of advance of 50.8 mm per minute until the maximum load is reached.
- 8.2.6 Record this maximum load, P (in kN), accurate to 0.1 kN.
- 8.3 The wet specimen procedure is as follows:**
- 8.3.1 Place three (3) cured specimens in a water bath and cover with distilled water at 25°C $\pm$ 1°C.
- 8.3.2 Soak the three (3) briquettes for 24 hours at 25°C $\pm$ 1°C. Alternatively, the three (3) briquettes can be covered with water at 25°C $\pm$ 1°C in a vacuum of 50 mm mercury for 60 $\pm$ 1 minutes.
- 8.3.3 Remove the specimen and surface dry.
- 8.3.4 Test for the ultimate tensile load, as described above in steps 8.2.3 through 8.2.6

- 8.4 Calculate the ITS for each specimen to the nearest 1 kPa using the following formula:

$$ITS = \frac{2 \times P}{\pi \times h \times d} \times 10000$$

where ITS = Indirect Tensile Strength in kPa

P = maximum applied load in kN

h = average height of the specimen in cm

d = diameter of the specimen in cm

- 8.4.1 Calculate the tensile strength ratio for each set of specimens using the following formula:

$$TSR = \frac{ITS_{wet}}{ITS_{dry}} \times 100\%$$

where ITS_{wet} = average ITS of all wet specimens in the set

ITS_{dry} = average ITS of all dry specimens in the set

9 REPORTING

- 9.1 Report the following measurements in the report as well as any observations:

9.1.1 Lab Moisture Content and Field Moisture Content

9.1.2 ITS of each specimen

9.1.3 TSR value

METHOD OF TEST FOR PREPARATION OF MARSHALL SPECIMENS FOR COLD IN-PLACE RECYCLED MIXTURES

1. SCOPE

1.1 This method covers the preparation of laboratory specimens used to establish a target density to measure pavement compaction for cold in-place recycled mixtures.

2. RELEVANT DOCUMENTS

- 2.1 ASTM D1188
- 2.2 ASTM D1559
- 2.3 ASTM E11
- 2.4 MTO Method LS-306
- 2.5 MTO Method LS-261
- 2.6 MTO Method LS-262

3. APPARATUS

- 3.1 CONVECTION OVEN(s): Capable of maintaining the required temperature(s) within 3°C
- 3.2 PANS: Baking type, approximately 300 x 400 x 60 mm
- 3.3 MIXING BOWL: Aluminum or stainless steel, approximately 250 mm diameter x 80 mm deep
- 3.4 SIEVE: 305 mm (12") diameter frame, 26.5 mm opening, meeting ASTM E-11 specifications
- 3.5 BALANCE: 4000 g capacity with an accuracy of ± 0.1 g
- 3.6 COMPACTION HAMMER(s): Hand operated or mechanical, meeting the requirements as specified in LS-261
- 3.7 COMPACTION PEDESTAL(s): For hand or mechanical compaction, as specified in LS-261
- 3.8 MECHANICAL COMPACTOR: As specified in LS-261
- 3.9 MARSHALL MOLDS: Meeting the requirements as specified in LS-261
- 3.10 SPATULA: Rounded end, rigid blade, approximately 250 mm long x 25 mm wide
- 3.11 METAL SCOOP: Flat bottomed, for batching materials
- 3.12 THERMOMETER OR TEMPERATURE PROBE: Capable of measuring the specified temperatures with a precision of 0.2°C
- 3.13 SPECIMEN EXTRUDER: Meeting the requirements as specified in LS-261

4. PROCEDURE

4.1 Number of Specimens - Prepare at least three specimens for each combination of aggregates and bitumen content..

4.2 Preparation of Mixtures:

4.2.1 Split the millings into representative batches of approximately 4000 g; this size of sample can be thoroughly mixed by hand and is sufficient to make three 63.5 mm high specimens.

4.2.2 Screen the samples over a 26.5 mm sieve. Reduce the size of the retained material by crushing using minimum effort so as not to produce excess fines. Material retained on the 26.5 mm sieve is too large for the 100 mm diameter molds.

4.2.3 Spread the sample onto a 300 x 400 x 60 mm baking pan and air dry for a period of not less than 4 hours, mixing the samples thoroughly at least once each hour. Take a representative portion of approximately 500 g to determine the moisture content of the air dried material (Note 1). Loosely cover and heat the remaining 3500 g sample as well as the emulsion to a temperature of $60 \pm 3^{\circ}\text{C}$ for not more than 1 hour prior to mixing.

Note 1: Weigh the portion taken for moisture content and record its mass to the nearest 0.1 g. Place in an oven maintained at $110 \pm 5^{\circ}\text{C}$ and dry to a constant mass. Constant mass is defined as no change in mass in excess of 0.1 % within two successive 30 minute intervals.

4.2.4 Add sufficient water to the sample such that the final liquid content of the mixture is 4.5 percent of the dry weight, i.e.:

4.5 % liquid = % emulsion (Note 2) + % water remaining in the air dried sample + % water added

From the above calculation, add water in the correct proportion to the mixture and thoroughly mix in by hand.

Note 2: Emulsion is added to the pre-moistened millings using the design application rate and mixed thoroughly into the batches by hand. The mixing time should not exceed 90 seconds.

4.2.5 Spread the sample onto a 300 x 450 x 60 mm baking pan, loosely cover, and allow to cure for 1 hour in an oven set at $60 \pm 3^{\circ}\text{C}$.

4.3 Compaction and Extrusion of Specimens:

Samples are molded using a modified Marshall procedure to produce briquettes with a height of 63.5 ± 1.27 mm as described below:

4.3.1 Preheat molds to $60 \pm 3^{\circ}\text{C}$.

4.3.2 Place a filter paper in the bottom of the mold and then add sufficient mix into the mold to obtain specimens of the required height. Using the heated spatula, quickly rod the mixture in the mold, 15 times around the outside and 10 times around the centre. Place a filter paper on top of the mix.

4.3.3 Apply 50 blows per side using a manual compactor or mechanical equivalent.

4.3.4 Remove the filter papers from both ends of the specimens but leave the specimens in the mold.

4.3.5 Cure the specimens for 20 ± 4 hours at $60 \pm 3^{\circ}\text{C}$ and recompact in the same order as previously with an additional 25 blows per side.

4.3.6 Lay the molded specimens on their side in an oven set at $60 \pm 3^{\circ}\text{C}$ for 24 hours prior to extrusion.

4.3.7 Extrude the briquettes and lay them on their sides to maximize surface exposure and cure for 72 hours at room temperature prior to testing in accordance with LS-306.

5. CALCULATIONS

5.1 Percent compaction calculation

$$\% \text{ compaction} = A/B \times 100$$

where

A = bulk relative density of pavement sample

B = bulk relative density average of recompact laboratory samples

Note 3: Testing for bulk relative density of both pavement and laboratory prepared specimens to obtain percent compaction shall be in accordance with LS-306.

METHOD OF MIX DESIGN FOR COLD MIXED DENSE GRADED BITUMINOUS MIXTURES

1. SCOPE

1.1 This method describes the procedure for preparing test specimens for Marshall testing and also for additional testing such as air void content and degree of compaction.

1.2 This method is for use with mixtures containing emulsified asphalt and aggregate.

2. RELEVANT DOCUMENTS

2.1 ASTM D 1559

2.2 MTO LS-261

2.3 MTO LS-262

2.4 MTO LS-263

2.5 MTO LS-264

2.6 MTO LS-265

2.7 MTO LS-266

3.1 MTO LS-302

3.2 MTO LS-303

3. APPARATUS

3.1 METAL CONTAINERS: Approximate 6000 g capacity (a 4.5 kg honey pail is convenient).

3.2 MARSHALL MOLDS: Mold cylinders shall conform to details shown in Figure 1.

3.3 COMPACTION HAMMERS:

3.3.1 Hand Type - A 4.54 kg mass free falling 45.7 cm onto a flat circular tamping foot. See Figure 2.

3.3.2 Mechanical Type - A 4.54 kg mass free falling 45.7 cm onto a bevelled circular tamping foot.

3.4 MECHANICAL COMPACTOR: Normally mounted on a concrete base, capable of lifting and dropping three mechanical type hammers the required 45.7 cm.

3.5 PEDESTAL

3.5.1 For hand compaction, a hardwood block, 25 cm x 25 cm x 45 cm high capped with a 25 mm thick steel plate. Three lugs are secured on top of the plate to position the mold during compaction. See Figure 3,4.

3.5.2 The mechanical compactor rests on a 50 mm thick oak plank or two 19 mm thick pieces of fir plywood glued together and bolted to a concrete block 30 cm x 75 cm x 40 cm high. This block rests on six 50 mm x 75 mm x 22 mm thick, rubber-cork-rubber vibration isolation pads. See Figure 5.

- 3.6 CABINET: Soudproof to enclose the mechanical compaction apparatus.
- 3.7 METAL TROUGH: Round bottom, 75 cm long and 13 cm wide at the top.
- 3.8 OVEN: Of suitable capacity and capable of maintaining a temperature of $60 \pm 2.5^{\circ}\text{C}$.
(Required to cure the specimens).
- 3.9 HOT PLATE: Thermostatically controlled and capable of heating emulsified asphalt to a temperature of 60 to $80 \pm 3^{\circ}\text{C}$.
- 3.10 METAL GARDEN TROWEL: Rounded end, slightly curved blade, 18 cm long, approximately 75 mm wide at the top and 50 mm wide at the bottom.
- 3.11 SPATULA: Rounded end, rigid blade, about 25 cm long and 25 mm wide.
- 3.12 MIXER: A mechanical mixer, capable of producing a well-mixed, homogeneous mixture of the required amount in the allowable time. See Figure 6.
- 3.13 KETTLE OR METAL CONTAINER: Sufficient capacity to hold approximately 1 L of emulsified asphalt.
- 3.14 BALANCE: 5 kg capacity, sensitive to 1 g.
- 3.15 METAL SCOOP: Flat bottomed - for batching aggregates.
- 3.16 THERMOMETER: Dial or mercury type suitable for measuring the temperature of emulsified asphalt in the range of 20 to $80 \pm 3^{\circ}\text{C}$.
- 3.17 DEMOLDING SOLUTION: (Solar Concentrated Liquid Soap) mixed 1:25 parts with water or any suitable solution that will prevent the mix from adhering to the molds, hammer feet and metal trough and will not affect the asphalt.
- 3.18 GLOVES: For handling equipment.
- 3.19 STOP WATCH OR TIMER.

