Revision 23 to

MTO

LABORATORY TESTING

MANUAL

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MINISTRY OF TRANSPORTATION
MATERIALS ENGINEERING AND RESEARCH OFFICE

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LS-102 MINIMUM REQUIREMENTS FOR LABORATORIES CONDUCTING ENGINEERING MATERIALS TESTING & EVALUATION SERVICES:

Section 6.12, Grout Testing is divided into Testing of Compressive Strength of Grout Specimens (Section 6.12.1) and Testing of Viscosity, Bleeding and Expansion and Making of Grout Cube Specimens (Section6.12.2).

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

Editorial changes are made to Sections 5.1, 5.2, 6.1, 7.2 and 8.2

Revised Hot Mix – Smoothness Acceptance and Price Adjustment Form to ensure all required information is provided to the ministry

LS-299 ASPHALT CEMENT'S RESISTANCE TO FATIGUE FRACTURE USING DOUBLE EDGE NOTCHED TENSION TEST (DENT):

This is a new test method.

LS-308 DETERMINATION OF PERFORMANCE GRADE OF PHYSICALLY AGED ASPHALT CEMENT USING EXTENDED BENDING BEAM RHEOMETER:

This is a new test method.

LS-407 COMPRESSIVE STRENGTH OF MOULDED CONCRETE CYLINDERS:

Scope of the test method, Section 1, is amended to include unshrinkable backfill and to clarify that the method is not applicable to concretes with strength higher than 50 Mpa.

New Sections, 4.1 – Apparatus, 4.2 – Materials, and 4.3 – Procedures, are created to include provisions for testing unshrinkable backfill and to include requirements from the Area Laboratory Testing Agreement.

LS-431 MICROSCOPICAL DETERMINATION OF AIR VOID SYSTEM PARAMETERS IN HARDENED CONCRETE FOR REFEREE TEST:

The term " conformance test " was replaced by a new term "referee test".

LS- 434 MECHANICAL CONNECTORS USED TO SPLICE STEEL REINFORCEMENT:

This is a new test method.

LS- 435 LINEAR SHRINKAGE OF CONCRETE:

This is a new test method, which is a modified version of ASTM C 157.

LS-602 SIEVE ANALYSIS OF AGGREGATES:

Section 3.2 is amended to allow the use of half height sieves if sieving adequacy required by the test method can be proven.

The requirements of mechanical sieve shaker in Section 3.4 are amended to include the sieving adequacy check as a part of the test procedure.

The terminology "maximum nominal" in Section 4.3 and Note 1 is changed to "nominal maximum" to conform to the title of column in Table 1.

The check for sieving thoroughness is included in the test procedure by creating Section 5.2.1, which was Note 5 in the previous versions and provided criterion for adequacy of sieving. Note 5 is revised to provide information on the impact of continued use of a mechanical sieve shaker to achieve the sieving adequacy.

Note 6 is added to provide information on the use of sieve to determine the sieving adequacy and the previous Notes 6 and 7 are re-numbered.

LS-603 RESISTANCE TO DEGRADATION OF COARSE AGGREGATE BY ABRASION AND IMPACT IN THE LOS ANGELES ABRASION MACHINE:

Section 5.1 and Note 2 are revised to provide the information pertaining to the introduction of Brechin Quarry No. 2 Control Aggregate.

LS-604 RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE:

The test method was completely re-written to include sample preparation procedures for blended aggregates.

LS-605 RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE:

The test method was completely re-written to include sample preparation procedures for blended aggregates.

LS-606 SOUNDNESS OF AGGREGATES BY USE OF MAGNESIUM SULPHATE:

Section 3.3 is amended to allow the use of wire baskets made of stainless steel.

The temperature of about 50° C that is specified for hot tap water in Section 7.1 is replaced with a temperature range of 40° to 60° C.

LS-608 DETERMINATION OF PERCENT FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE:

Editorial changes are made to the requirements of callipers specified in Section 4.2 and in the associated Note.

LS-609 PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE:

Section 5.5 is amended to include the procedures for examining samples that contain carbonates and or metavolcanics, and revised Note 2 indicates only the advantages of soaking.

Section 3, Definition is introduced and a definition is provided for siliceous aggregates. The types of aggregates that are included in this group are identified by Type Numbers.

LS-628 VOLUME OF VOIDS (RIGDEN VOIDS) IN COMPACTED FILLER OR FINES:

This is a new test method.

LS-629 UNCOMPACTED VOID CONTENT OF FINE AGGREGATE:

This is a new test method.

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 – Marshal 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

6.12.1 Compressive Strength of Grout Specimens

CSA certification for Category 0 or higher and successful participation in the Ministry proficiency program for testing of cube compressive strength is required. The successful laboratories are placed on the list of laboratories qualified to test compressive strength of grout specimens. This list is available from the Concrete Section.

6.12.2 Viscosity, Bleeding, Expansion and Making Grout Cube Specimens

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 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-100 – 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 sublot 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 profile trace (2.0 for Ministry work).

3.4 PROFILE INDEX is the rate of smoothness averaged over both wheelpaths for any given sublot of surface course or a section of pavement.

3.5 An ODODMETER is a device for measuring longitudinal distance along a profile.

3.6 A PROFILE MEASURING DEVICE (PMD) is a device used for measuring the surface smoothness of a pavement.

3.7 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 sublot length or the length of any given pavement section; expressed in mm/km.

3.8 REDUCTION LENGTH is an input parameter equal to the sublot length (normally set at 100 m).

3.9 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).

3.10 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 sublot. 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 sublot 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, the PMD operator must demonstrate to a Ministry representative that the PMD and all appropriate accessories and peripherals (including power assist if applicable) are in proper operation.

5.1.1.1 Checking Tire Pressure of Measuring Wheel

The tire pressure of the measuring wheel must be 172 kPa $\pm$ 7 kPa (25 psi $\pm$ 1 psi). Note that over inflation of the measuring wheel can cause it to permanently become distorted or out of round.

5.1.1.2 Checking Height Sensor Calibration

The height sensor must be properly calibrated. Move the PMD to a relatively flat area of pavement and lower the measuring wheel onto a thin flat steel plate (sitting on the pavement surface). Measure and record the height, M1, shown on the PMD's screen (see Figure 2). Place one of the metal calibration blocks on top of the thin plate and under the measuring wheel and record the second height measurement, M2. Repeat the process for at least two calibration blocks of different heights (usually 12.7 mm and 38.1 mm). The absolute value of the difference between M1 and M2 shall be within 0.5 mm of the heights of both blocks in order for the height sensor to be properly calibrated. If the absolute value of the difference between M1 and M2 is greater than 0.5 mm then the height sensor, the sensor must be recalibrated by the manufacturer.

5.1.1.3 Checking Odometer Calibration

The PMD's odometer must be properly calibrated. Align the longitudinal centreline of the PMD along the 100 m calibration line established at the correlation site. Lower the PMD's measuring wheel onto the pavement surface so that its geometric centre is sitting at the beginning of the line. Set the station reading on the PMD to 0 and then push the PMD along the calibration line and stop the PMD at the point where the odometer reads exactly 100 m. Measure the distance between the geometric centre of the PMD's measuring wheel and the end of the 100 m calibration line using the small tape measure. The absolute distance shall be within 1.0 m. If the absolute distance is more than 1.0 m, the PMD's odometer must be recalibrated using the manufacturer's procedure and rechecked.

5.1.1.4 Checking Tracking (Skewness)

The horizontal tracking of the PMD is such that the frame of the profilograph remains parallel to the direction of travel with no more than a 50 mm transverse difference between the front and back of the profilograph. If the horizontal tracking is deemed to be unacceptable, then the run will be terminated. The PMD operator may adjust the PMD to improve tracking and repeat the check.

5.1.1.5 Conducting Correlation Runs

The correlation run is conducted by aligning the geometric centre of the PMD's measuring wheel with the beginning of the 300 m long correlation line with the computer generated blanking band set at 0 mm, the reduction length at 100 m and the data filter factor at 2.0. Run the PMD a distance of exactly 300 m based on the PMD's internal odometer. Measure the distance between the centreline of the measuring wheel and the end of the 300 m correlation line to ensure the they are within 3.0 m (i.e. $\pm$1%). If the distance is greater than 3.0 m then the odometer must be recalibrated and the correlation run repeated. Repeat the correlation run to provide for a total of three runs for each combination of mode of operation (manual or power-assist), measuring wheel and blanking band that the PMD operator intends to use.

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

Where measurements of the existing pavement surface or an underlying pavement layer are to be taken, the measurement sections (stations and sublots) must correspond with that used for the overlying surface course.

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:

$$(1) \qquad \overline{X} = \frac{\sum x_i}{n}$$

$$(2) \qquad s = \sqrt{\frac{\sum \left(x_i - \overline{X}\right)^2}{n-1}}$$

(3) Coefficient of Variation (%) = $\frac{s}{\overline{X}} \times 100$

Where:

$\overline{X}$ = 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

The Ministry 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.

6.1.5 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 sublot by averaging the rate of smoothness, which was measured for both wheelpaths.

6.2.2 The profile Index for a given sublot 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.

7.2.2.2 Within Each Individual Run

Areas of special conditions, such as superelevations, curves, joints, 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.

7.2.2.3 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, and tracking of the PMD.

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 172 kPa $\pm$ 7 kPa (25 psi $\pm$ 1 psi) 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.

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.

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 to 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

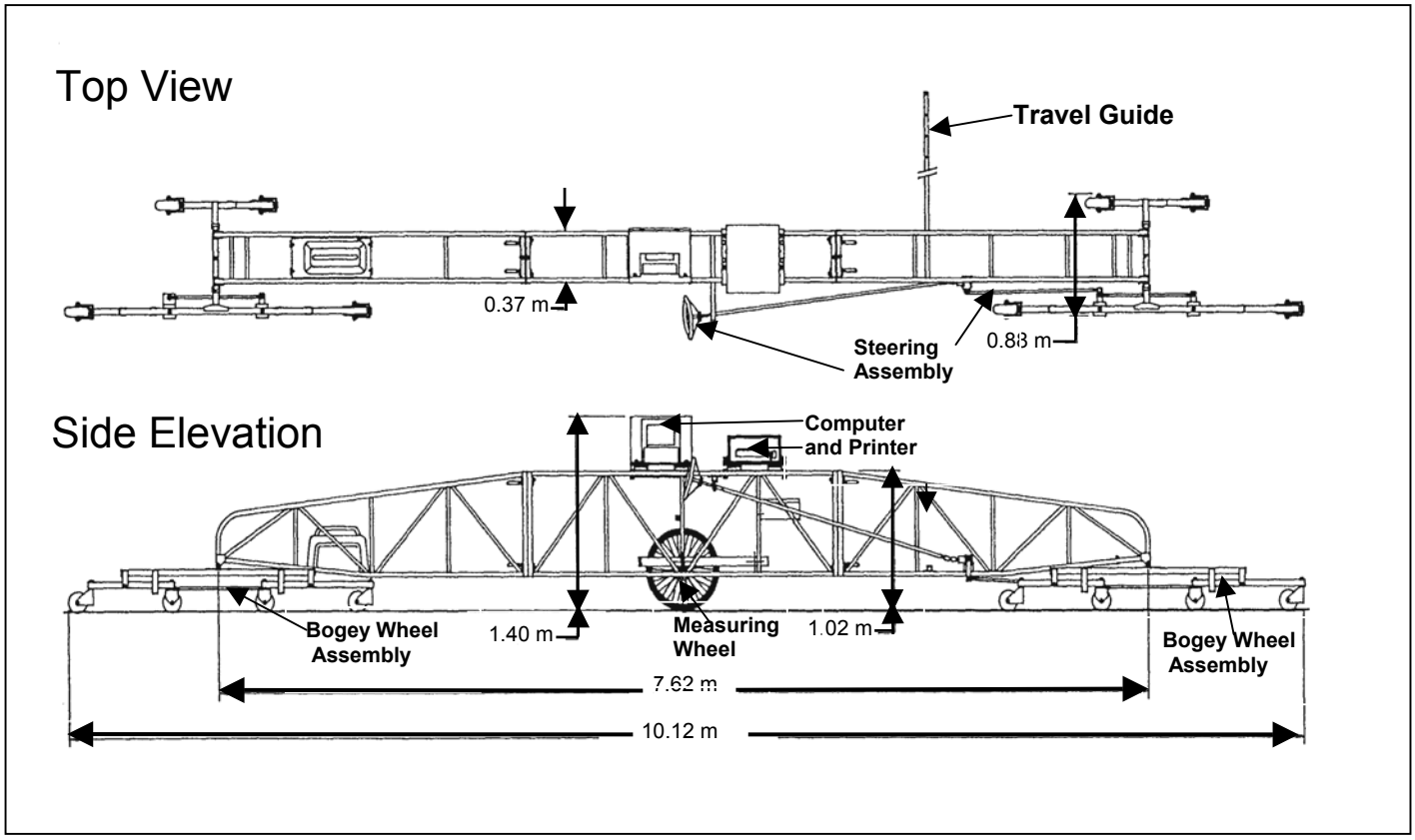

Figure 2 - Checking the Calibration of the Height Sensor

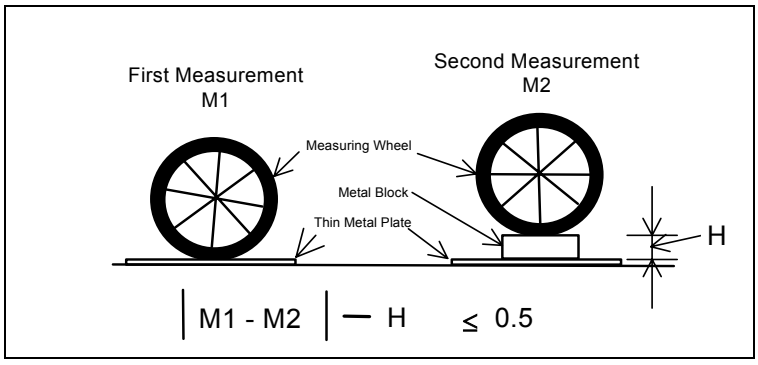

Figure 3 – Measuring Scallop Height Using a Bump Template

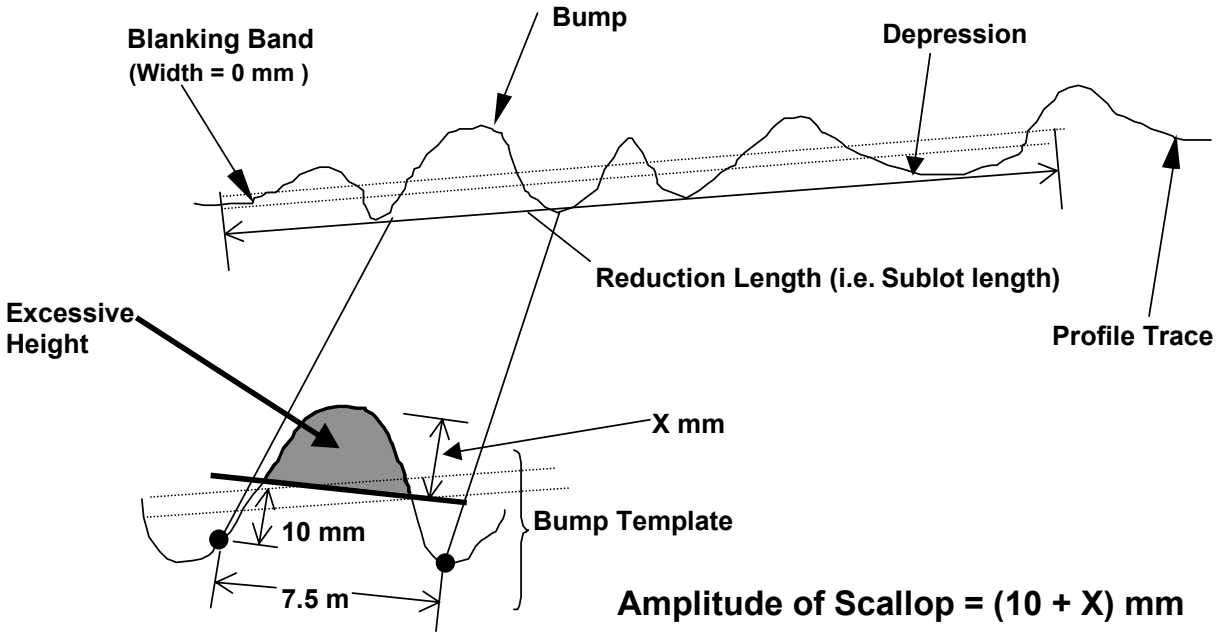

Figure 4 – Sheet For Correlation of Profilographs

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 = _____

Figure 5 – Summary Sheet for PMD Measurements

Hot Mix - Smoothness Acceptance and Price Adjustment Sheet

☐ Daily Working Sheet ☐ Final Summary Sheet (for Payment)

Contract No.:		Mix Type:		Page		of	
PMD Type / Manufacturer		PMD Serial No:		Wheel Designation:			
Contractor/Owner-Operator:		Completed by:		Date:			
Highway No.:		Lane No. and Direction:		Sublots		to	

Notes: *Areas that are superelevated or on curves should be designated as "(S)" or "(C)", re † If a scallop is left unrepaired, write "(U)" after its height

Sublot Information				Surface Smoothness Measurements (mm/km)						Sublot Payment Factor	Scallop Locations and Heights							
											Initial Measurements				Final Measurements †			
											Left Wheelpath		Right Wheelpath		Left Wheelpath		Right Wheelpath	
SubLot #	Stations* (Start / End)	Length (m)	Date of Measurement	Initial/ Subsequent Measurements (Mark "F" for Final Payment)	Wheelpath Left	Wheelpath Right	Mean (PI)	Initial PI	Final PI	(Based on Final run)	Stations	Heights (mm)	Stations	Heights (mm)	Stations	Heights (mm)	Stations	Heights (mm)
				Initial														
				Sub#1														
				Sub#2														
				Sub#3														
				Initial														
				Sub#1														
				Sub#2														
				Sub#3														
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DRAFT
METHOD OF TEST FOR DETERMINING ASPHALT CEMENT'S RESISTANCE TO FATIGUE FRACTURE USING DOUBLE EDGE NOTCHED TENSION TEST (DENT)

1. SCOPE

The double edge notched tension test is carried out to determine the cracking potential of asphalt cement. The test is conducted after thermal conditioning to determine fracture energies, essential works of fracture, plastic works of fracture, and critical crack tip opening displacement at a specified temperature and rate of loading.

Note: This test method is still under development. Specific details are subject to change.

2. RELEVANT DOCUMENTS

AASHTO T240 Effect of Heat and Air on Rolling Film of Asphalt (Rolling Thin-Film Oven Test).
AASHTO T300 Force Ductility Test of Bituminous Materials
AASHTO T315 Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
AASHTO PP 1 Standard Practice for Accelerated Aging of Asphalt Cement Using a Pressurized Aging Vessel (PAV).
ASTM D 8 Standard Definitions of Terms Relating to Materials for Roads and Pavements.
ASTM D 113 Standard Test Method for Ductility of Bituminous Materials.

3. DEFINITIONS

W_t - total works of fracture, area under the load versus load-line displacement curve, J
w_t - specific total works of fracture(W_t / Bℓ), kJ/m^2
w_e - specific essential work of fracture, the energy required to fracture or break the sample without plastic deformation away from the fracture zone, kJ/m^2
w_p - specific plastic work of fracture, the work necessary to deform a volume of asphalt to fracture, MJ/m^3
β - geometric constant describing the area of the plastic zone.
δ_t - critical crack tip opening displacement also referred to as CTOD, mm

P = load, N

d - displacement in test, m

B = sample thickness, m

ℓ = ligament length, the space between the 30° notches, m

a = sample notch depth, m

W - sample cross section width, m

σ_n = net section stress of sample, J/m^2

4. APPARATUS

Testing Apparatus – A constant rate of displacement device capable of maintaining rates of displacement of 3.33 mm/min, 10 mm/min, and 50 mm/min. The set rate of displacement shall not fluctuate more than ± 1%. The minimum stroke for the instrument(s) shall be 200 mm. The apparatus should have a set of loading pins that assure precise alignment of the sample during the test. The apparatus shall be able to determine displacement to an accuracy of ± 0.05mm.

Note: Testing Apparatus is commonly a Force Ductility Apparatus installed in a Ductilometer, shown in Figure 1.

Load Sensor – The sensitivity of the load sensor and recording electronics shall allow the load, P, to be measured every 0.3 seconds during the test within an accuracy of ± 1 %. The load sensor shall have a nominal maximum force of 500 N.

Temperature Controlled Bath for testing – The bath shall be sufficiently large enough to contain the Testing Apparatus and samples in their molds prior to testing. The equipment shall be capable of maintaining the testing temperature without fluctuating more than ± 0.5°C.

Temperature Controlled Bath for conditioning – capable of maintaining conditioning temperature requirements to within ± 0.5°C.

Glass stir – stick capable of stirring the hot asphalt cement vigorously.

DENT Molds – 2 molds of each different ligament length of 20, 15, 10 and 5mm for a total of 8 individual molds. The double edge notched tension (DENT) geometry shall be used with aluminum end pieces (inserts) that attach to the testing apparatus loading pins. The design of

the DENT fracture mold shall be as shown in Figure 2, and will be obtained from silicone molds capable of holding aluminum end pieces, which are made from a Master mold, shown in Figures 3, 4 and 5.

Aluminum End Pieces – 16 inserts made from a 9.525 mm aluminum bar, built to dimensions shown in Figure 6. An aluminum end piece is shown in Figures 7 and 8.

5. PREPARATION OF SAMPLES

Eight samples shall be prepared using degassed PAV aged asphalt cement, two for each ligament length, ℓ, of 20, 15, 10 and 5 mm to a tolerance of 0.5 mm. Aging shall consist of 20-hours in a pressure-aging vessel as per AASHTO T240 and PP1. The aged asphalt cement shall than be heated for one hour at 160 ± 5°C to ensure that the asphalt cement readily flows when dispensed from the container and then poured into the prepared DENT Molds, see Figure 9.

Note that the heating temperature may be raised to a maximum of 180°C to provide a low enough viscosity but the sample material shall not be overheated. To avoid orientation and structure formation in modified asphalt cement, the mold cavity is filled by slowly pouring the asphalt cement from end to end in one pass so that the mold cavity is slightly overfilled according to AASHTO T315. After cooling the asphalt cement shall fill the space within the aluminum end pieces completely and the top surface of the asphalt cement shall not be higher than the top surface of the aluminum end pieces. Once the sample has cooled to room temperature, measure and record the sample thickness, B to four decimal places. The sample is ready for conditioning.

6. TEST PROCEDURES

6.1 Condition the samples at 20°C for a minimum of 24 hours in their DENT Molds in a temperature controlled bath. The temperature of the samples shall not fluctuate by more than ± 0.5°C during the conditioning periods and the conditioning times shall be within 1 hour of the specified time.

6.2 Remove the sample from the mold, and set the aluminum end piece's holes onto the loading pins without causing excessive deformation or stress concentrations to the sample. Allow the sample to sit and normalize for 5 minutes before starting the test. Run test according to AASHTO T300 at a displacement rate of 50 mm/minute ± 1 % until ductile failure is reached or the maximum

stroke length is reached. If the sample does not fail, an additional sample with the same ligament length shall be tested at a faster speed (or at a lower temperature).

6.3 Record sample ligament length, ℓ, displacement rate, temperature, and load every 0.3 second for the entire test time.

6.4 Calculate and report W_t, w_t, w_e, βw_p and δ_t on Form "A".

6.5 Repeat steps 6.1 to 6.4 for all samples.

7. CALCULATIONS

7.1 Calculate the average W_t for each ligament length where:

$$W_t = \int_0^{T_f} P \times d \text{ , J}$$

T_f = time ductile failure is reached or the maximum stroke length is reached.

7.2 Calculate w_t for each ligament length for each average W_t where:

$w_t = W_t/(B\ell)$, J/m^2

7.3 Plot w_t for various ligament lengths, ℓ, and draw a best fit straight line. From the graph or using the method of least squares fitting obtain values for w_e, and the term, βw_p where:

- w_e is the specific essential work of fracture for $\ell = 0.0$
- βw_p is the slope of the best fit straight line, for $w_t = w_e + \beta w_p \ell$

7.4 Plot w_e verses ℓ and report r^2 for the best fit line.

7.5 Determine $\delta_t = w_e / \sigma_n$ where:

$\sigma_n = P_{peak} / (B\ell)$,

P_{peak} = peak load obtained for the sample tested with the smallest ligament length, i.e. the average maximum load for the two 5 mm ligament samples.

8. EXAMPLE CALCULATIONS AND LOAD DISPLACEMENT CURVES

Typical Load-Displacement Curves for Essential Work of Fracture Testing of two modified asphalt cements that individually show self-similar behaviour yet different from each other are shown in Figure 10.