4. TEST PROCEDURE

- 4.1 Arrange the individually sized coarse aggregate in bags or in suitable containers on a bench in order of decreasing sieve sizes.
- 4.2 Place the pass 4.75 mm of the coarse aggregate and the fine aggregate(s) in individual flat bottom pans of suitable size.
- 4.3 Using the flat bottom scoop weigh, in the metal containers, a 3800 g oven-dried sample of the selected aggregates.
- 4.4 Place the aggregate in the mixing bowl and add moisture (cold tap water) equivalent to the site moisture content. Mix thoroughly for 60 s, cover with a damp towel and let stand for 1 h.
- 4.5 Heat the emulsion to 60°C and add a previously determined amount to the moistened aggregate. Mix for 60 s maximum.
- 4.6 Remove the trough and molds from the oven. Apply a thin coating of the demolding solution to the trough, the molds (lower section and base plates) and the tamping face of each hammer used.

- 4.7 At the end of the mixing cycle, scrape as much of the mix as possible from the mixing padle and scraper blade using the spatula.
- 4.8 Spread the mixture into the metal trough using a back and forth motion. Scrape all the loose mixture in the bowl into the trough.
- 4.9 Using the metal trowel for removing the mix from the trough, place approximately 1250 g into each of the tared molds. Weigh in sufficient quantities of the mixture to produce compacted briquette(s) with volumes ranging from 509 to 522 mL. Refer to: MTO Mix Design Manual for bituminous materials, for approximate weights of briquettes for each aggregate type. Make certain that the bottom of the trowel is in contact with the bottom of the trough so that the mixture is not removed in layers.
- 4.10 Using the spatula, quickly rod the mixture in the mold 25 times - 15 around the outside, 10 around the centre. When rodding around the outside, keep the spatula blade flat against the inside of the mold. When rodding around the inside, do not change direction of the blade and finish by leaving a small cone of mix in the centre of the mold.
- 4.11 The three briquettes shall be compacted immediately. If hand hammers are used, each briquette receives 75 blows per side. Make sure the hammer is kept as vertical as possible during compaction. With the mechanical hammer, 60 blows are given to each side.
- 4.12 A second set of three briquettes is prepared as described in Section 4.1.1 to 4.1.11.
- 4.13 Leave the six specimens in their molds and place in the oven set at 60°C for 3 h.
- 4.14 Remove the specimens from the oven and carefully extract the specimens from the molds. Immediately place the specimens back in the oven for an additional 17 h.
- 4.15 Remove the briquettes from the oven and allow them to cool to room temperature in preparation for determination of the Bulk Relative Densities.

5. REPORT

- 5.1 For identification purposes, number each briquette. This can be related to the stone content and asphalt content.

6. GENERAL NOTES AND PRECAUTIONS

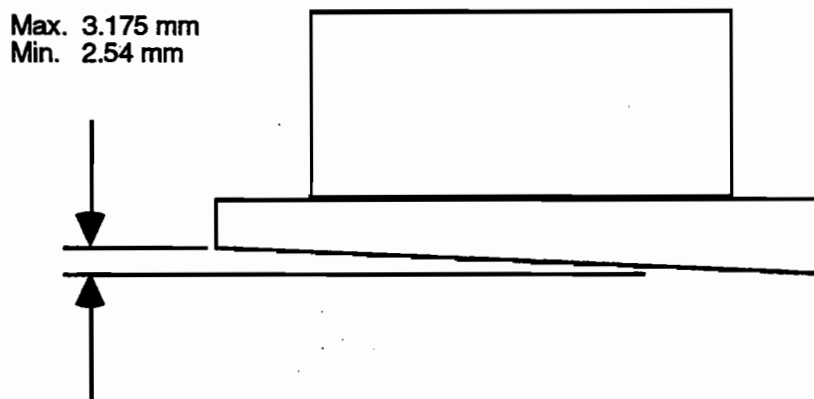
- 6.1 HAND COMPACTION
- 6.1.1 The wooden pedestal should be level and firmly emplaced in sand or soil.
- 6.1.2 When compacting, keep the hammer shaft vertical.
- 6.2 MECHANICAL COMPACTION
- 6.2.1 Ensure that the compactor is levelled and securely fastened to the pedestal.
- 6.2.2 Ensure that the molds rotate at 1/3 revolution per hammer blow.

6.2.3 With the bevelled tamping foot, the position of the foot (i.e. the thick edge to the front, sides, or back) may change the percentage compaction. The foot must be positioned so that maximum compaction is obtained.

6.2.4 The hammers must be secure and the ball masses in place.

6.2.5 The hammers weights must be picked up at the bottom and released at the top of the stroke without missing.

6.2.3 Every fifty compaction tests or if compaction testing is not carried out frequently, at least once a year, check the bevel of the mechanical hammer tamping foot. If the bevel is less than 2.54 mm, as measured with a micrometer, maximum compaction may not be obtained.



7. HAZARDS

- 7.1 Handle all hot equipment with heat resistant gloves.
- 7.2 Always use the rubber hand guards with the hand hammers.
- 7.3 Wear proper protective safety gear for each operation.
- 7.4 Adequate ventilation is essential when using solvent.