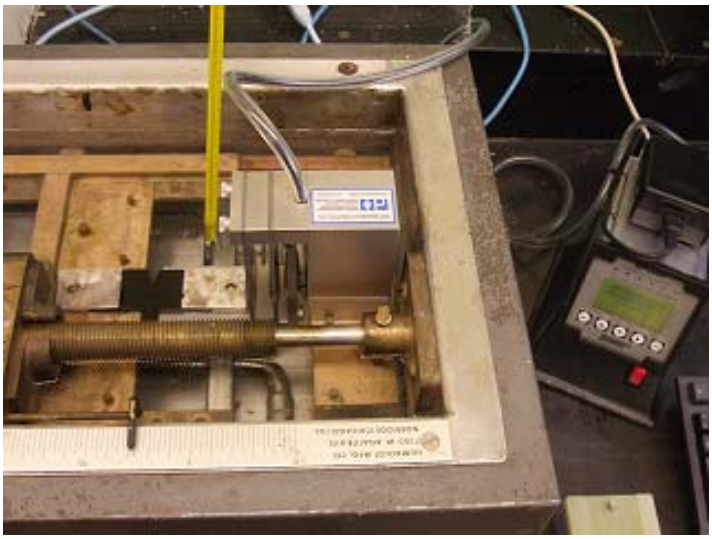


Figure 1 – D.E.N.T. Testing Apparatus

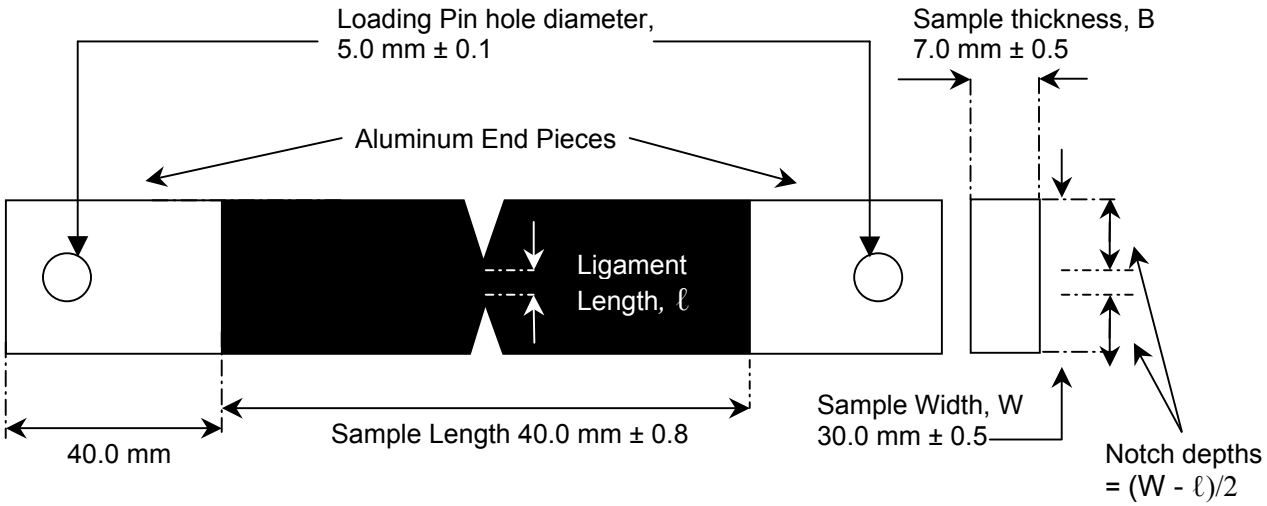


Figure 2 – D.E.N.T. Specimen Geometry, Dimensions and Tolerances

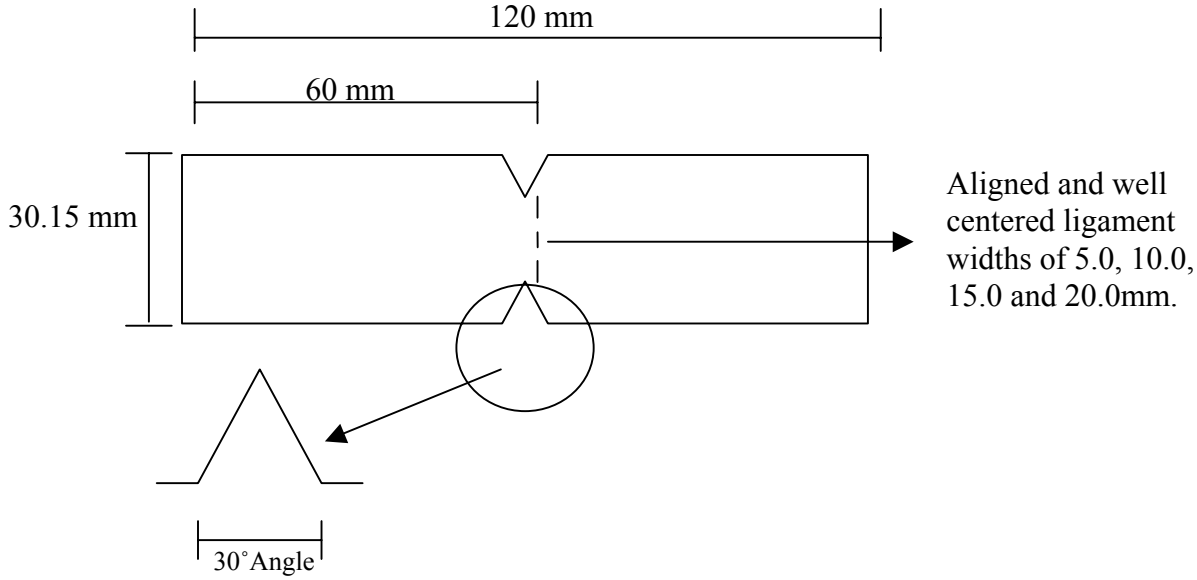


Figure 3 – Top View of the Master Mold

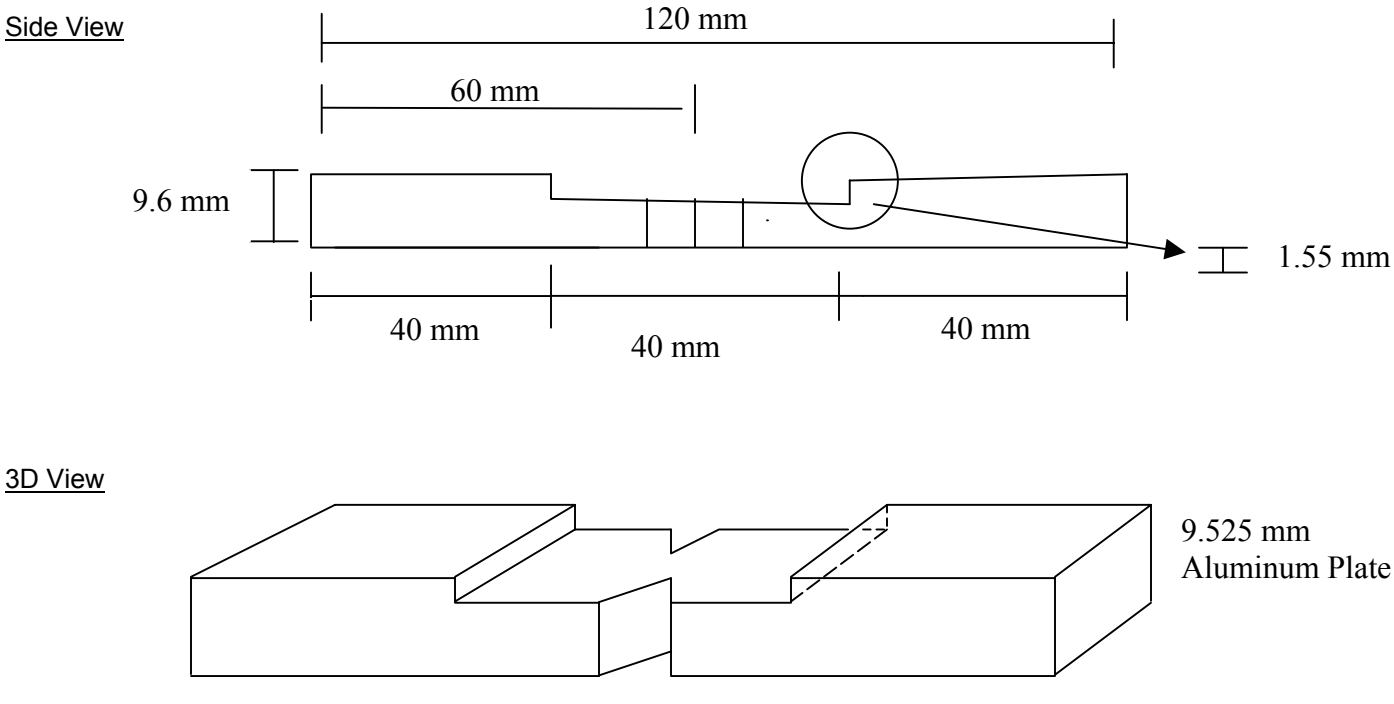


Figure 4 – Side Views of the Master Mold

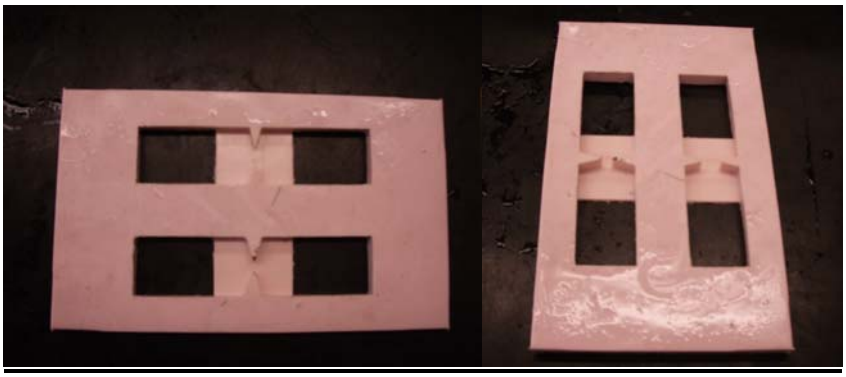


Figure 5 – D.E.N.T. Silicone Molds

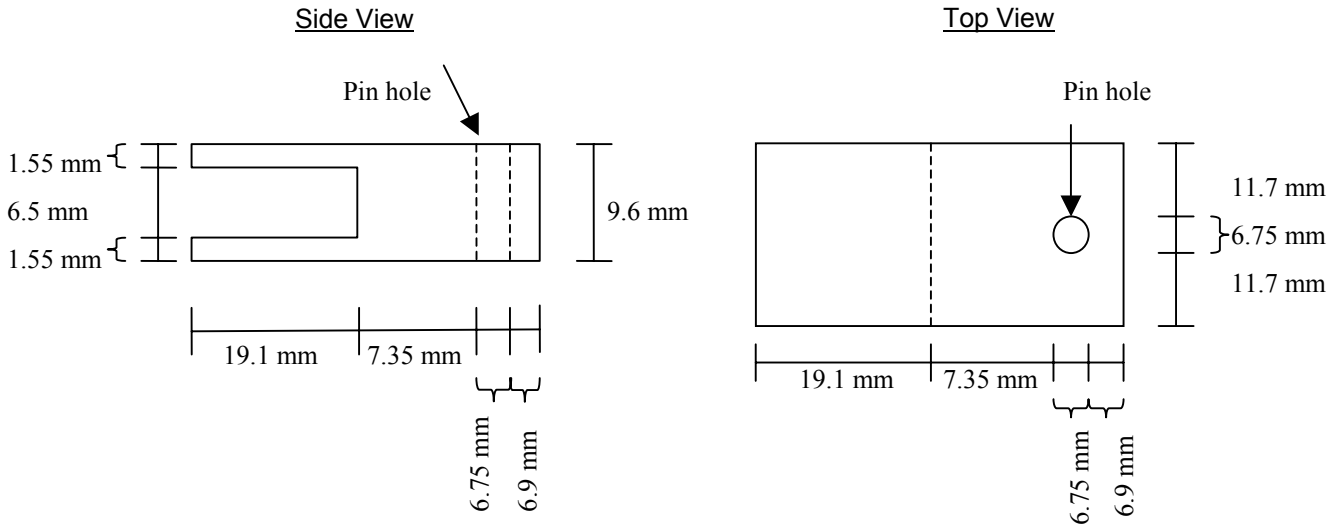


Figure 6 – Diagram of Aluminum End Piece

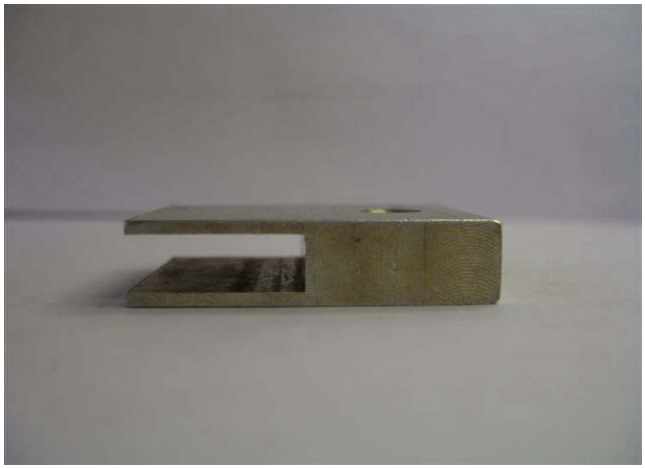


Figure 7– Side View of Aluminum End Piece

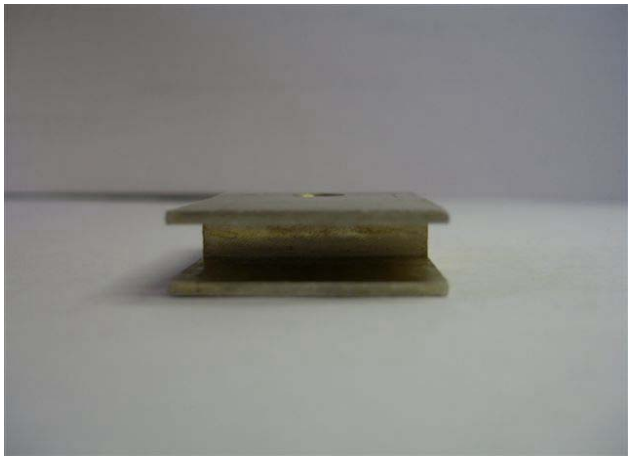


Figure 8 – Front View of Aluminum End Piece

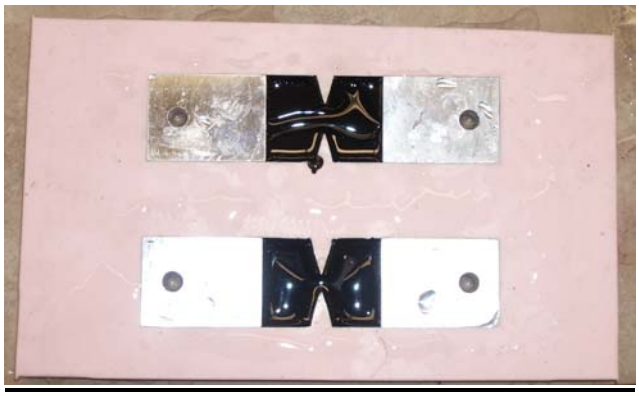


Figure 9 – Silicone Mold with Asphalt Samples in Aluminum End Pieces

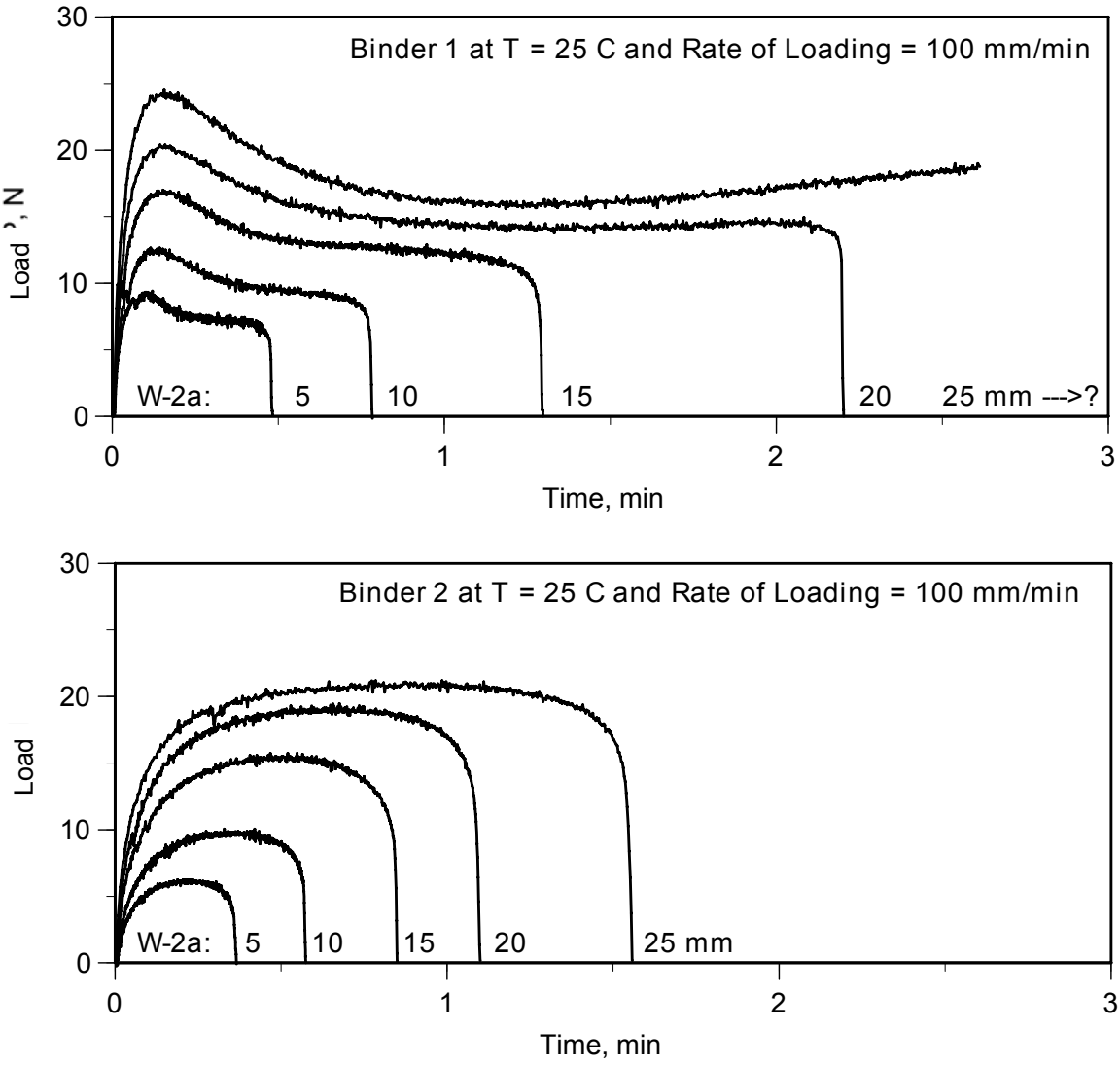


Figure 10 – Typical Load-Displacement Curves for Essential Work of Fracture Test

METHOD OF TEST FOR DETERMINATION OF PERFORMANCE GRADE OF PHYSICALLY AGED ASPHALT CEMENT USING EXTENDED BENDING BEAM RHEOMETER (BBR) METHOD

1. SCOPE

1.1 The extended bending beam rheometer test is carried out to determine if an asphalt cement meets the low temperature performance grade after going through a physical ageing (physical hardening) process.

1.2 Samples that have been Rolling Thin Film Oven, RTFO and Pressure Aging Vessel, PAV aged are tested after conditioning at low temperatures for periods of 1 hour, 1 day and 3 days to simulate the effect of extended exposure to cold temperature.

2. RELEVANT DOCUMENT

2.1 AASHTO M320, Standard Specification for Performance-Graded Asphalt Binder

2.2 AASHTO R28, Accelerated Aging of Asphalt Binder Using a Pressure Aging Vessel (PAV)

2.3 AASHTO T 240, Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-film Oven Test)

2.4 AASHTO T 313, Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)

3. APPARATUS

3.1 All equipment and material as noted in Section 6 of AASHTO T 313 with the addition of one more similarly controlled-temperature fluid bath for a total of two baths.

3.2 Two air-cooled freezers that maintain the conditioning temperature requirements to within a temperature tolerance of ± 0.5 ^{o}C

4. PREPARATION OF SAMPLES

4.1 Ten samples shall be aged according to AASHTO T240 (RTFO) and AASHTO R28, (PAV) and prepared following AASHTO T 313 procedures.

5. TEST PROCEDURE

5.1 Samples shall be conditioned and stabilized at prescribed temperatures prior to testing.

All conditioning shall be carried out in air cooled freezers on a flat plate of aluminum. If required a Teflon sheet can be placed between the sample and the aluminum plate to prevent the sample from sticking to the plate.

5.2 The conditioning temperature shall be chosen based on the proposed asphalt cement's low temperature grading. Samples shall be conditioned in Container I and Container II as shown in Figures 1 and 2. The air temperature in Container I shall be kept at T+20°C, where T = -YY for PGAC XX–YY. Five test samples A1, A2, B1, B2 and a spare shall be conditioned in Container I. The air temperature in Container II shall be set at T+10°C. Five test samples C1, C2, D1, D2 and a spare shall be placed in Container II.

5.3 Samples shall be conditioned for 50 + 5 minutes, (referred to as 1 hour conditioning) at the conditioning temperature indicated in section 5.2.

5.4 Determine appropriate test temperatures T_{HT} and T_{LT}

where:

T_{HT} is the higher test temperature, a temperature for which the asphalt cement is expected to pass the limiting BBR criteria (S≤300 MPa and m-value≥0.3). T_{HT} is normally 20°C more than the asphalt cement's actual low temperature grade as determined by AASHTO T313; and

T_{LT} is the lower test temperature, a temperature for which the asphalt cement just reaches or fails the limiting BBR criteria (S>300 MPa or m-value<0.3). T_{LT} shall be 6°C to 10°C cooler than T_{HT}.

5.5 Following conditioning, samples A1 and A2 from Container I, and samples C1 and C2 from Container II shall be stabilized for 10 ± 0.5 minutes at T_{HT}. After stabilizing, samples A1, A2, C1 and C2 are then tested following AASHTO T 313 procedures at T_{HT}. Similarly, samples B1 and B2 from Container I and samples D1 and D2 from Container II, are stabilized for 10 ± 0.5 minutes at T_{LT}. After stabilizing samples B1, B2, D1 and D2 are tested following AASHTO T 313 procedures at T_{LT}. Immediately after testing, samples shall be returned to their respective conditioning Container I at T+20°C and Container II at T+10°C.

5.6 Samples shall be conditioned lying flat on their side on a flat aluminium plate in their respective air cooled freezers, Containers I and II, at T+20°C and T+10°C for an

additional 23 hours ± 5 minutes (referred to as 1 day conditioning) and then repeat step 5.5.

5.7 Samples shall be conditioned lying flat on their side on a flat aluminium plate in their respective air cooled freezers, Containers I and II, at T+20°C and T+10°C for an additional 48 hours ± 5 minutes (referred to as 3 day conditioning) and then repeat step 5.5.

5.8 If during the testing sequence sample A1, A2, B1 or B2 becomes damaged, the damaged sample shall be replaced with the spare in Container I. If during the testing sequence sample C1, C2, D1 or D2 becomes damaged, the damaged sample shall be replaced with the spare in Container II.

Figure 1 – Samples Conditioned at Temperature T + 20 °C

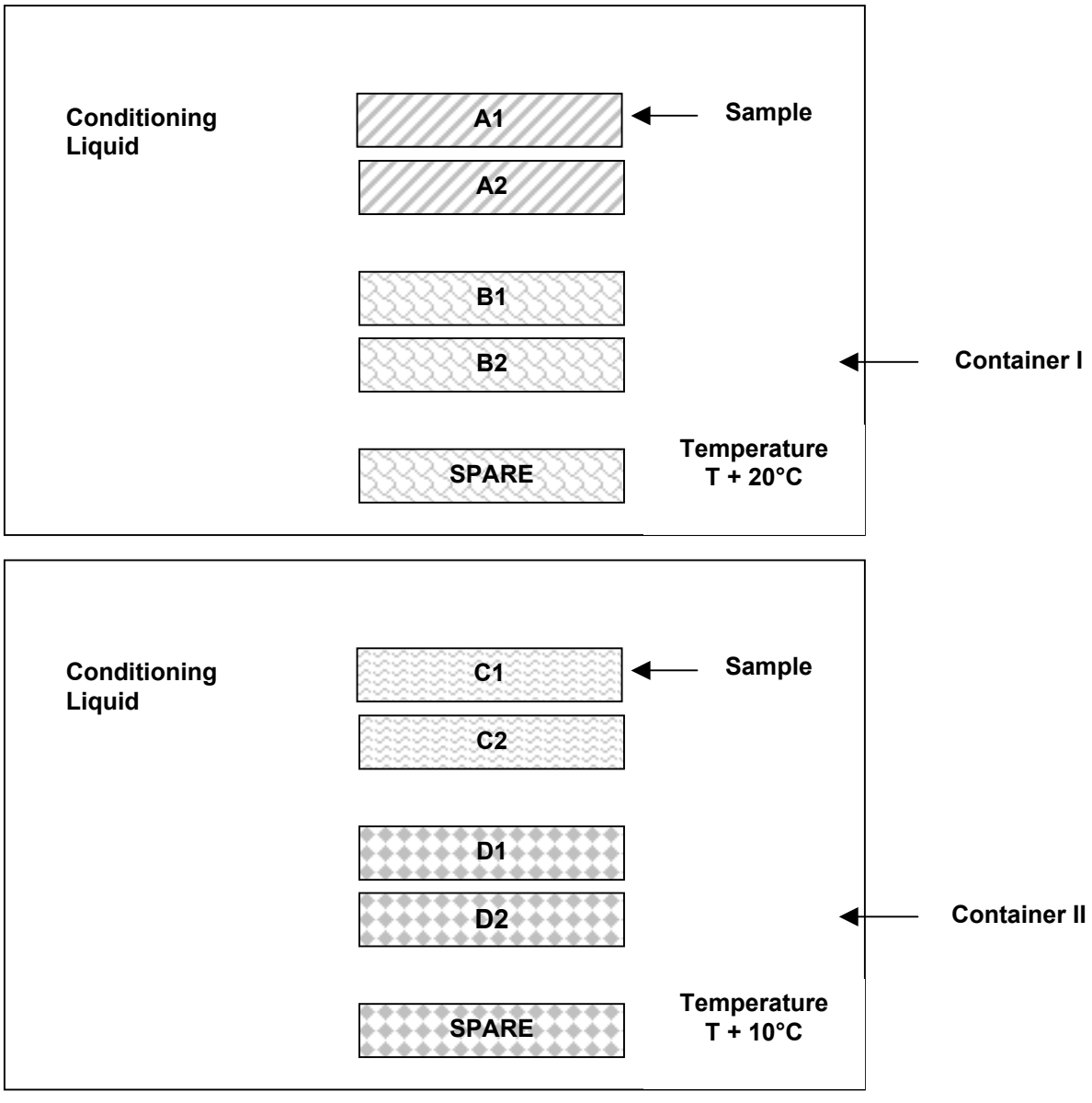


Table 1 – Example Test Matrix (see note 1)