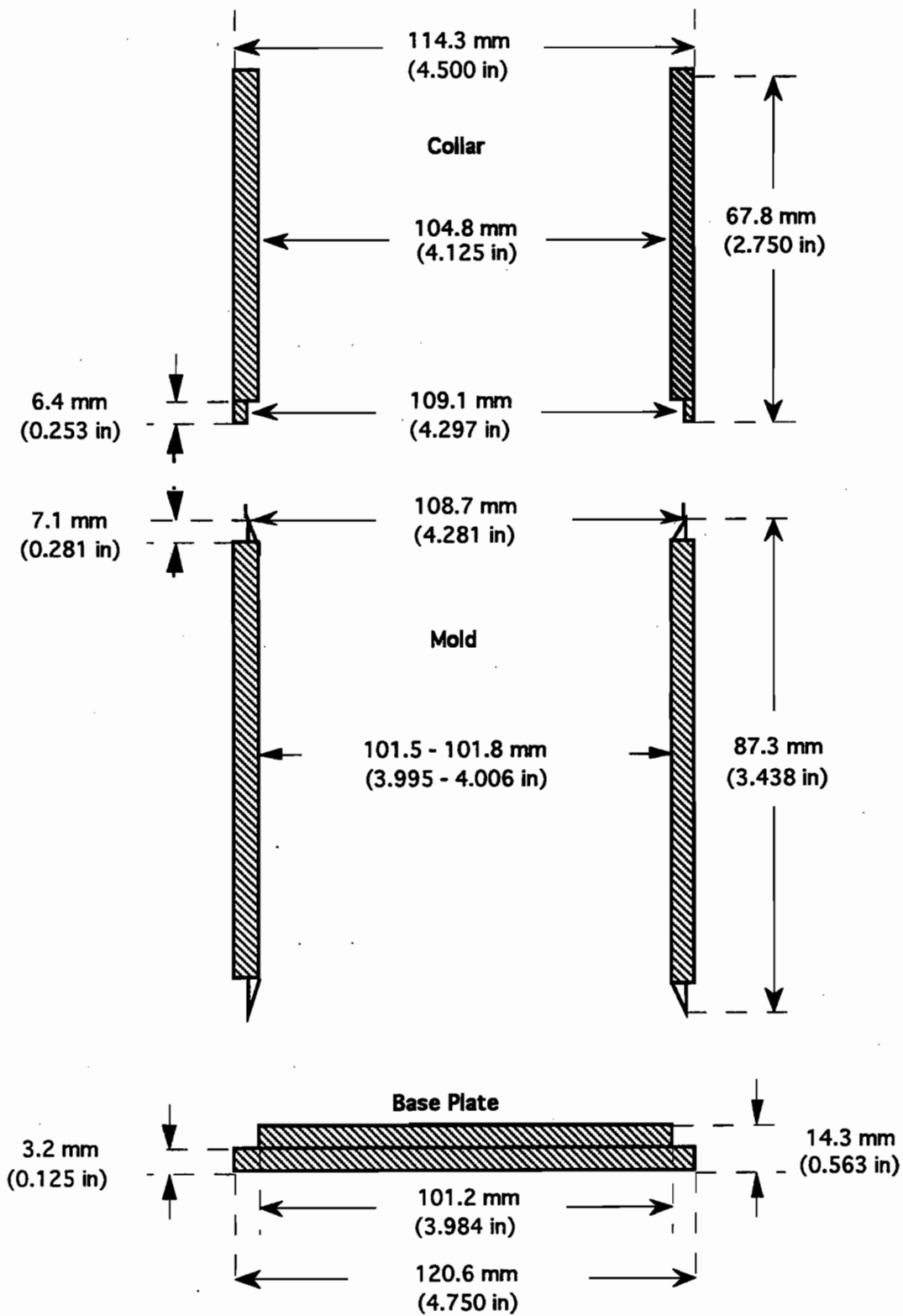


Figure 1
Dimensions for 4" Compaction Mold

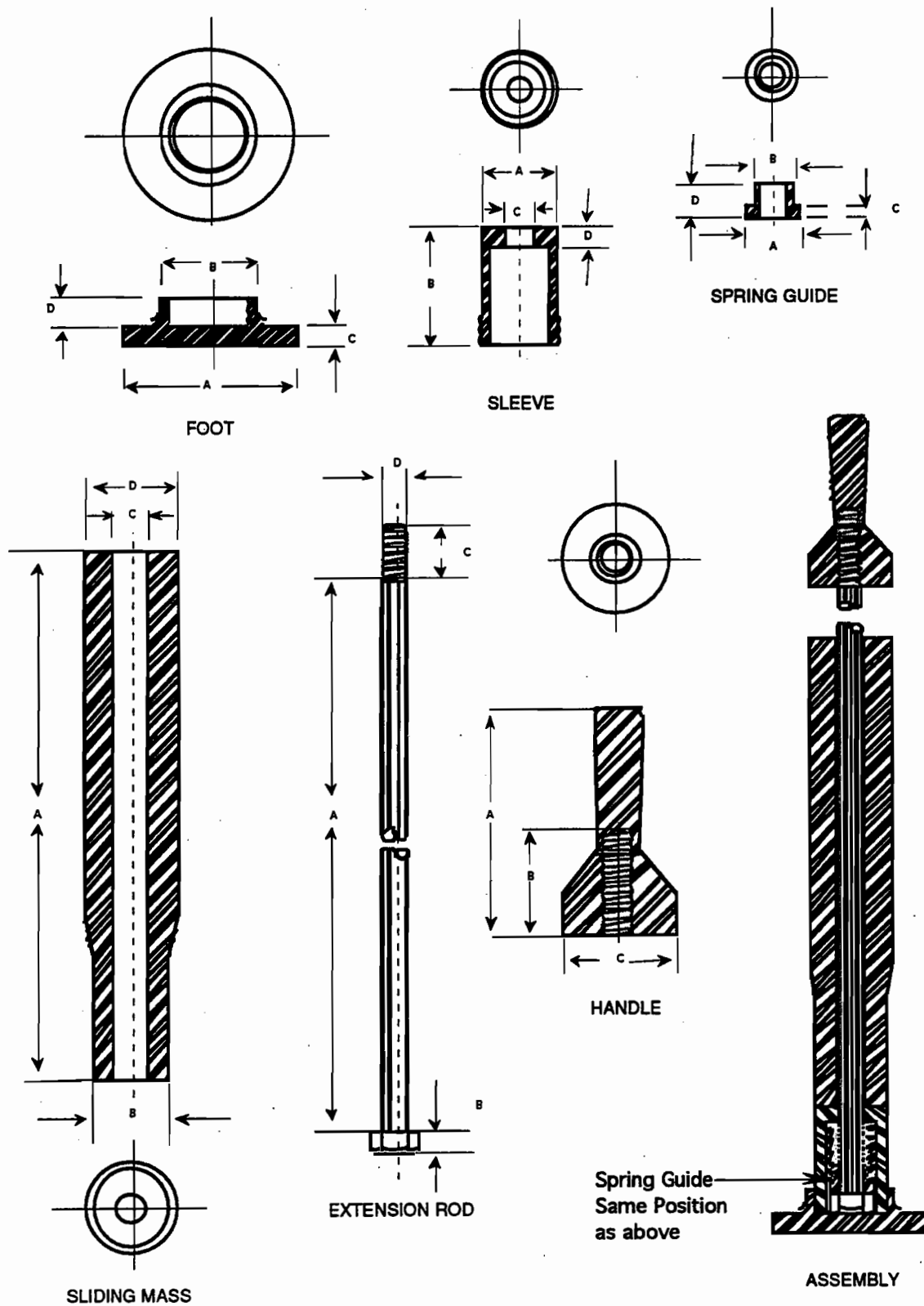


Figure 2
Dimensions for Manual Marshall Compaction Hammer

Table 1
Dimensions for Marshall 4" Manual Compaction Hammer

Measurement Location*	Hammer					
	Actual Hammer Measurements			Specification		
	inches	mm	grams	inches	mm	grams
Handle						
A				5.50	139.7	-
B				2.00	50.8	-
C				2.25	57.2	-
Foot						
A				3.88	98.6	-
B				2.25	57.2	-
C				0.50	12.7	-
D				0.63	16.0	-
Sleeve						
A				1.75	44.4	-
B				2.25	57.2	-
C				0.63	16.0	-
D				0.38	9.7	-
Spring Guide						
A				1.25	31.8	-
B				0.94	23.9	-
C				0.25	6.4	-
D				0.75	19.0	-
Extension Rod						
A				32.5	825.5	-
B				0.50	12.7	-
C				1.50	38.1	-
D				0.63	16.0	-
Sliding Mass						
A				12.0	304.8	4535 ±9**
B				1.75	44.4	-
C				0.69	17.5	-
D				2.16	54.9	-
Spring (1) -						
unconfined				2.1	53.3	-
confined				1.50	38.1	-
I/D coil				> 0.94***	> 23.88***	-
wire diameter				0.155	3.94	-
Overall Mass				-	-	7853 ±16**

* See Figure 2 for dimension locations.

** Including finger guard

*** Just slightly larger than .94" (23.88mm)/

(1) Spring: # of coils = 5

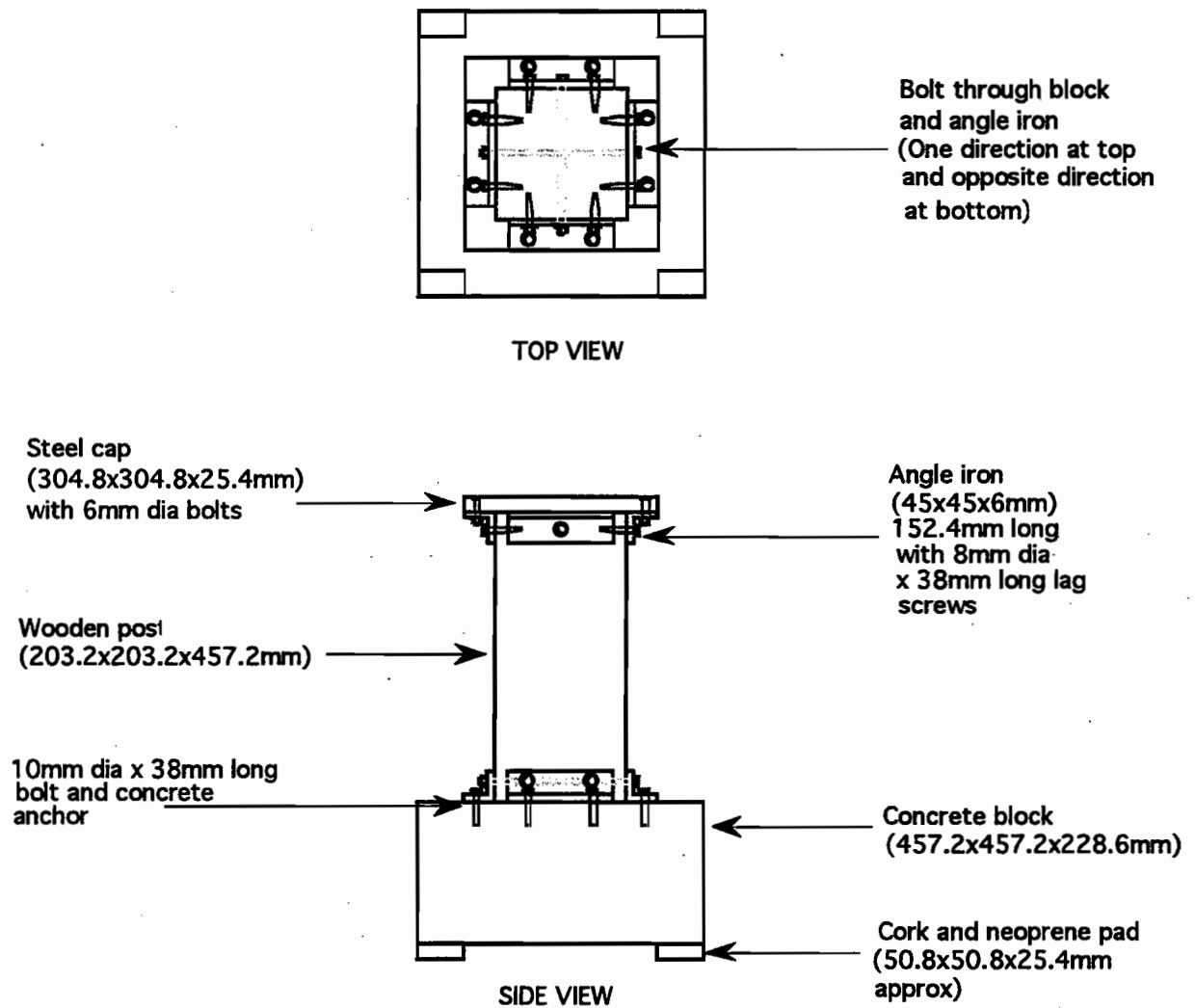


Figure 3
Compaction Pedestal (without mold holder)

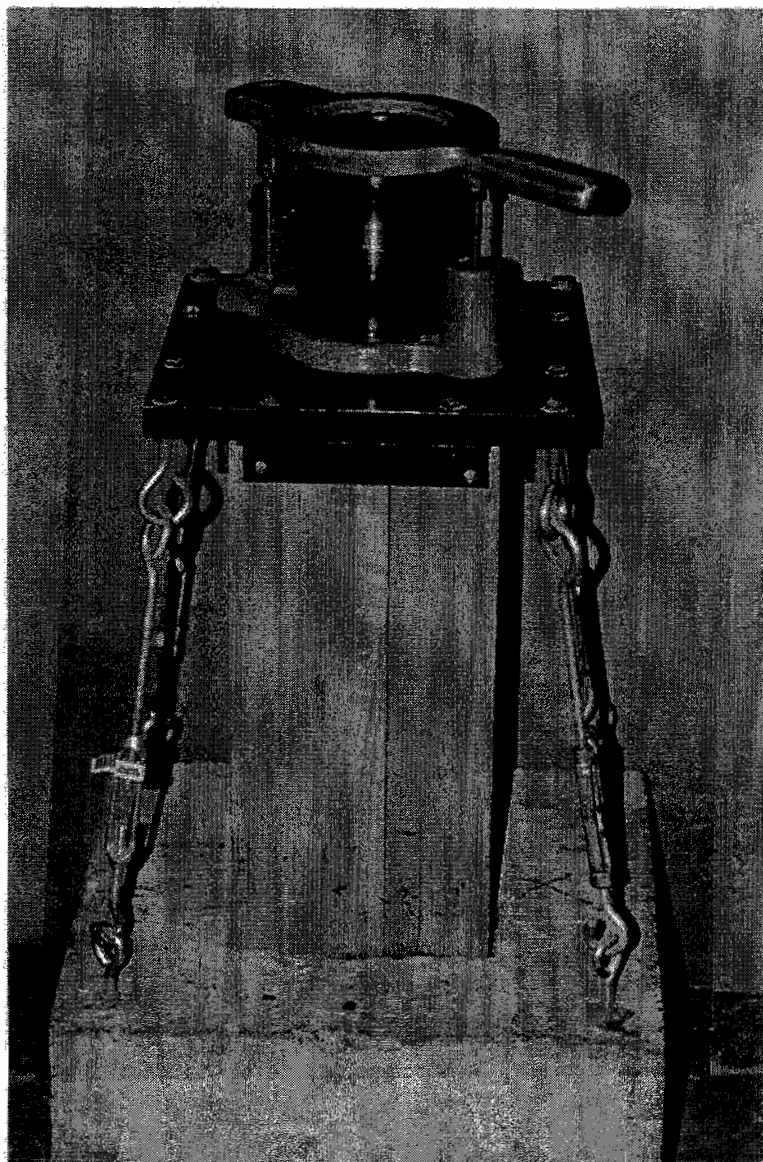


Figure 4
Pedestal (with Mold Holder)

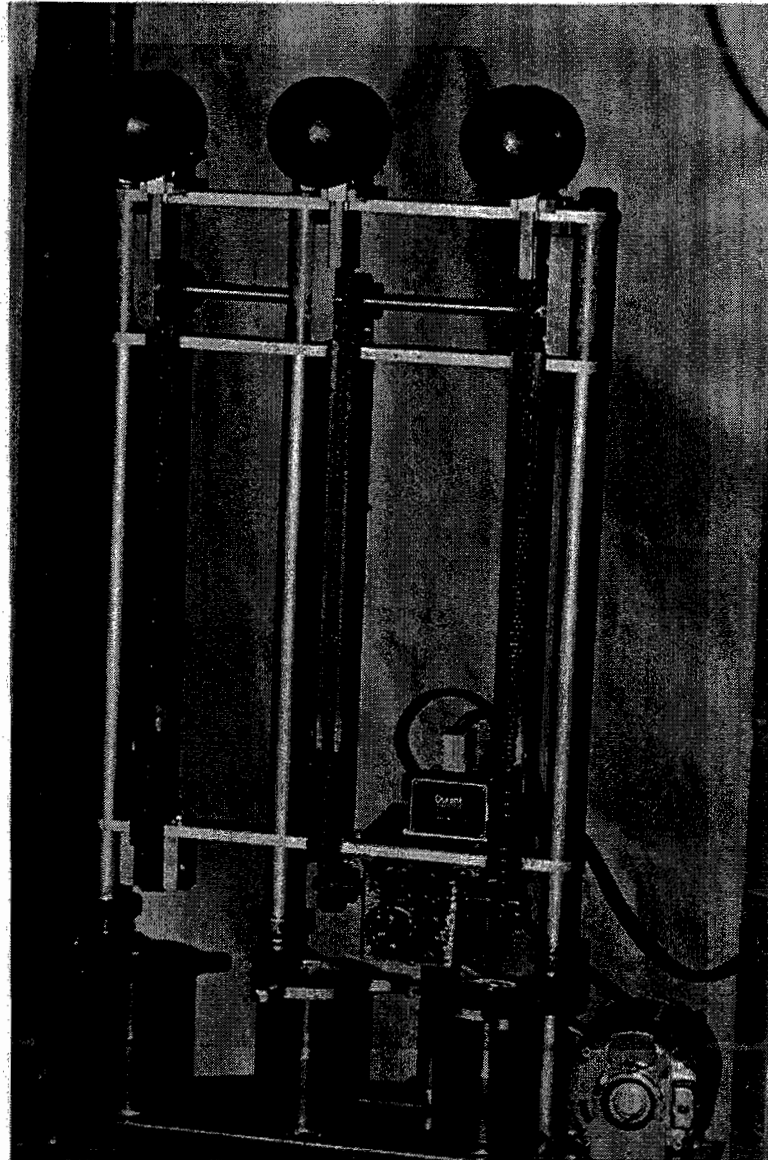


Figure 5
Mechanical Compactor

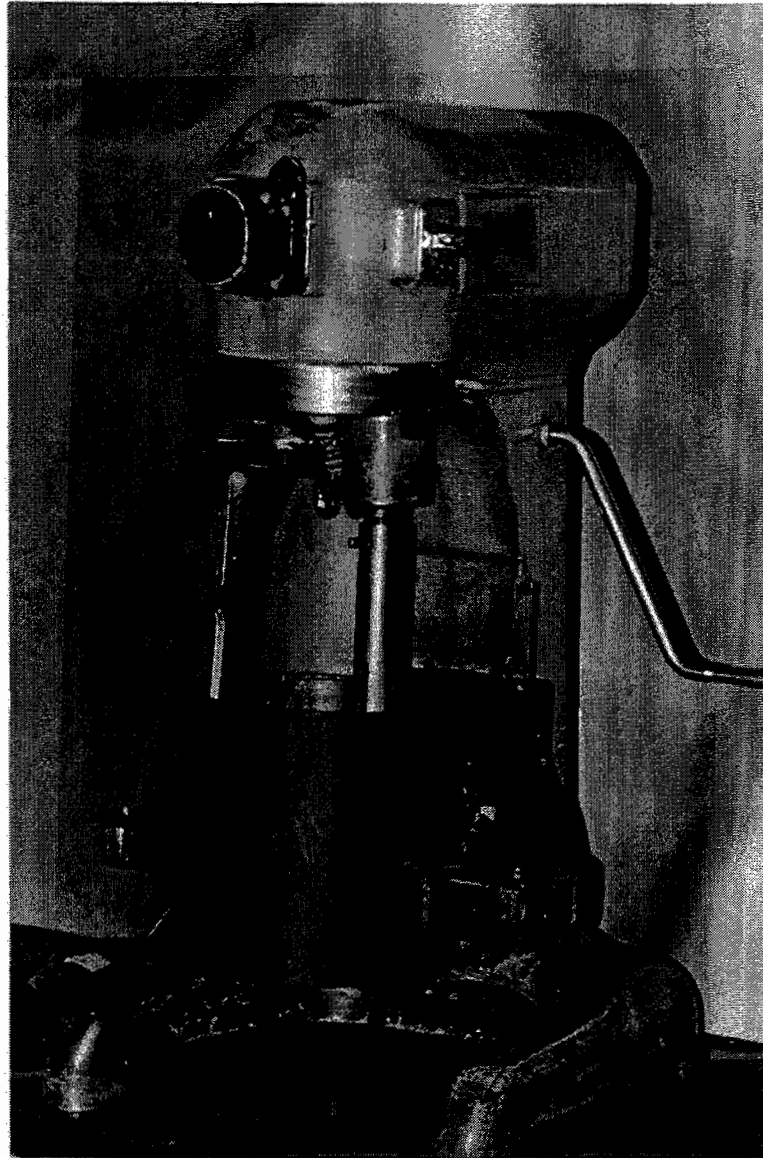


Figure 6
Mechanical Asphalt Mixer

METHOD OF TEST FOR COATING DENSE GRADED AGGREGATES

1. SCOPE

1.1 This method covers the procedure for the mixing of an emulsified asphalt with an aggregate and then rinsing the mixture with water after the completion of the mixing cycle.

1.2 This method is to be used only to evaluate the suitability of dense graded aggregates for cold mix pavements.

2. RELEVANT DOCUMENTS

2.1 Asphalt Institute - Manual Series No. 19.

2.2 MTO LS-701

2.3 MTO LS-706

3. DEFINITION

This coating test performs two functions:

(1) The coating of aggregate after mixing provides an indication of the ability of the emulsion to coat the surface of an aggregate particle which may be excessively dirty.

(2) The rinsing provides a measure of the demulsibility of the emulsion and its ability to resist washing off in the event of rainfall occurring shortly after the placing of the mixture.

4. APPARATUS

4.1 BALANCE: Minimum of 1000 g capacity and accurate to 0.1 g.

4.2 HOT PLATE: Thermostatically controlled.

4.3 MIXING BOWL: A round bottom kitchen saucepan of approximately 1 L capacity.

4.4 SPATULA: A steel spatula, or its equivalent, having blade length of approximately 200 mm.

4.5 ROOFING PAPER.

5. TEST PROCEDURE

5.1 Obtain a representative aggregate gradation with limits of 100 % passing 13.2 mm and retained on 4.75 mm sieves. Weigh out 500 g of these dried aggregates and place into a metal mixing bowl. The aggregate should be at 25°C (room temperature).

5.2 Moisten the aggregate with tap water using a quantity equivalent to the site moisture content of the aggregate. Mix the water and aggregate with the steel spatula until thoroughly coated. Cover with a damp towel and let stand 1 h.

5.3 Heat the emulsion to 60°C on the hot plate and add a quantity equivalent to the % Optimum Moisture Content, (see LS-706), of the aggregate minus the % Site Moisture Content. Mix the emulsion and aggregate with the metal spatula for 3 minutes or less to obtain 100 % coating. Record the time when the mixture stiffens.

Note 1: 100 % coating may not be achieved with all mixes.

Note 2: Do not rate non-cohesive mixes which fail to stiffen.

5.4 Place the mixture on roofing paper and let stand for 30 min.

5.5 Put approximately 50 % of the mixture into the bowl.

5.6 Direct a gentle stream of water down the side of the bowl. Rinse the mixture until the water runs clear. Drain off all the water and spread onto the roofing paper.

5.7 Allow the rinsed and unrinsed samples to completely air dry on roofing paper at room temperature.

5.8 Visually rate the percent coating, (See Section 7), and estimate the cohesive properties of the rinsed and unrinsed mixtures.

5.9 If necessary, mixtures using higher or lower emulsion quantities may be tried to achieve the desired percent coating.

6. CALCULATIONS

Preliminary estimates of emulsion quantities are determined in the following manner:

$$\text{OMC} - \text{SMC} = \% \text{ Emulsion required}$$

where:

OMC = % Optimum Moisture Content of Aggregate.

SMC = % Site Moisture Content of Aggregate.

7. REPORTING OF RESULTS

7.1 VISUAL RATING CRITERIA: Aggregate coating quality shall be made on the basis of visual observations of the aggregate coating. There are three ratings available for this visual coating classification.