CONDITIONING CONTAINERS & CONDITIONING TEMPERATURE	SAMPLE NUMBER	CONDITIONING TEMPERATURE (for T=-34°C) (See note2)	TEST TEMPERATURE T_{HT}	TEST TEMPERATURE T_{LT}
I (T+20°C)	A1	–14°C	–14°C	
	A2		–14°C	
	B1			–24°C
	B2			–24°C
	SPARE			
II (T+10°C)	C1	–24°C	–14°C	
	C2		–14°C	
	D1			–24°C
	D2			–24°C
	SPARE			

Notes:
1 This same test matrix is used for each of the 1 hour, 1 day and 3 day conditioning and testing periods.
2 An asphalt cement with a proposed Low Temperature Grade of -34.0 °C was used in this table.

6. REPORTING OF RESULTS

6.1 Record test data on Form A, "Extended BBR Test Results". Creep Stiffness is to be recorded to the nearest 0.1 MPa and m-values to the nearest 0.001.

6.2 Calculate the average m-value and creep stiffness using the m-values and creep stiffnesses at 60 seconds from Form A, "Extended BBR Test Results" and record them on Form B, "Limiting Grade Report for Extended BBR Test".

6.3 Determine by interpolation or extrapolation T_m, the continuous limiting BBR temperature at m-value=0.3, and T_S, the continuous limiting BBR temperature at S=300 MPa for tests conducted after conditioning samples in Container I and Container II for 1 hour, 1 day and 3 days. Example equations for interpolation and extrapolation are provided below. T_m and T_S are to be recorded to within the nearest 0.1°C on Form B, "Limiting Grade for Extended BBR Test".

6.4 Determine and record limiting temperatures, limiting grades, and grade loss using Form B, "Limiting Grade for Extended BBR Test" form.

FORMULAE FOR CALCULATING ACTUAL GRADE TEMPERATURES, T_m and T_S

Determine T_m for m-value equal to 0.3 and T_S for creep stiffness equal to 300 MPa using the average m-values and creep stiffnesses by interpolating or extrapolating from the m-values and creep stiffness' obtained at T+10°C and T+20°C using the appropriate formulae below.

CASE I Two m-values for T_{HT} and T_{LT} are both less than 0.3. Determine temperature, T_m at which the m-value is equal to 0.3 using

$$T_m = T_1 + (T_2 - T_1)\,[(0.3-m_1)/(m_2-m_1)] \quad \text{.....[1]}$$

where

$m_1 < m_2$

T_1 = test temperature for m_1 and

T_2 = test temperature for m_2.

Two creep stiffnesses for T_{HT} and T_{LT} are both less than 300 MPa. Determine temperature, T_S at which the creep stiffness is equal to 300 MPa using

$$T_S = T_1 + (T_2 - T_1)\,[(\log(300) - \log(S_1))/(\log(S_2) - \log(S_1))] \quad \text{.....[2]}$$

where

$S_1 < S_2$

T_1 = test temperature for S_1 and

T_2 = test temperature for S_2.

CASE II - For T_{HT} and T_{LT}, one m-value is less than 0.3 and the other is greater than 0.3. Determine temperature, T_m at which m-value is equal to 0.3 using

$$T_m = T_2 = T_1 + (T_3 - T_1)\,[(0.3-m_1)/(m_3-m_1)] \quad \text{.....[3]}$$

where

$m_1 < 0.3$

$m_3 > 0.3$

T_1 = test temperature for m_1 and

T_3 = test temperature for m_3.

For T_{HT} and T_{LT}, one creep stiffness is less than 300 MPa and the other is greater than 300 MPa. Determine T_S at which creep stiffness is equal to 300 MPa using

$$T_S = T_1 + (T_3 - T_1) [(\log (300) - \log (S_1))/(\log (S_3) - \log (S_1))] \quad \text{.....[4]}$$

where

$S_1 < 300$ MPa

$S_3 > 300$ MPa

T_1 = test temperature for S_1 and

T_3 = test temperature for S_3.

CASE III – Two m-values are for T_{HT} and T_{LT} are both greater than 0.3 for T_{HT} and T_{LT}. Determine temperature, T_m at which m-value is equal to 0.3 using

$$T_m = T_1 = T_2 - (T_3 - T_2) [(m_2-0.3)/(m_3-m_2)] \quad \text{.....[5]}$$

where

$m_2 < m_3$

T_2 = test temperature for m_2 and

T_3 = test temperature for m_3.

Two creep stiffnesses are both greater than 300 MPa for T_{HT} and T_{LT}. Determine T_S at which creep stiffness is equal to 300 MPa using

$$T_S = T_2 + (T_3 - T_2) [(\log (S_2)-\log (300))/(\log (S_3) - \log (S_2))] \quad \text{.....[6]}$$

where:

$S_2 < S_3$

T2 = test temperature for S_2 and

T3 = test temperature for S_3.

Form A:EXTENDED BENDING BEAM RHEOMETER TEST RESULTS

AFTER 1 HOUR CONDITIONING

SAMPLE NUMBER	TEMPERATURE FOR 1 HOUR CONDITIONING	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+20°C	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+10°C	ACTUAL GRADE TEMPERATURE T_m (°C)	ACTUAL GRADE TEMPERATURE T_S (°C)
A1	T+20°C	A1 - tested at T+20°C			
A2	T+20°C	A2 - tested at T+20°C			
B1	T+20°C		B1 - tested at T+10°C		
B2	T+20°C		B2 - tested at T+10°C		
C1	T+10°C	C1 - tested at T+20°C			
C2	T+10°C	C2 - tested at T+20°C			
D1	T+10°C		D1 - tested at T+10°C		
D2	T+10°C		D2 - tested at T+10°C		

AFTER 24 HOUR CONDITIONING

SAMPLE NUMBER	TEMPERATURE FOR 24 HOUR CONDITIONING	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+20°C	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+10°C	ACTUAL GRADE TEMPERATURE T_m (°C)	ACTUAL GRADE TEMPERATURE T_S (°C)
A1	T+20°C	A1 - tested at T+20°C			
A2	T+20°C	A2 - tested at T+20°C			
B1	T+20°C		B1 - tested at T+10°C		
B2	T+20°C		B2 - tested at T+10°C		
C1	T+10°C	C1 - tested at T+20°C			
C2	T+10°C	C2 - tested at T+20°C			
D1	T+10°C		D1 - tested at T+10°C		
D2	T+10°C		D2 - tested at T+10°C		

AFTER 72 HOUR CONDITIONING

SAMPLE NUMBER	TEMPERATURE FOR 72 HOUR CONDITIONING	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+20°C	TEMPERATURE FOR 10 MINUTE CONDITIONING PRIOR TO TEST T+10°C	ACTUAL GRADE TEMPERATURE T_m (°C)	ACTUAL GRADE TEMPERATURE T_S (°C)
A1	T+20°C	A1 - tested at T+20°C			
A2	T+20°C	A2 - tested at T+20°C			
B1	T+20°C		B1 - tested at T+10°C		
B2	T+20°C		B2 - tested at T+10°C		
C1	T+10°C	C1 - tested at T+20°C			
C2	T+10°C	C2 - tested at T+20°C			
D1	T+10°C		D1 - tested at T+10°C		
D2	T+10°C		D2 - tested at T+10°C		

Form B: LIMITING GRADE REPORT for EXTENDED BBR TEST

Conditioning Temperature	**Conditioning Period**	**Average of two known m-values**	**Average of two known creep stiffnesses**	**T_m**	**T_S**	**Limiting Temperature at m=0.30 T_m -10 (^oC)**	**Limiting Temperature at S=300 T_S -10 (^oC)**	**Limiting Grade, T_L (see note 1) (^oC)**	**Grade Loss T_{LBBR} -T_L (see note 2) (^oC)**
T+20^{o}C	1 hour								
	24 hours								
	72 hours								
T+10^{o}C	**1 hour**								
	24 hours								
	72 hours								

Notes:
(1) Where the Limiting Grade, $\mathbf{T_L}$ is the greater of $\mathbf{T_m - 10}$ and $\mathbf{T_S - 10}$.
(2) Where $\mathbf{T_{LBBR}}$ is the Limiting Grade for **T+10^{o}C at 1 hour.**

METHOD OF TEST FOR COMPRESSIVE STRENGTH OF MOULDED CYLINDERS

1. SCOPE

1.1 This method covers apparatus and procedures for testing compressive strength of normal concrete using 150 mm diameter and 300 mm long cylinders. It is not intended for concretes with a specified strength of 50 MPa or higher (such as high performance concrete) which shall be tested using 100mm diameter and 200mm long cylinders.

1.2 The method may be used for compressive strength determination of treated aggregate known as unshrinkable backfill with exceptions as noted.

2. RELEVANT DOCUMENTS

2.1 CSA-A23.2-9C

2.2 ASTM E4

2.3 ASTM C 39

3. PROCEDURE

3.1 Procedure of CSA Standard A 23.2-9C shall be followed, except as noted below.

4. EXCEPTIONS

4.1 APPARATUS

4.1.1 Calibration of compression testing machine: The compression testing machine shall be calibrated, at 6 month intervals or more frequently, in accordance with ASTM test method E4.

4.1.2 The maximum calibrated and certified load of the compression testing machine shall not be less than 1300 kN.

4.1.3 Compression testing machine used for testing of unshrinkable backfill shall have load indicating mechanism capable of showing load changes of 100 newtons or less.

4.1.4 The bearing faces of blocks used for compression testing of concrete must have a Rockwell hardness of not less than 55 HRC.

4.2 MATERIALS

4.2.1 Capping materials: Compressive strength of capping material shall be tested every week, at a minimum. Capping materials shall not be re-used.

4.3 PROCEDURES

4.3.1 Procedure for Concrete Cylinders

4.3.1.1 Each set of cylinders shall consist of two cylinders. The contract cylinders should be delivered to the laboratory with a Concrete Construction Report, form PH-CC-322.

4.3.1.2 Immediately after arrival at the laboratory, each concrete cylinder shall be demoulded and properly identified by a laboratory number, and date and time of arrival noted. The type of mould used and the laboratory number shall be recorded.

Each cylinder shall be examined for its condition on arrival and its mass shall be determined to the nearest 0.05 kg with the results recorded. All cylinders having a condition on arrival of 2, 3 or 4 or a mass of less than 12.5 kg shall be immediately reported to the Owner.

Cylinders with a condition 2 or 3, as detailed in Table 1, shall not be tested and shall be stored by the testing laboratory until advised otherwise by the Owner.

Table 1

Condition of cylinder on arrival	
1	Cylinder is acceptable for testing
2	Cylinder improperly made, testing not possible
3	Cylinder damaged, testing not possible
4	Concrete frozen

4.3.1.3 All contract cylinders shall be placed in the moisture room or temperature controlled water tank immediately after their arrival in the laboratory and demoulding and kept there until cylinder end preparation and testing in compression.

4.3.1.4 The diameter of each cylinder shall be determined with two measurements at right angles to each other at about midheight of the cylinder and recorded to the nearest 0.1 mm. The two measurements shall then be averaged to the nearest 0.5 mm. The average diameter of each cylinder shall be recorded and used for calculating the cross-sectional area of the cylinder.

4.3.1.5 If the two diameter measurements on a cylinder differ by more than 2 % of the smaller reading, the cylinder shall not be tested.