7.1.1 Excellent: 90 - 100 % of the aggregates coated.

7.1.2 Fair - Good: 80 - 90 % of the aggregates coated.

7.1.3 Poor: Less than 80 % of the aggregates coated.

7.2 Adjustments to the emulsion formulation within the specifications should be considered. If a minimum coating of 80 % cannot be achieved this should be reported and the aggregate shall be tested with a liquid asphalt.

7.3 Non-stiffening mixtures shall not be visually rated, report the mix as non-stiffening.

METHOD OF TEST FOR DETERMINATION OF PERCENT MOISTURE PICK UP IN COMPACTED DENSE GRADED BITUMINOUS MIXTURES

1. SCOPE

1.1 This method indicates the amount of water absorption into the compacted specimen after immersion in water. The amount of absorption of moisture into the specimen is indicative of its permeability and resistance to moisture penetration.

2. RELEVANT DOCUMENTS

- 2.1 Asphalt Institute - Manual Series No. 19.
- 2.2 MTO LS-262
- 2.3 MTO LS-263

3. APPARATUS

- 4.1 BALANCE: Minimum of 1000 g capacity and accurate to 0.1 g.
- 4.2 PAPER TOWELS OR CLOTH.

4. PROCEDURE

- 5.1 After 24 h immersion in a water bath maintained at 60°C, remove the briquettes and allow them to drain for 1 h at room temperature.
- 5.2 Surface dry the briquettes and weigh them in air to 0.1 g accuracy.

5. CALCULATIONS

$$M = \frac{A_2 - A_1}{A_1} \times 100$$

where

M = Percent Moisture Pickup

A₁ = Mass of briquette in air, g (Refer to LS-262)

A₂ = Surface dry mass of briquette in air after draining for 1 h, g.

6. REPORTING OF RESULTS

- 7.1 Percent Moisture Pickup is reported to one decimal place.

METHOD OF TEST FOR COATING OPEN-GRADED AGGREGATES

1. SCOPE

1.1 This method covers the procedure for the mixing of an emulsified asphalt with an aggregate and then rinsing the mixture with water after the completion of the mixing cycle.

This coating test performs two functions:

- (1) The coating of aggregate after mixing provides an indication of the ability of the emulsion to coat the surface of a stone particle which may be excessively dirty,
- (2) The rinsing provides an evaluation of the demulsibility of the emulsion and its ability to resist washing off in the event of a rain-fall occurring shortly after the placing of the mixture.

2. RELEVANT DOCUMENTS

- 2.1 Asphalt Institute - Manual Series No. 19.

3. APPARATUS

- 3.1 BALANCE: Minimum of 1000 g capacity and accurate to 0.1 g.
- 3.2 HOTPLATE: Thermostatically controlled.
- 3.3 MIXING BOWL: A round bottom kitchen saucepan of approximately 1 L capacity.
- 3.4 SPATULA: A steel spatula, or its equivalent, having a blade approximately 200 mm in length.
- 3.5 ROOFING PAPER.

4. TEST PROCEDURE

4.1 Using a representative gradation with limits of 100 % passing 13.2 mm and retained on 4.75 mm, weigh 500 g of dried aggregates into a metal mixing bowl. The aggregate should be at 25°C (room temperature).

4.2 Moisten the aggregate with a sufficient amount of tap water so that the aggregate surface is in a surface damp condition. Normally, this is just enough to darken the aggregate surface with no evidence of free water. Use the spatula for mixing the water and aggregate. Cover with a damp towel and let stand for 1 h.

4.3 Heat the emulsion to 60°C on the hotplate and add 6 % emulsion (based on the dry aggregate weight) to the centre of the aggregate in the bowl. Using the metal spatula, quickly mix the emulsion and aggregate until the mix is 100 % coated or no longer than three min. Record the time when the mixture stiffens.

- 4.4 Place mixture on roofing paper and let stand for 30 min.
- 4.5 Put approximately 50 % of the mixture into the bowl.
- 4.6 Directing a gentle stream of water down the side of the bowl, rinse the mixture until the water runs clear. Drain off all the water.
- 4.7 Allow the rinsed and unrinsed samples to completely air dry on roofing paper at room temperature.
- 4.8 Visually rate the percent coating of the rinsed and unrinsed samples.
- 4.9 If required, mixtures using higher or lower emulsion quantities may be necessary to achieve the desired percent coating.

5. REPORTING OF RESULTS

- 5.1 90 % coating is considered as excellent.
- 5.2 80 % coating is considered as fair to good.
- 5.3 Less than 80 % coating is considered as poor and the aggregate/emulsion mix should be rejected.
- 5.4 Should the coating be less than 80 %, adjustments to the emulsion formulation within the specifications should be considered. The tests should be repeated with a suitable emulsion.

METHOD OF TEST FOR DETERMINATION OF RUN OFF FOR OPEN GRADED MIXTURES

1. SCOPE

1.1 This method covers the procedure for the mixing of an emulsified asphalt with an open graded aggregate and placing the mixture in a wire screen funnel where the excess asphalt is allowed to drain off.

2. RELEVANT DOCUMENTS

2.1 Asphalt Institute - Manual Series No. 19.

3. DEFINITION

The asphalt coating retained on the aggregate, after the excess emulsion has drained off, is the desired amount of asphalt needed to obtain 100 % coating of the aggregate. Any excess asphalt is considered run-off, and this quantity should be kept to a maximum of 0.5 % residual asphalt by weight of dry aggregate.

4. APPARATUS

- 4.1 BALANCE: Minimum of 1000 g capacity and accurate to 0.1 g.
- 4.2 HOTPLATE: Thermostatically controlled.
- 4.3 MIXING BOWL: A round-bottom kitchen saucepan of approximately 1 L capacity.
- 4.4 SPATULA: A steel spatula, or its equivalent, having a blade approximately 200 mm in length.
- 4.5 WIRE SCREEN FUNNEL: Approximately 125 mm diameter at the top, closed at the bottom, approximately 390 mm in length and made of 850 μ m mesh wire screen.
- 4.6 OVEN: Of suitable capacity and capable of maintaining a temperature of $110 \pm 3^{\circ}\text{C}$.
- 4.7 LABORATORY STAND AND HOLDER: To hold the wire mesh funnel.
- 4.8 BEAKERS: 600 mL capacity.

5. TEST PROCEDURE

5. Using a representative gradation with limits of 100 % passing 13.2 mm and retained on 4.75 mm, weigh 500 g of dried aggregates into a metal mixing bowl. The aggregate should be at 25°C (room temperature).

5.2 Moisten the aggregate with a sufficient amount of tap water so that the aggregate surface is in a surface damp condition. Normally, this is just enough to darken the aggregate surface with no evidence of free water. Use the spatula for mixing the water and aggregate.

5.3 Heat the emulsion to 60°C on the hotplate and add to the aggregate a predetermined mass of emulsion to obtain a desired 100 % coating of the aggregate. Mix with the metal spatula until the mixture is 100 % coated or no longer than three min. Mixtures using varying amounts of emulsion may have to be tried to obtain the desired 100 % coating.

5.4 Pour or spoon all of the mixture into the 850 µm mesh wire screen funnel which has been positioned over a 600 mL beaker.

5.5 Allow the mixture to drain into the beaker at room temperature for 30 min.

5.6 Place the beaker containing the excess asphalt (run-off) into an oven set at 110°C and dry to a constant mass. Determine the final mass.

5.7 Determine the mass of all samples to 0.1 g accuracy.

6. CALCULATIONS

$$6.1 \quad \% \text{ Run-off} = \frac{\text{Mass of beaker and residue} - \text{Mass of beaker}}{\text{Dry aggregate mass}} \times 100$$

7. REPORTING OF RESULTS

7.1 Calculate % Run-off to 0.1 % accuracy.

7.2 A 100 % coating of the aggregate is required.

7.3 Mixtures are considered acceptable if their run-off is less than 0.5 % residual asphalt by weight of dry aggregate.

**METHOD OF TEST FOR
BULK RELATIVE DENSITY OF
COMPACTED BITUMINOUS MIXTURES
USING PARAFFIN COATED SPECIMENS**

1. SCOPE

1.1 This method covers the procedure for the determination of the bulk relative density of compacted bituminous mixtures with air voids of approximately 10 % and greater.

2. RELEVANT DOCUMENTS

2.1 ASTM D1188

2.2 MTO Method LS-262

3. DEFINITION

3.1 The bulk relative density of a compacted bituminous mixture is the ratio of the mass in g of the specimen in air to the mass in g of an equal volume of water at a specified temperature which is generally 25°C.

4. APPARATUS

4.1 **BALANCE:** Minimum of 2000 g capacity and accurately to 0.1 g.

4.2 **WIRE BASKET:** Made from copper or brass wire mesh, 20 cm dia. by 18 cm high to contain a sample when determining mass in water. For flat pavement samples, a flat piece of copper or brass wire mesh approximately 20 cm square.

4.3 **THIN COPPER WIRE:** To suspend basket or platform from balance.

4.4 **CONTAINER:** 60 to 90 L capacity galvanized or plastic garbage can with an overflow spout to maintain a constant water level.

4.5 **REFRIGERATING UNIT:** Capable of maintaining a temperature of approximately 4°C.

4.6 **WAX BATH:** Thermostatically controlled electric pot.

4.7 **PARAFFIN**

4.8 **POWDERED TALC:** For dusting specimens.

4.9 **CONSTANT TEMPERATURE OVEN:** With a range of 110 to 170 ± 5°C.

5. TEST PROCEDURE

5.1 Allow the specimen to stand in air for at least 1 h. Carefully brush off any loose particles adhering to the sample, determine the mass and record the sample mass in air, as "A".

5.2 If further tests on the specimens will be required, the wax can be removed easier by liberally dusting the specimen with powdered talc prior to coating with wax. Determine the mass of the talc-coated sample mass in air as "A₁".

5.3 Easier removal of the paraffin coating may be accomplished by first chilling the specimen in a refrigerating unit to a temperature of approximately 4°C for 30 min. and then dipping the specimen in warm wax (5°C above the melting point).

5.4 Coat the test specimen on all surfaces with melted paraffin sufficiently thick to seal all surface voids. Small holes in the coating may be filled in by brushing on hot paraffin. Allow the sample to cool in air at room temperature for a minimum of 30 min. Again determine the mass and record the talc/paraffin coated sample mass in air as "A₂".

5.5 Determine the waxed sample mass in water and record a "B".

5.6 If air bubbles are noticed rising from the specimen during the weighing in water, it indicates that holes are present in the wax coating and water is being absorbed into the specimen. Quickly remove the specimen from the water and seal the pin hole(s) using a hot spatula. After attaining the mass of the specimen in water, surface dry the specimen with a towel and record the new mass in air as "A₃".

5.6.1 When a Marshall briquette or pavement core is being weighed, rest the sample with the curved side on the bottom of the basket.

5.6.2 When a rectangular pavement sample is being weighed, place the sample on its side or end on the bottom of the basket.

5.7 Determine the mass of all samples to 0.1 g accuracy.

6. CALCULATIONS

6.1 Calculate the bulk relative density of the sample as follows:

$$\text{Bulk Relative Density} = \frac{A}{A_3 - B - \left\{ \frac{A_1 - A}{D_1} + \frac{A_2 - A_1}{D_2} \right\}}$$

- where
- | | | |
|----------------|---|--|
| A | = | Mass of dry specimen in air, g. |
| A ₁ | = | Mass of specimen plus talc coating in air, g. |
| A ₂ | = | Mass of specimen including talc plus paraffin coating in air, g. |
| A ₃ | = | Surface dry mass of specimen including talc plus paraffin after immersion in water, g. |
| B | = | Mass of specimen including talc and paraffin, in water, g. |
| D ₁ | = | Bulk relative density of talc. |
| D ₂ | = | Bulk relative density of paraffin. |

6.2 Moisture correction for pavement, or other specimens that may contain absorbed moisture, is done in the following manner:

- 6.2.1 Remove the paraffin coating and brush off the talc.
- 6.2.2 Place the uncoated sample in an oven maintained at a temperature of approximately 110°C.
- 6.2.3 Dry the sample to a constant mass.
- 6.2.4 Record this corrected mass in "A" (dividend only).

7. REPORTING OF RESULTS

- 7.1 Report the sample number.
- 7.2 Report the bulk relative density to three decimal places with the third decimal place having been "rounded off".

8. GENERAL NOTES AND PRECAUTIONS

- 8.1 When determining the mass of samples in water both the basket and handle, where provided, must be completely immersed in water.
- 8.2 Be certain that no air bubbles adhere to the wire basket or waxed specimen when it is immersed in water.
- 8.3 Use as thin a wire as possible to suspend the basket from the balance.
- 8.4 For Marshall briquettes, all bulk relative density (B.R.D.) determinations should be done in triplicate. If the B.R.D. of any one briquette is more than 0.015 from the mean of the triplicate values, recheck the calculations and, if necessary, re-weigh.
- 8.5 If the percentage voids for any one briquette is less than 0.5 % from the mean of the triplicate values, then the B.R.D., M.R.D. and percent void values of that briquette are acceptable.
- 8.6 Mass of pavement samples should be minimum of 1000 g.
- 8.7 Pavement samples must be free of cracks.
- 8.8 The water in the weigh bucket must be maintained as close to room temperature as possible (25°C).
- 8.9 B.R.D. for talc is 2.78.
- 8.10 B.R.D. for paraffin is 0.89.
- 8.11 The above noted B.R.D.s are only for the products tested by the MTO Downsview Laboratory and may vary with the sources of material.

METHOD OF TEST FOR DRY RODDED DENSITY OF COARSE AGGREGATE

1. SCOPE

- 1.1 This method covers the determination of the dry rodded density of coarse aggregate.

2. RELEVANT DOCUMENTS

- 2.1 CSA - A23.2 10 A

3. PROCEDURE

- 3.1 Procedure of CSA Standard A23.2 10A shall be followed.

METHOD OF MAKING AND CURING CONCRETE COMPRESSION AND FLEXURE TEST SPECIMENS IN THE LABORATORY

1. SCOPE

1.1 This test method covers procedures for making and curing compression specimens of concrete in the laboratory under accurate control of quantities of materials and test conditions using concrete that can be consolidated by rodding or vibration.

2. RELEVANT DOCUMENTS

2.1 CSA A 23.2 2C

2.2 CSA A 23.2 3C

3. PROCEDURE

3.1 Procedures of CSA Standard A 23.2 2C and A 23.2 3C shall be followed, except as noted below.

4. EXCEPTIONS

4.1 COMPRESSION SPECIMEN

The specimen shall be cylindrical with a length equal to twice the diameter. The standard compression specimen is a cylinder having a 150 mm diameter and 300 mm length. The standard size cylinder is suitable for concrete with aggregates not exceeding 40 mm in nominal size. If other than the standard specimen is used, its diameter shall be a minimum of 75 mm. The diameter of the specimen shall be at least 3 times the maximum nominal size of the coarse aggregate in the concrete.

4.2 FLEXURE SPECIMEN

The standard flexure specimen is 150x150x500 mm.

4.3 PREPARATION OF COARSE AGGREGATE

The coarse aggregate (as received) shall be brought to an oven -dry condition by drying in an oven at $110 \pm 5^{\circ}\text{C}$ to a constant mass and then cooling it to the temperature of 20 to 25°C . Its mass shall be determined in the dry condition in the amount required for the batch, placed into a watertight container and then brought to a saturated condition by immersion in water for 24 ± 4 h. After immersion, excess water is drained by opening valve at the bottom of the container, and then the container is completely emptied into a pre-tarred open-mouth metal tray. The mass of the tray with its contents is then determined and the tray emptied into the pan of the mixer. The mass of the total

water in the aggregate (absorbed and surface water) is calculated by subtracting the mass of the dry aggregate from the mass of the wet aggregate.

4.4 PREPARATION OF FINE AGGREGATE

The fine aggregate shall be prepared in the same manner as the coarse aggregate except that , instead of immersing it in water, it shall be placed into a watertight container in approximately three equal layers. Each layer shall be mixed with water by means of spade or shovel. The total amount of water shall be approximately 6 % of the mass of the aggregate.

Note: The use of more water than 6 % by mass of the fine aggregate to saturate the fine aggregate may cause excessive water content in the concrete and result in a rejection of the batch.

METHOD OF TEST FOR SLUMP OF PORTLAND CEMENT CONCRETE

1. SCOPE

- 1.1 This method of test covers the procedure for determining slump of freshly mixed concrete.

2. RELEVANT DOCUMENTS

- 2.1 CSA A23.2 1C
- 2.2 CSA A23.2 5C

3. PROCEDURE

- 3.1 Procedures of CSA Standard A23.2 1C and A23.2 5C shall be followed.

**METHOD OF TEST FOR
AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE PRESSURE METHOD**

1. SCOPE

1.1 This method covers the determination of the air content of freshly mixed concrete from observations of the change in volume with a change in pressure.

2. RELEVANT DOCUMENTS

2.1 CSA-A 23.2 4C

3. PROCEDURE

3.1 Procedure of CSA Standard A 23.2 4C shall be followed.

**METHOD OF TEST FOR
AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE VOLUMETRIC METHOD**

1. SCOPE

1.1 This method covers the procedure for determining the air content of freshly mixed concrete containing any type of aggregate, whether it be dense, cellular, or lightweight.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-7C

3. PROCEDURE

3.1 Procedures of CSA Standard A23.2-7C shall be followed.

METHOD OF TEST FOR DENSITY, YIELD AND CEMENTING MATERIALS FACTOR OF PLASTIC CONCRETE

1. SCOPE

1.1 This method of test covers the procedure for determining the density of freshly mixed concrete and gives formulae for calculating the :

- (a) volume of concrete produced from a mixture of known quantities of the component materials
- (b) yield,
- (c) cementing materials factor

2. RELEVANT DOCUMENTS

- 2.1 CSA-A23.2-1C
- 2.2 CSA-A23.2-6C

3. PROCEDURE

- 3.1 Procedures of CSA Standards A23.2-1C and 6C shall be followed.

METHOD OF TEST FOR SLUMP OF PORTLAND CEMENT CONCRETE

1. SCOPE

- 1.1 This method of test covers the procedure for determining slump of freshly mixed concrete.

2. RELEVANT DOCUMENTS

- 2.1 CSA A23.2 1C
2.2 CSA A23.2 5C

3. PROCEDURE

- 3.1 Procedures of CSA Standard A23.2 1C and A23.2 5C shall be followed.

**METHOD OF TEST FOR
AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE PRESSURE METHOD**

1. SCOPE

1.1 This method covers the determination of the air content of freshly mixed concrete from observations of the change in volume with a change in pressure.

2. RELEVANT DOCUMENTS

2.1 CSA-A 23.2 4C

3. PROCEDURE

3.1 Procedure of CSA Standard A 23.2 4C shall be followed.

**METHOD OF TEST FOR
AIR CONTENT OF FRESHLY MIXED CONCRETE
BY THE VOLUMETRIC METHOD**

1. SCOPE

1.1 This method covers the procedure for determining the air content of freshly mixed concrete containing any type of aggregate, whether it be dense, cellular, or lightweight.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-7C

3. PROCEDURE

3.1 Procedures of CSA Standard A23.2-7C shall be followed.

METHOD OF TEST FOR DENSITY, YIELD AND CEMENTING MATERIALS FACTOR OF PLASTIC CONCRETE

1. SCOPE

1.1 This method of test covers the procedure for determining the density of freshly mixed concrete and gives formulae for calculating the :

- (a) volume of concrete produced from a mixture of known quantities of the component materials
- (b) yield,
- (c) cementing materials factor

2. RELEVANT DOCUMENTS

- 2.1 CSA-A23.2-1C
- 2.2 CSA-A23.2-6C

3. PROCEDURE

- 3.1 Procedures of CSA Standards A23.2-1C and 6C shall be followed.

METHOD OF CAPPING MOULDED CONCRETE CYLINDERS WITH SULPHUR MORTAR

1. SCOPE

1.1 This method covers apparatus, materials and procedures for capping concrete cylinders with sulphur mortar for compressive strength tests.