4.3.1.6 Cylinder Ends Preparation

The cylinder ends may be prepared by grinding or capping with sulphur mortar. The cylinders shall be kept moist after end preparation. If the cylinder ends are prepared more than 3 hours prior to the scheduled testing time, the cylinders shall be kept in a curing facility after the completion of end preparation until the time of testing.

4.3.1.7 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.

4.3.2 Procedure for Unshrinkable Backfill Cylinders

After arrival at the laboratory, each unshrinkable backfill cylinder shall be properly identified by a laboratory number, and date and time of arrival noted. The type of mould used and the laboratory number shall be recorded.

The cylinders shall be left in their molds in laboratory air until time of testing. The demoulding shall be carried out on the same day of testing for compressive strength. The cylinder ends shall be prepared by capping with sulphur mortar. The loading rate shall be 0.11MPa/s or lower.

4.3.8 Testing Compressive Strength

All cylinders shall be tested to complete failure. The type of failure shall be recorded according to ASTM C39 (Section 9.1.6 and Figure 2.).

4.4 REPORTING OF RESULTS: The report shall also include:

4.4.1 The type of failure

4.4.2 Mass of specimen, in kilograms, reported to two decimal places.

4.4.3 Test results obtained on standard concrete cylinders from MTO construction contracts shall be reported on Concrete Construction Report form PH-CC-322.

METHOD OF TEST FOR MICROSCOPICAL DETERMINATION OF AIR VOID SYSTEM PARAMETERS IN HARDENED CONCRETE FOR REFEREE TEST

1. SCOPE

1.1 This method covers the apparatus and procedure to determine the air-void system parameters in hardened concrete for referee testing purposes.

2. RELEVANT DOCUMENTS

2.1 ASTM C 457-98 “Standard Test Method for Microscopical Determination of Parameters of the Air-void System in Hardened Concrete”

3. PROCEDURES

3.1 Procedure B-Modified Point-Count Method of ASTM C 457-98 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 APPARATUS

4.1.1 Stereoscopic Microscope: The magnification of the microscope shall be between 100x and 125x.

4.2 PROCEDURE

4.2.1 Minimum Area of Finished Surface for Microscopical Measurement: The total area to be tested shall be twice the size specified in Table 1 of ASTM C457-98 for the same Nominal Or Observed Maximum Size Of Aggregate In the Concrete. The following table provides examples for the minimum area requirements for the two Nominal Maximum Sizes of aggregate used in MTO contracts.

For specimens prepared by cutting cores lengthwise, if the total available area is larger than that specified above, test either the entire available area or an area of the specified size adjacent to the surface of the concrete structure or concrete component.

For specimens with total area available for testing smaller than that specified above, test the entire available area.

4.2.2 Minimum Length of Traverse and Minimum Number of Points: The length of traverse and the number of points shall be twice those specified in Table 3 of ASTM

C457-98. The following table provides examples for the minimum length of traverse and the minimum number of points for two Nominal Maximum Sizes of aggregates used in MTO contracts.

Nominal Or Observed Maximum Size Of Aggregate In the Concrete (mm)	Minimum Area To Be Traversed (cm^2)	Minimum Length Of Traverse (mm)	Minimum Number Of Points
19	142	4572	2700
13.2	130	4064	2400

4.2.3 Calculation: Use the following equation to calculate the spacing factor.

If *p/A* is less than or equal to 4.342

$$\overline{L} = \frac{S_p \cdot I}{4N}$$

If p/A is greater than 4.342

$$\overline{L} = \frac{3I \cdot S_a}{4N}[1.4(1 + \frac{S_p}{S_a})^{1/3} - 1]$$

Note 1: These equations are based on the equations in ASTM C457. These equations use the data recorded on the counters directly to avoid rounding the numbers in subsequent steps.

Note 2: If the there is a difference between the result provided by the built-in program of computerized system and the result calculated according to the above equations, the result calculated according to the above equations shall be used.

4.2.4 Report of results: Report the total air content in percentage to one decimal point and report spacing factor in micrometers with no decimal point.

METHOD OF TEST
FOR
MECHANICAL CONNECTORS USED TO SPLICE STEEL REINFORCEMENT

1. SCOPE

1.1 This test method covers the test procedures for determining the slip (axial displacement) and tensile strength of mechanical connectors for splicing steel reinforcement.

1.2 Job control testing is carried out on samples assembled in the field by the Contractor.

2. RELEVANT DOCUMENT

2.1 E 4 Standard Practices for Force Verification of Testing Machines

3. DEFINITION

3.1 *Mechanical Connector*: The mechanical device used to splice reinforcing steel bar.

3.2 *Sample:* Spliced reinforcing steel bar including the mechanical connector.

3.3 *Specified Yield Strength,* σ_y*:* Yield strength for the reinforcing steel bar as specified in the governing standard, specification, or contract drawing. Typically σ_y = 400 MPa

3.4 *Mean Yield Strength,* σ*:* Average yield strength of representative reinforcing steel bars used in the test of mechanical connection. The yield strengths are obtained from the Mill Test Certificates.

3.5 Slip: The axial displacement of the reinforcing steel bar measured relative to the mechanical connector. Displacement is measured at a reinforcing steel bar stress of $0.05\sigma_y$, after the mechanical connection has been loaded to a reinforcing steel bar stress of $0.5\sigma_y$, and then unloaded to a reinforcing steel bar stress of $0.05\sigma_y$.

3.6 *Sample Strength:* The load or stress on the sample at failure.

4. APPARATUS

4.1 *Tensile Testing Machine* - A compression testing machine conforming to the requirements of ASTM E 4. The machine shall be of sufficient capacity to fully load the sample by applying force without impact.

4.2 *Dial Gauge:* The dial gauge may be analogue or digital and shall be accurate to within 0.025mm.

5. TEST SAMPLES

5.1 Samples for Designated Sources of Materials evaluation shall be supplied with the following information: model number of the mechanical connector, production date, supplier/manufacturer, and assembler's name.

5.2 Job control samples shall be supplied with the following information: contract number, model number, sublot number, connector bar size, number of connectors within the sublot, date of supply to the contract site and name of manufacturer. Mill test certificates for the steel reinforcement used in the sample shall be supplied with the job control sample.

5.3 The total length of the sample shall be between one and two meters.

6. PREPARATION OF SPECIMENS

6.1 Before testing ensure that:

a) each sample has been assembled.

b) there is room to mount dial gauges and hardware to measure slip.

6.2 No adjustments or modifications shall be made to the sample except that the reinforcing steel bar may be cut to allow the sample to fit into the test frame.

7. SLIP

7.1 Place the sample in the test machine and attach all necessary hardware for the dial gauges that are to be used for measurement. Specimen set up and gauge length shall be as illustrated in Figure 1.

7.2 Preload the sample to $0.05\sigma_y$ to set the samples in the jaws.

Example: A reinforcing steel bar with σ_y of 400MPa is preloaded to 20MPa (0.05x400)

7.3 Attach the dial gauges across the mechanical connector and establish an initial length by zeroing out the dial gauges or by recording readings on the dial gauges.

7.4 Load the sample to $0.5\sigma_y$ of the reinforcing steel bar and maintain the load until a steady reading is obtained on the dial gauges.

Example: A reinforcing steel bar with σ_y of 400M is loaded to 200MPa (0.5x400)

7.5 Reduce the load to a reinforcing steel bar stress of $0.05\sigma_y$ and take readings on the dial gauges. This will be the measured length.

7.6 Loading and unloading of the sample shall be at a rate in which σ_y is reached between one and two minutes.

Example: To reach σ_y in 90 second, the rate of loading is 4.5 MPa/Second (400/90) or 267MPa/minute (400/1.5).

7.7 Calculate slip as follows:

Slip = Measured length – Initial length

8. TENSILE STRENGTH

8.1 Remove all dial gauges and hardware from the sample.

8.2 Place sample in the test machine.

8.3 For reinforcing bars of diameters 40-55M, load the sample in tension to a load equal to $1.2\ \sigma_y$ and $1.1\ \sigma$. Observe and record condition of the sample at each load and at the end of the test. Record the maximum load or stress achieved.

Example: A reinforcing steel bar with σ_y of 400M is loaded to 480MPa (1.2x400).

Using yield strength provided in the Mill Test Certificate(s) for reinforcing steel representative of the bars used in the test, calculate mean yield strength, σ, and $1.1\ \sigma$. Use single value of yield strength where the Mill Test Certificate(s) provide a single yield strength result.

8.4 For reinforcing bars of diameters 15-35 M, load the sample in tension to a failure.

8.5 Record the maximum load or stress.

8.6 Remove the sample from the test machine.

9. REPORTING

9.1 GENERAL REPORTING

9.1.1 The contract number, sublot number.

9.1.2 Connector bar size, number of connectors within the sublot,

9.1.3 Date of supply to the contract site and name of manufacturer

9.1.4 Name of manufacturer and model number

9.1.5 Test operator's name, and date tested.

9.2 SLIP TEST REPORTING

9.2.1 The preload or prestress value and the load rate.

9.2.2 The maximum load or stress reached during the slip test.

9.2.3 Initial and measured length measurements.

9.2.4 Slip in mm.

9.3 STRENGTH TEST REPORTING

9.3.1 The load rate.

9.3.2 The required test loads, 1.2 σ_y and 1.1 σ including values σ_y and σ used to calculate these loads.

9.3.3 The maximum load or stress reached during the strength test.

9.3.4 Description of sample condition at a load of 1.2σ_y and 1.1 σ (for 40-55M bars).

9.3.5 Description of sample condition at the maximum load or stress.

9.3.6 A copy of the Mill Test Certificate(s) for the steel reinforcement used in the sample shall be attached with the report.

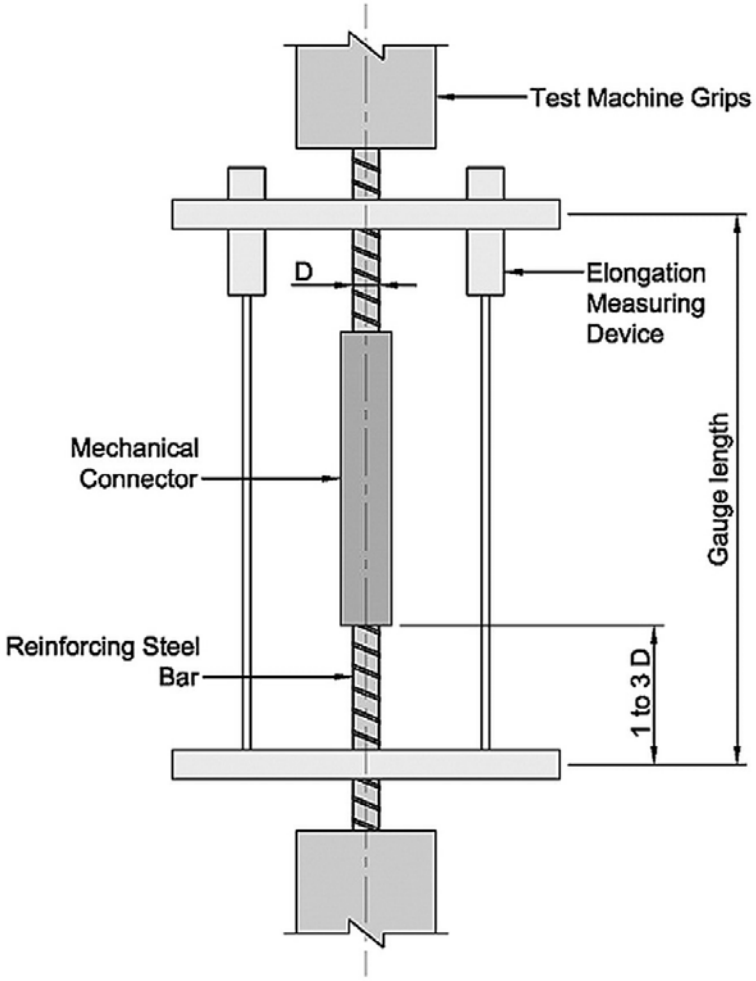


Figure 1

Specimen Set-Up and Dial Gauge Length

METHOD OF TEST FOR LINEAR SHRINKAGE OF CONCRETE

1. SCOPE

1.1 This method of test covers the procedure for determining linear shrinkage of concrete with a maximum nominal aggregate size of up to and including 19mm.

2. RELEVANT DOCUMENTS

2.1 ASTM C 157/C157M-04 Standard Test Method For Length Change of Hardened Hydraulic Cement Mortar and Concrete.

3. PROCEDURE

3.1 Procedures of ASTM C 157 shall be followed, except as noted below.

4. EXCEPTIONS

4.1 TEST SPECIMEN

Standard specimen size shall be 75mm x 75mm x 285mm.

4.2 PROCEDURES

4.2.1 The specimens shall be demoulded at the age of 24 ± 0.5 hours after the addition of water to the cement, and immediately placed in lime-saturated water at a temperature of 23 ± 2^{o}C, where they shall remain until they reach the age of 7 days.