2. RELEVANT DOCUMENTS

- 2.1 CSA Standard-A 23.2-9C
- 2.2 CSA Standard-A 5

3. PROCEDURE

3.1 Procedures of CSA Standard A23.2 9C and A5 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 APPARATUS

4.1.1 Cylinder capper: The capper shall consist of a machined metal plate and alignment device. The plate shall be at least 12 mm thick and 25 mm greater in diameter than the specimen to be capped. The capping surface shall not depart from a plane by more than 0.05 mm. It shall be free of gouges, grooves or indentations greater than 0.25 mm deep or greater than 30 mm² in surface area. The alignment device shall consist of a base plate and vertical guide plates or bars. The surface planes of the vertical guide plates shall be adjusted so that they do not depart from perpendicularity to the surface of the capping plate by more than 0.5° (approximately equivalent to 1 mm in 100 mm). The location of each guide plate with respect to the capping plate shall be such that no cap will be off-centered on the concrete cylinder by more than 2 mm. The base plate shall be equipped with adjustable legs for levelling the capping surface.

4.1.2 Melting Pot: The pot used for melting sulphur mortar shall be equipped with automatic temperature controls and shall be made of metal. The heating elements shall be separated from the sulphur by a steel wall.

4.1.3 Small Tools: Metal ladle (250 mL), rawhide or nylon hammer, scoop, scraper, brush (50 mm), metal stirring paddle, spoon (30 mL), all-metal thermometer (0 to 200°C), screw-driver, 0.05 mm feeler gauge, 150 mm metal ruler, 100 mm level and cloth wipers.

4.2 MATERIALS

4.2.1 Sulphur Mortar: The capping compound shall be a proprietary mixture of sulphur and granular materials. When tested in accordance with CSA Standard A23.2-9C, the mortar shall have a minimum compressive strength of 35 MPa at 2 hours.

4.3 CAPPING PROCEDURE

4.3.1 Capping: Dry off any excess moisture from the ends of the cylinder with an absorbent cloth or jet of dry air. Place the cylinder near the capper. Oil the capping plate lightly, fill the capper with the molten sulphur mortar and then immediately take the cylinder and, pressing its side surface lightly against the vertical guide plates, lower it gently onto the capping plate and hold it against the guide plates until the sulphur mortar hardens. Then pull the cylinder gently with one hand away from the guide plates and hit the plate with the rawhide hammer with the other hand to release it from the capper. Repeat this procedure to cap the other end of the cylinder. Place the cylinder under a double layer of wet burlap for temporary storage before breaking.

4.3.2 Checking: Check each cylinder cap for bond and large air voids between the cap and the cylinder by sounding with your knuckles. A hollow sound indicates poor bond or air voids. Check the planeness of the caps with the metal ruler and feeler gauge on at least three cylinders, representing the start, middle and end of each day's capping operation.

4.4 GENERAL NOTES

4.4.1 The cylinders must be kept under a double layer of wet burlap when removed from the moisture room and waiting to be capped and then, after capping, either under wet burlap (broken the same day) or in moisture room (broken the next day) when waiting to be tested.

4.4.2 The sulphur mortar must be dry at the time it is placed in the pot to avoid foaming.

4.4.3 Do not reuse the sulphur mortar. Recovered mortar has lower strength and is less pourable due to contamination with oil.

4.4.4 If recess is machined into the metal plate, the thickness of the plate beneath the recess shall not be less than 12 mm. In no case shall the recess be deeper than 12 mm.

4.4.5 The cap shall be 1 to 3 mm thick.

4.4.6 Cylinder ends that are obviously uneven, convex or concave shall be squared before capping by sawing. If a saw is unavailable, the cylinder shall not be tested.

METHOD OF TEST FOR COMPRESSIVE STRENGTH OF MOULDED CONCRETE CYLINDERS

1. SCOPE

1.1 This method covers determination of compressive strength of moulded cylindrical concrete specimens.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-9C

3. PROCEDURE

3.1 Procedure of CSA Standard A 23.2-9C shall be followed, except as noted below.

4. EXCEPTIONS

4.1 REPORTING OF RESULTS: The report shall also include :

4.1.1 The type of fracture

4.1.2 Mass of specimen, in kilograms

Test results obtained on standard concrete cylinders from MTO construction contracts shall be reported on Form PH-CC-322.

4.2 GENERAL NOTES AND PRECAUTIONS

4.2.1 The mass of each field cylinder is determined immediately after arrival of the cylinder in the laboratory (after demoulding) to provide early information on possible deficiencies in the quality of the concrete (high or low air content). This mass is reported to the nearest 0.05 kg together with the compressive strength test result.

4.2.2 All contract cylinders are demoulded and placed in the moisture room immediately after their arrival in the laboratory and kept there until capping and testing in compression.

4.2.3 Before placing capped cylinder in the machine, check caps for any damage or contamination of the surface with sand grains, etc. that might affect the strength of the concrete. If the cap is damaged, it shall be removed and the cylinder recapped. To avoid contamination of the caps with debris, place capped cylinders only on clean, dust-free surfaces.

**METHOD OF TEST FOR
FLEXURAL STRENGTH OF CONCRETE
(USING SIMPLE BEAM WITH THIRD POINT LOADING)**

1. SCOPE

1.1 This procedure covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading.

2. RELEVANT DOCUMENTS

2.1 LS 401

2.2 CSA-A23.2-8C

3. PROCEDURE

3.1 Specification LS 401 and procedure of CSA Standard A-23.2-8C shall be followed.

**METHOD OF TEST FOR
DETERMINATION OF SPLITTING TENSILE STRENGTH
OF CYLINDRICAL CONCRETE SPECIMENS**

1. SCOPE

1.1 This method covers the procedure for determining the splitting tensile strength of cylindrical concrete specimens such as moulded cylinders and drilled cores.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-13C

3. PROCEDURE

3.1 Procedure of CSA Standard A23.2-13C shall be followed.

METHOD OF TEST FOR DRILLED CORES IN COMPRESSION

1. SCOPE

1.1 This method covers the procedure for preparing and determining the compressive strength of drilled core specimens of hardened concrete.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-14C

3. PROCEDURE

3.1 Procedure of CSA Standard A23.2-14C shall be followed.

**METHOD OF TEST FOR
DETERMINATION OF WATER SOLUBLE CHLORIDE ION
IN CONCRETE**

The LS Method 411 has been replaced by LS Method 417, Method Of Test For Determination Of Total Chloride Ion In Concrete (Acid Soluble).

METHOD OF TEST FOR SCALING RESISTANCE OF CONCRETE SURFACES EXPOSED TO DEICING CHEMICALS

1. SCOPE

1.1 This test method covers determination of resistance to scaling of a horizontal concrete surface exposed to freezing and thawing cycles in the presence of deicing chemicals. It is intended for use in evaluating this surface resistance quantitatively by determining the dry mass of the flaked off concrete.

2. RELEVANT DOCUMENTS

- 2.1 MTO Test Method LS-401
- 2.2 CSA A23.2 - 2C

3. DEFINITION

3.1 Scaling is flaking or peeling away of the near surface portion of hardened concrete or mortar, or a thin layer of mortar flakes off the surface of coarse aggregate.

4. SIGNIFICANCE AND USE

- 4.1 This test method can be used to evaluate the effect of mix proportions, surface treatment, curing, or other variables on resistance to scaling.
- 4.2 This test method is also used to evaluate salt scaling resistance of slabs cut from hardened concrete such as barrier walls, precast manholes, and noise barriers.

5. APPARATUS

- 5.1 **FREEZING EQUIPMENT:** A cabinet or room of sufficient size to hold specimens and capable of lowering the temperature of the specimens to $-18 \pm 2^{\circ}\text{C}$ within 16 to 18 hours and maintaining this temperature with a full load of specimens.
- 5.2 **THAWING ROOM:** A room or cabinet maintaining an air temperature of $23 \pm 2^{\circ}\text{C}$ and a relative humidity of $50 \pm 5\%$.
- 5.3 **SCALES:** Scales for determining mass of batches of materials and concrete shall conform to the requirements of CSA A23.2 – 2C.
- 5.4 **BALANCE:** A balance or scale having minimum capacity of 5000 g and an accuracy of 0.1 g
- 5.5 **CONCRETE MIXER:** A mixer complying with the requirements of CSA A23.2 – 2C.

5.6 SLUMP CONE AND AIR METER: The apparatus shall comply with the requirements of CSA A23.2 - 5C, 4C (or 7C).

5.7 MOULDS: Moulds shall be 300 x 300 x 75 mm in inside dimensions and have collars attached to form ledges for the installation of a dyke. They shall conform to the requirements of ASTM C 192. Moulds made of 19 mm thick plywood are acceptable provided that they are waterproofed to make them non-absorptive and leakproof.

5.8 TAMPING ROD: A round straight steel rod 16 mm in diameter and approximately 600 mm in length, having the tamping end rounded to a hemispherical tip of the same diameter as the rod.

5.9 DRYING OVEN: An oven capable of maintaining a temperature of $105 \pm 2^{\circ}\text{C}$.

5.10 FILTER PAPER: Whatman No. 2, 320 mm in diameter or equivalent.

5.11 SMALL TOOLS: Wood strike-off board, 75 mm paint brush to provide the desired texture of the test surface, and a polyethylene sheet 350 x 350 mm, mounted on a plywood frame to cover the plastic concrete prior to placing in the moisture room.

6. PROPORTIONING AND MIXING

6.1 PROPORTIONING: The air content, cementing materials content, water cement ratio, slump, and other characteristics of the concrete and its ingredients shall be those appropriate for the purposes for which the tests are to be made.

6.2 MIXING: The mixing shall be in accordance with CSA A23.2 - 2C.

6.3 TESTING PLASTIC CONCRETE: All the standard tests shall be carried out in accordance with CSA A23.2 - 4C, 5C, (or 7C).

7. SPECIMENS

7.1 NUMBER OF SPECIMENS: At least two duplicate specimens, each 300 x 300 x 75 mm, shall be made for each test condition.

7.2 FABRICATION OF SPECIMENS: Coat the inside surface of each mould with a light film of form oil just prior to fabrication of the specimens. Fill the mould in one layer and rod one time for each 1300 mm² of surface (300 x 300 mm area requires 70 strikes of the rod), leaving a slight excess of material after the final rodding. Tap around the mould perimeter with a nylon tipped hammer to close any remaining voids and immediately screen excess concrete with a wood strike-off board and finish the surface with two passes of a wood float, one in each direction. When the sheen of water has disappeared, gently brush the top surface with the paint brush to remove any laitance and to leave a slightly textured surface unless another method of surface finishing is to be evaluated.

7.3 SPECIMENS FROM HARDENED CONCRETE: Slabs obtained from hardened concrete shall have a test area approximately equal to the area of the cast specimens (7.1). The surface to be tested shall be free of any damage.

8. CURING AND DYKING

8.1 LABORATORY CAST SPECIMENS: Immediately after finishing the surface (7.2), cover the surface with a polyethylene sheet (5.11) and move the specimens into moist storage ($23 \pm 2^{\circ}\text{C}$, at least 95% R.H.). At 20 to 24h after addition of water to the mix, remove the specimens from the moist storage, demould, identify each and return them to the moist storage. Remove the specimens from the moist storage at the age of 14 d and place them in air for 14 d at $23 \pm 2^{\circ}\text{C}$ and relative humidity of 45-55%. The dyke may be made of any material that will adhere to the specimen and serve to maintain the salt solution on the surface of the specimen throughout the period of the test. The dyke must be applied during the dry period. The dyke must not affect the test results. If a dyke is a precast mortar dyke, an air entrained paste shall be applied to the recessed edges around the perimeter of the test specimen. Then the precast mortar dyke shall be lowered into the recess (Fig. 1) and any excess paste shall be removed. After allowing the paste to harden for 24 h, apply epoxy sealant to the inside, top, and outside of the dyke extending the outside surface epoxy treatment to 25 mm below the joint.

8.2 SPECIMENS FROM HARDENED CONCRETE: The dyke requirements are the same as those for laboratory cast specimens.

9. TEST PROCEDURE

9.1 SALT SOLUTION: The deicing salt shall be a 3% solution of sodium chloride. The test surface shall be covered with approximately 6 mm of the solution.

9.2 FREEZE-THAW CYCLE: At the age of 28 d, cover the test surface with the salt solution and expose the specimens to continuous freeze-thaw cycling, each cycle consisting of 16-18 h in the freezing environment followed by storage at $23 \pm 2^{\circ}\text{C}$ relative humidity of 45-55% for 6-8 h. Add the salt solution before each freezing phase of the cycle as necessary to maintain the required depth. During the test, each specimen shall be supported by means of wood strips to allow free air circulation under, around, and over it (Fig. 1).

9.10 MASS LOSS: After each 5 cycles, remove the salt solution together with all the flaked off concrete from the surface and place into a watertight container. The operation is best accomplished by tilting the slab into a funnel approximately 500 mm in diameter and washing the surface of the specimen with the salt solution. The washing should continue until all loose particles are removed from the concrete. The solution shall then be strained through a filter and the residue dried out in an oven at 105°C to a constant mass condition. This residue shall be cumulatively weighed after each 5 cycles. This residue shall be defined as the loss of mass and expressed in kilograms per square metre of exposed slab area. The loss of mass shall be calculated to the nearest 0.01 kg/m^2 . After the washing of each slab, the surface shall be covered with a new solution of sodium chloride.

9.11 NUMBER OF CYCLES: Unless otherwise stated in the test program, terminate the test after exposure to 50 cycles.

10. REPORT

The report shall include the following:

10.1 SPECIMENS FABRICATED IN THE LABORATORY.

10.1.1 Mix proportions.

10.1.2 Source and type of each concrete ingredient.

10.1.3 Slump and air content.

10.1.4 Curing of specimens if other than standard.

10.1.5 Area of the surface exposed to scaling (each slab).

10.1.6 Cumulative mass loss after each 5 cycles (each slab).

10.1.7 Photographs of each slab at 0, 10, 25 and 50 cycles (if test is extended, photographs also required at completion of test).

10.2 SPECIMENS FROM HARDENED CONCRETE

10.2.1 The size and shape of the specimen.

10.2.2 Orientation of the specimen in the structure.

10.2.3 Curing if other than standard.

10.2.4 Area of the surface exposed to scaling (each slab).

10.2.5 Cumulative mass loss after each 5 cycles (each slab).

10.2.6 Visual rating of the surface after each 5 cycles (each slab).

10.2.7 Photographs of each slab at 0, 10, 25 and 50 cycles (if test is extended, photographs also required at completion of test).

11. GENERAL NOTES

11.1 If the method is used to evaluate a concrete coating or penetrating sealant, the sealant shall be applied during the dry storage period at the time and in the manner specified by the test program for the sealant. The treated specimens shall be exposed to the cycling at the time required by the test program.

11.2 Curing of the specimens may differ from the standard depending on the mix, e.g. latex mix. In such cases, the specimens are cured as required by the test program.

11.3 If there is any interruption in the daily cycling, the specimens shall be kept frozen.

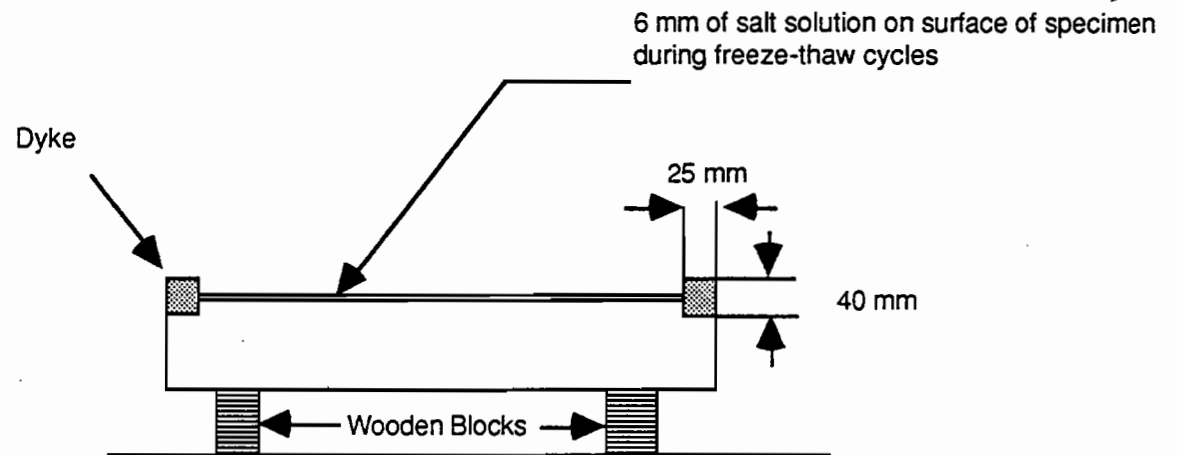


Figure 1

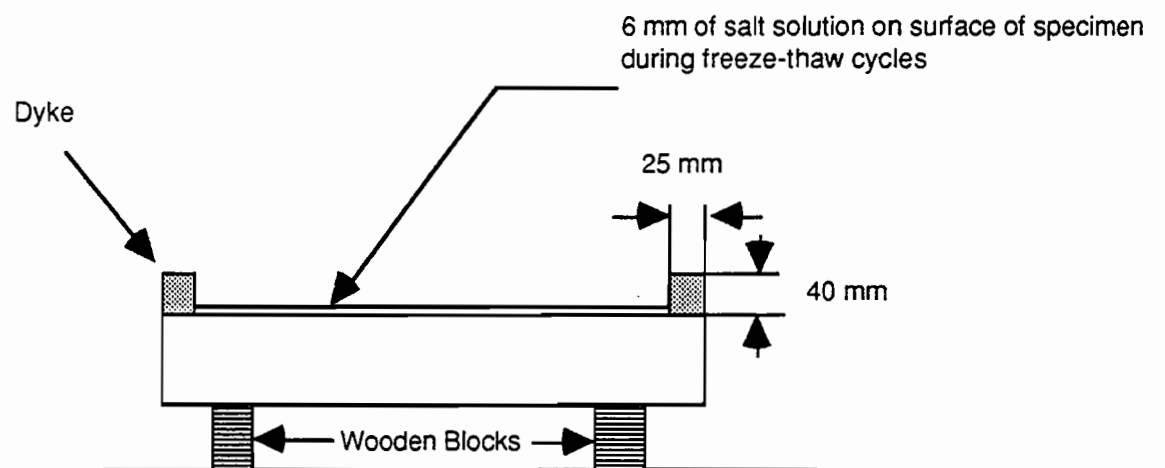


Figure 2

**METHOD OF TEST FOR
NON-VOLATILE CONTENT OF
CHEMICAL ADMIXTURES, LATEX ADMIXTURES
AND CURING COMPOUNDS**

1. SCOPE

1.1 This method covers the determination of non-volatile content (%) for concrete chemical admixtures (liquid), latex modifiers and curing compounds.

2. RELEVANT DOCUMENTS

- 2.1 ASTM C 494 18.2
- 2.2 ASTM D 1644

3. DEFINITION

3.1 Determination of the fraction of an admixture that is relatively stable at the temperature of the test while solvents are driven off.

4. CHEMICAL ADMIXTURES

4.1 PROCEDURE

Procedure of ASTM C 494, clause 18.2 shall be followed for determination of non-volatile content of chemical admixtures.

5. LATEX ADMIXTURES

5.1 APPARATUS

- 5.1.1 Syringe without needle, 10 mL
- 5.1.2 Aluminum dishes - approximately 60 mm in diameter, 15 mm in depth, 2 g or less in mass, and disposable
- 5.1.3 Oven - ventilated, $140 \pm 2^{\circ}\text{C}$, forced circulation type or one with provision for free access of air
- 5.1.4 Desiccator
- 5.1.5 Balance - accurate to 0.001 g

5.2 PROCEDURE

- 5.2.1 Weigh each of three aluminum dishes to nearest 0.001 g.
- 5.2.2 Thoroughly mix sample. Place a portion of mixed sample in a 10 mL syringe with needle and discharge 1.2 ± 0.1 g into each of the aluminum dishes. Record the mass of each dish plus sample to nearest 0.001 g.