4.2.2 At 7 days of age the specimens shall be removed from the lime-saturated water and the initial comparator reading shall be taken. This reading shall be used as initial reading for calculation of linear shrinkage.

4.2.3 Following the initial reading, the specimens shall be placed in a drying room until the age of 35 days.

4.2.4 The final comparator reading shall be taken at 35 days of age.

4.2.5 The linear shrinkage at 35 days of age shall be calculated using the initial and final readings as defined in this test method.

4.3 REPORTING

4.3.1 Length change data, reported as percent decrease or increase in linear dimension to the nearest 0.001% of the gauge length based on the initial measurement made at 7 days of age at the time of removal from the lime-saturated water storage.

4.3.2 Records of the drying room's rate of evaporation. A minimum of one result for each day of the drying period shall be reported.

4.3.3 Records of the drying room's temperature and humidity. A minimum of two sets of measurements for each day of the drying period shall be reported.

4.3.4 Mix Design Number

4.3.5 Contract Number

METHOD OF TEST FOR

SIEVE ANALYSIS OF AGGREGATES

1. SCOPE

1.1 This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

2. REFERENCES

2.1 LS-600, Method of Dry Preparation of Aggregates for the Determination of Physical Constants

2.2 LS-601, Method of Test for Materials Finer than 75 μm Sieve in Mineral Aggregate by Washing.

2.3 LS-625, Guidelines for Sampling of Granular Materials

2.4 ASTM C 136 Standard Method for Sieve Analysis of Fine and Coarse Aggregates.

2.5 ASTM D 75 Standard Practice for Sampling Aggregates

2.6 ASTM E 11 Standard Specification for Wire-Cloth Sieves for Testing Purposes

2.7 ASTM Manual on Testing Sieving Methods - Publication STP 447B

2.8 CAN/CGSB, 8.1, Sieves, Testing, Woven Wire, Inch Series

2.9 OPSS 1010, Ontario Provincial Standard Specification for Granular A, Granular B, Granular M, and Select Subgrade Material (SSM)

3. APPARATUS

3.1 BALANCE:

3.1.1 Fine Aggregate: A balance or scale readable to 0.1 g and accurate to within 0.1% of the test load at any point within the range of use.

3.1.2 Coarse Aggregate or a mixture of Coarse and Fine Aggregates: A balance or scale accurate to within 0.1% of the test load at any point within the range of use.

3.2 SIEVES: With square openings and of suitable sizes to furnish the information required by the specification covering the material to be tested. The sieve cloth and frame shall conform to ASTM E11 or CAN/CGSB 8.1. Half-height sieves shall not be used for sieving material coarser than 9.5 mm, unless results of sieving sufficency tests show that proper sieving action can be obtained.

3.3 OVEN: Of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C.

3.4 SIEVE SHAKER: A mechanical apparatus capable of creating lateral and vertical motion of sieves accompanied by a jarring motion so as to keep aggregate particles moving continuously over the surface of the sieve.

3.5 SAMPLE SPLITTERS: For fine and coarse aggregates. (See Test Method LS-600, para. 3.6.)

4. PREPARATION OF TEST SAMPLE

4.1 Aggregate test samples for sieve analysis should be split from a larger field sample taken in accordance with LS-625, ASTM D75, or as otherwise specified. Where no sampling specification is given, the field sample should be at least four times the minimum test sample mass given in Table 1.

4.2 The sample of aggregate to be tested shall be, if necessary, thoroughly mixed and reduced by use of a sample splitter or by coning and then quartering to an amount suitable for testing. The sample to be tested shall be the end result of the reduction method used. No attempt shall be made to select samples of an exact predetermined mass.

4.3 Except for aggregate specifications included in OPSS 1010 as noted in para. 4.4 below, the minimum mass of the test sample is determined by the nominal maximum particle size as shown in Table 1.

Note 1: Nominal maximum particle size is defined as "the largest sieve in the applicable specification upon which any material is permitted to be retained".

Table 1

Nominal Maximum Size	Minimum Test Sample Mass, Kg
9.5 mm	1
13.2 mm	2
16.0 mm	3.5
19.0 mm	5
26.5 mm	10
37.5 mm	15
53.0 mm	20
63.0 mm	25
75.0 mm	45

4.4 For OPSS aggregate specifications, the minimum test sample mass for Granular A and M shall be 10 kg. For Granular B Type I, Granular B Type II and SSM, the minimum test sample mass shall be determined by the smallest sieve in Table 1 that 100 per cent of the material passes.

Note 2: Because of the wide range of possible gradations within the Granular B and SSM specifications, test sample sizes need to vary with the material, rather than the specification. Examples include: for a Granular B, Type I, with 100% passing the 53.0 mm sieve (some material retained on the 37.5 mm sieve), the minimum test sample mass is 20 kg; for an SSM with 100% passing the 13.2 mm sieve, the minimum test sample mass is 2 kg.

4.5 Fine aggregate portions (material passing 4.75 mm sieve) for testing should be reduced in size by splitting to 250 – 300 g. If the test sample is predominantly composed of fine sand, i.e., 100% passing 600 μm sieve, the sample size should be reduced to 125 - 150 g to prevent overloading on one or more sieves.

4.6 When greater precision is specified for testing fine aggregate, obtain 500 – 600 g of dried fine aggregate by use of a sample splitter or by quartering. Split this sample into two sub-samples of 250 – 300 g each. Fine sand samples should be reduced accordingly as directed in para 4.5.

5. TEST PROCEDURE

5.1 Dry the test sample to a constant mass using an oven operating at a temperature of 110 ± 5°C. If the sample contains asphalt coated particles, i.e., reclaimed asphalt pavement, the sample shall be dried to constant mass in an oven set at maximum 40°C or by air drying. Allow the sample to cool to room temperature before proceeding.

Note 3: For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless: (a) the nominal maximum size is smaller than 13.2 mm; (b) the coarse aggregate contains appreciable material finer than 4.75 mm, or; (c) the coarse aggregate is highly absorptive, e.g, light-weight aggregate.

Note 4: Samples may be dried at higher temperatures associated with the use of hot plates without affecting results provided that steam is allowed to escape freely without generating pressures sufficient to fracture the particles, and that temperatures are not so great as to cause chemical alteration or physical breakdown of the aggregate.

5.2 Coarse Sieving Operation: Weigh and record the total mass of the dried test sample. Place the test sample in the uppermost sieve of a progressive series of sieves selected according to the specification requirements or material characteristics and vibrate by means of a lateral and vertical motion of the sieve accompanied by a jarring motion so as to keep the sample moving continuously

over the surface of the sieves. Continue the sieving operation by hand or by sieve shaker for a sufficient period, established by trial to meet the criterion for adequacy of sieving requirement specified in para 5.2.1. In no case should the particles be turned or manipulated through the sieve by hand.

Note 5: Use of a sieve shaker in excess of about 15 minutes to achieve adequate sieving may result in degradation of the sample. If the sieving sufficiency requirement cannot be achieved within 15 minutes of operation, the sieve shaker may have to be repaired or replaced. After separating the sample on each sieve by the sieve shaker, the sieving operation should be continued by hand to achieve the sufficiency requirement.

5.2.1 Continue sieving for a sufficient period and in such manner that, after completion, not more than 1.0 % by mass of the residue on any individual sieve will pass that sieve during 1 minute of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75 mm sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203 mm diameter sieves to verify the sufficiency of sieving.

Note 6: Individual coarse aggregate sieves meeting the requirements of E 11 may have sufficiently wide variations in opening size that difficulties may be experienced in measuring sieving sufficiency. It is preferable to determine the sieving sufficiency using the sieve the sample was first sieved on. If this is impractical, check that the sieve intended for determination of sieving sufficiency not only meets the requirements of E 11 but also has an opening size the same as, or smaller than that of the sieve on which it is desired to determine the sufficiency of sieving.

5.3 To prevent overloading of individual sieves, additional sieves to those required by the specification should be inserted so as to distribute the fractions more evenly. Material retained on these sieves shall be added in cumulative weighing to the next smallest specification sieve

Note 7: To determine the maximum amount of material allowed on a given sieve, refer to the information given in ASTM C136 or the tables published in ASTM STP 447B - ASTM Manual on Test Sieving Methods.

5.4 On completion of the coarse sieving operation, separate the sieves and weigh and record the individual mass of the fraction retained on each sieve.

5.5 Weigh and record the mass of material that passes the 4.75 mm sieve (pan portion). Check the initial dry mass of the sample against the mass of the sample after sieving. This mass is obtained by adding the mass of material passing the 4.75 mm sieve in the pan to the cumulative mass retained on the 4.75 mm sieve. The difference between the initial mass and the mass after sieving shall be no more than 0.30%, otherwise, a re-test is required.

Note 8: There is a probability of particle loss during sieving, causing a testing error. This loss is usually in the form of fines. However, occasionally, it could be in the form of coarse particles.

5.6 Reduce the pan portion according to para. 4.5 or para. 4.6 to produce the fine aggregate test portion. Where the fine aggregate test portion is prepared according to para. 4.6, perform the test on each sub-sample.

5.7 Fine Sieving Operations: Weigh and record the total mass of the prepared test sample. Wash the fine aggregate test portion according to the procedure given in LS-601. Dry the material retained on the 75 μm sieve to constant mass as described in para. 5.1. Weigh and record the total mass of the dried test sample.

5.8 Sieve the remaining test portion through the required nest of fine aggregate sieves in the manner described in para. 5.2.

5.9 On completion of the sieving operation, separate the sieves and weigh and record, cumulatively, the mass of the fraction retained on each sieve. Record the mass of any portion which passes the smallest sieve size (pan portion).

5.10 For test portions consisting of two sub-samples, weigh and record the cumulative mass of the fraction retained on each sieve (and pan portion) for each sub-sample separately. Provided that the difference on any sieve between the two individual sub-samples is no greater than 5%, a combined grading is calculated from the sum of the cumulative masses for each sieve (and pan portion), otherwise a re-test is required.

6. CALCULATIONS

6.1 All determinations shall be made to the nearest 0.1% of the mass of the sample.

6.2 Calculate the percentage of coarse and fine aggregates in the sample as follows:

$$\text{Per cent coarse aggregate, } D = \frac{B}{A} \times 100$$

$$\text{Per cent fine aggregate, } E = \frac{C}{A} \times 100$$

6.3 Calculate the cumulative percentages on each sieve for the coarse aggregate portion and the fine aggregate portion of the test sample.

6.3.1 Coarse Aggregate Portion:

Per cent retained $= \frac{X}{B} \times 100$

Per cent passing $= \frac{B-X}{B} \times 100$

6.3.2 Fine Aggregate Portion:

Per cent retained $= \frac{Y}{F} \times 100$

Per cent passing $= \frac{F-Y}{F} \times 100$

6.4 Calculations to obtain the complete gradation of the sample.

6.4.1 To determine the percentage retained on each sieve:

Per cent retained coarse aggregate sieves $= \frac{X}{A} \times 100$

Per cent retained fine aggregate sieves $= \frac{Y}{F} \times E + \%\ Ret.\ 4.75$

6.4.2 To determine the percentage passing on each sieve:

Per cent passing coarse aggregate sieves $= \frac{A-X}{A} \times 100$

Per cent passing fine aggregate sieves $= \frac{F-Y}{F} \times E$

where: A = Mass of total sample

B = Mass retained on the 4.75 mm sieve

C = Mass passing the 4.75 mm sieve, $C = A\text{-}B$

D = Per cent coarse aggregate

E = Per cent fine aggregate

F = Mass of fine aggregate test portion before washing

X = Cumulative mass retained on each sieve, coarse portion

Y = Cumulative mass retained on each sieve, fine portion

6.5 Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100 : 150 µm, 300 µm, 600 µm, 1.18 mm, 2.36 mm, 4.75 mm, 9.5 mm, 19.0 mm, 37.5 mm, and larger, increasing in the ratio of 2:1.

7. REPORTING RESULTS

7.1 The report shall include the following, as necessary:

7.1.1 Total percentages of coarse and fine aggregates.

7.1.2 Total percentage of material retained on or passing each coarse aggregate sieve based on the total mass of the oven-dry coarse aggregate portion.

7.1.3 Total percentage of material retained on or passing each fine aggregate sieve based on the total mass of the oven-dry test sample of the fine aggregate before washing.

7.1.4 Total percentage of material retained on or passing each sieve based on the total mass of the oven-dry total sample.

7.1.5 When two sub-samples of fine aggregate are tested, the mean of the results shall be reported as the final result.

7.1.6 Report the difference between the initial dry mass of the sample and the sum of the individual masses retained on each sieve as a percentage of the initial dry mass.

8. GENERAL NOTES

8.1 Figure 1 shows a laboratory worksheet that may be used to record test data and calculate results.

8.2 Check all sieves regularly to ensure that the mesh is not blinded, and is free from defects and distortion. Fine mesh sieves, if blinded by sand particles, can be cleaned using an ultrasonic bath. If this equipment is not available, a soft brass brush may be used for cleaning sieves coarser than the 150 µm and a nylon brush for finer sieves. This is done by brushing the underside of the wire cloth with a circular motion, taking care not to use too much pressure. The frame of the sieve may be gently tapped with the wooden handle of the brush. Under no circumstances should embedded particles be forced out of the openings with a pick or needle.

8.3 Small holes or breaks in fine mesh sieves may be repaired with an appropriate epoxy.

8.4 When emptying each of the sand sieves, brush the bottom of the inverted sieve gently, but firmly with the proper sieve brush, using a circular motion. This ensures that all sand particles are included with the sample, and that the sieve is kept clean, and its efficiency maintained.

8.5 In the case of Granular B and SSM (OPSS 1010). Particles larger than 26.5 mm may be removed, and hand sieved through the larger specified sieves. It is permissible to determine the percentage passing the 75 mm and larger sieves without drying the test sample. Remove any adhered fines from these larger particles, and return them to the test sample. The gradation of the passing 75 mm portion must be carried out after drying.

8.6 Unless a sieve shaker is used, hand sieve particles larger than 75 mm by determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

Figure 1. Gradation Computation Worksheet

Lab №:	Date:
Sample Description:	Specification:

Note: All masses are for dried aggregate.

Total Sample Mass *[A]* : g	% Coarse Aggregate *[D]*: %	% Fine Aggregate *[E]* : %

Coarse Aggregate

Sieve	Individual Mass Retained (g)	Cumulative Mass Retained (g) *[X]*	(Coarse Aggregate Portion Only)		% Passing (Total Sample)
			% Retained	% Passing	
106 mm					
75 mm					
63 mm					
53 mm					
37.5 mm					
26.5 mm					
22.4 mm					
19.0 mm					
16.0 mm					
13.2 mm					
9.5 mm					
6.7 mm					
4.75 mm		[B]			
Pan		Pan + [B]	Mass passing 4.75 mm (g) *[C = A – B]:*		

Fine Aggregate

Sample mass before washing (g): *[F]*		Mass passing 75μm sieve by washing (g):	
Sample mass after washing (g)		Mass passing 75μm sieve by sieving (g):	

Sieve	Cumulative Mass Retained (g) *[Y]*	(Fine Aggregate Portion Only)		% Passing (Total Sample)
		% Retained	% Passing	
4.75 mm				
2.36 mm				
1.18 mm				
600 μm				
300 μm				
150 μm				
75 μm				
Pan		Total mass passing 75 μm sieve (g):		

Note: Space provided for sub-samples

Technician: _____

METHOD OF TEST FOR RESISTANCE TO DEGRADATION OF COARSE AGGREGATE BY ABRASION AND IMPACT IN THE LOS ANGELES ABRASION MACHINE

1. SCOPE

1.1 This method covers the determination of resistance to degradation of coarse aggregate by abrasion and impact using the Los Angeles testing machine.

2. RELEVANT DOCUMENTS

2.1 ASTM C 131

2.2 ASTM C 535

2.3 AASHTO T 96

2.4 CSA-A23.2-16A

2.5 CSA-A23.2-17A

3. PROCEDURE

3.1 Procedures of ASTM Standard C 131 and C 535 shall be followed, except as noted below, for the determination of degradation of coarse aggregate by abrasion and impact using the Los Angeles testing machine.

4. EXCEPTIONS

4.1 SIEVES: Conforming to ASTM Specification E11, except use 13.2 mm sieve size instead of 12.5 mm.

4.2 Replace ASTM Standard Clause 5.4.1, with Table 1 as follows:

The abrasive charge, depending upon the grading of the test sample as described in Table 2, shall be as follows:

Table 1

GRADING	# OF SPHERES	MASS, g
A	12	5000 ± 25
B	11	4580 ± 25
C	8	3330 ± 20
D	9	3740 ± 20

Table 2: Gradation of Test Samples

SIEVE SIZE		MASS OF INDICATED SIZES, g			
PASSING	RETAINED	A	B	C	D
37.5 mm	26.5 mm	1250 ± 25			
26.5 mm	19.0 mm	1250 ± 25			
*19.0 mm	13.2 mm	1250 ± 10	2500 ± 10	-	2500 ± 10
13.2 mm	9.5 mm	1250 ± 10	2500 ± 10	-	1250 ± 10
* 9.5 mm	4.75 mm	-	-	-	1250 ± 10
9.5 mm	6.7 mm	-	-	2500 ± 10	-
6.7 mm	4.75 mm	-	-	2500 ± 10	-
	TOTAL	5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

* Material previously separated into individual sizes shall be recombined in proportion to the original or laboratory crushed gradation.

5. USE OF LABORATORY CONTROL AGGREGATE

5.1 Every ten samples, but at least every week in which a sample is tested, a sample of a reference aggregate shall also be tested. The material shall be taken from a stock supply maintained by the laboratory.

Note: The material selected by the laboratory may be calibrated against a supply of Brechin Quarry No. 2 stone. When prepared to an 11-B grading, the mean loss of the Brechin standard reference aggregate is 21.4% (MERO-015, 2005). Individual test data should not normally be greater than 24.1%, or less than 18.7%.

5.2 Control Chart Use: The percent loss of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the performance of the laboratory.

6. REPORT

The report shall also include the following:

6.1 The percent loss of the reference sample, tested closest to the time at which the aggregate sample was tested, to one decimal place.

6.2 The percent loss of the last twenty samples of reference material on a control chart.

Ministry of Transportation
Ontario

LOS ANGELES ABRASION TEST

LAB. NO.	% CRUSH	NO. OF BALLS	TYPE OF GRADE	MASS RETAINED							TOTAL MASS	RET. 1.70 mm (500 REV'S.)	
				26.5 mm	19.0 mm	16.0 mm	13.2 mm	9.5 mm	6.7 mm	4.75 mm		BEFORE WASHING	AFTER WASHING

PH-CC-333 78-06

Date _____ **Operator** _____ **Computed by** _____

Figure 1 Los Angeles Abrasion Data Card

METHOD OF TEST FOR
RELATIVE DENSITY AND ABSORPTION OF COARSE AGGREGATE

1. SCOPE

1.1 This method covers the determination of relative density (oven-dry and saturated-surface dry) and apparent relative density at 23°C and absorption of coarse aggregate.

2. RELEVANT DOCUMENTS

2.1 ASTM C 127

2.2 AASHTO T 85

3. DEFINITION

Coarse aggregate – For the purpose of this test is all aggregate material retained on the 4.75 mm sieve. This includes material retained on the 4.75 mm sieve contained in fine aggregates.

4. PROCEDURE

4.1 Procedures of ASTM Standard C 127 (concrete aggregate) and AASHTO T 85 (asphalt aggregate) shall be followed, except as noted below, for the determination of relative density at 23°C and absorption of coarse aggregate. When the material passing the 4.75 mm sieve in coarse aggregate exceeds 5%, this material shall be blended with the fine aggregate in Test Method LS-605 clause 6.2.1.

5. EXCEPTIONS

5.1 Individual coarse aggregates for hot mix asphalt mixture design process

5.1.1 Obtain a representative sub-sample of approximately 3000 g of oven-dried coarse aggregate by use of a sample splitter or by quartering.

5.1.2 Remove all material finer than 4.75 mm by dry sieving. Remove all dust or other coatings by thorough washing. In the case of RAP, use a wetting agent.

5.1.3 Saturate the samples in water by immersion for 15-19 hours.

5.2 Blended coarse aggregates for hot mix asphalt mixture design process (Note 1).

5.2.1 Prepare two 3-kg sub-samples and perform the test on each.

5.2.2 Sample preparation for hot mix asphalt coarse aggregates shall be modified as follows: When more than one coarse aggregate will be used, the coarse aggregates shall be blended in the volume or mass proportion in which they will be used. When the densities of individual aggregates are within 0.02 of each other, the per cent by mass can be assumed to the same as per cent by

volume. When there is more than 5% by mass coarse aggregate in the blended fine aggregate, the coarse fraction of the blended fine aggregate shall be included in the coarse aggregate test sample in the correct proportion.

Note 1: Testing of blended coarse aggregate is carried out only when specified by the Owner. If the densities of the individual coarse aggregates used in the mix are significantly different, follow the example provided in Appendix A to prepare the test sample.

5.3 Coarse aggregates extracted from RAP for both Marshall and Super Pave mix design

5.3.1 Remove the asphalt from the RAP by solvent extraction with a suitable solvent. Soak the extracted aggregates in denatured methyl alcohol overnight, drain off the alcohol.

5.3.2 Follow the procedures of 5.1.

5.4 Combinations of virgin coarse aggregate and RAP for Marshall and SuperPave processes

5.4.1 Calculate the density of the coarse aggregate in the asphalt mixture by using a calculation based on the density of the virgin coarse aggregate determined following 5.1 or 5.2 and the density of the RAP coarse aggregate determined following 5.3. The calculation shall be based on the mass proportions of virgin coarse aggregate to the mass proportion of coarse aggregate contributed to the mixture by the RAP.

5.5 If duplicate tests of relative density differ by more than 0.020, the material shall be retested.

5.6 If duplicate tests of absorption differ by more than 0.20%, the material shall be retested.

6. USE OF LABORATORY CONTROL AGGREGATE

6.1 Every ten samples, but at least every week in which a sample is tested, a sample of the standard reference aggregate shall also be tested. Material shall be taken from a stock supply of Brechin Quarry No. 2 stone maintained by the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8, Fax (416) 235-4101. Only material retained 4.75 mm and coarser shall be tested. It is permissible to re-use the reference material provided it does not degrade due to multiple wetting and drying cycles.

6.2 Control Chart Use: The relative density and absorption of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the performance of the laboratory.

6.3 The mean absorption of the Brechin Quarry No. 2 standard reference aggregate is 0.68% (MERO-002 & 008, 2003, & 2004). Individual test data should not normally be greater than 0.81% or less than 0.55%.

6.3.2 The mean relative density (oven-dry) of the Brechin standard reference aggregate is 2.670. Individual test data should not normally be greater than 2.682 or less than 2.658.

7. REPORT

The report shall include the following:

7.1 If duplicate tests of absorption and relative density are made, the mean of the results shall be reported as the final "test result".

7.2 If more than one aggregate is tested report the density and absorption of each and the weighted average of the combination.

7.3 The percent absorption to the nearest 0.01%, and relative densities to the nearest 0.001 of the reference sample, tested closest to the time at which the aggregate sample was tested.

7.4 The percent absorption and relative density of the last twenty samples of reference material on control charts.

APPENDIX A

Development of Equations for Preparation of Test Samples with Different Densities

The equations are derived for an asphalt mix consisting of three types of coarse aggregates, Type A, B, and C, with different densities and the blended fine aggregate portion used will contain P_f% by mass of material coarser than 4.75 mm. The mass, bulk specific gravity, and volume of coarse aggregate Type A in the blended portion M_a in grams, G_a and P_a% by volume. The mass, bulk specific gravity, and volume of other two coarse aggregates (Type B and C) in the mix are M_b, G_b and P_b%, and M_c, G_c, P_c%, respectively.

Mass of coarse aggregate from fine aggregate M_f in grams $= (M_t)\left(\frac{P_f}{100}\right)$

Mass of blended coarse aggregates (Type A, B, & C) in the test sample = $(M_t - M_f)$ grams

$$P_a + P_b + P_c = 100$$

$$M_a = G_aV_a,\ M_b = G_bV_b \text{ and } M_c = G_cV_c$$

$$(V_a)/(V_b) = (P_a)/(P_b)$$

$$M_a + M_b + M_c = (M_t - M_f)$$

Where, V_a, V_b, V_c are the volume of coarse aggregates Type A, B, and C in the mix.

Manipulation of the above equations yields masses M_a, M_b and M_c of coarse aggregates in the test sample.

$$M_a = (M_t - M_f)\left[\frac{(P_a G_a)}{(P_a G_a + P_b G_b + P_c G_c)}\right],$$

$$M_b = (M_t - M_f)\left[\frac{(P_b G_b)}{(P_a G_a + P_b G_b + P_c G_c)}\right] \text{ and}$$

$$M_c = (M_t - M_f)\left[\frac{(P_c G_c)}{(P_a G_a + P_b G_b + P_c G_c)}\right]$$

Example: The proposed asphalt mix will use three types of coarse aggregates, Types A, B, and C, in the proportion of 50%, 30%, and 20% by volume. The bulk specific gravity of coarse aggregates A, B, and C are 2.600, 2.685, and 2.750. The fine aggregates in the proposed mix will contain 10% by mass of material coarser than 4.75 mm. Prepare 3000 grams of test sample in the proportion of coarse aggregates expected in the proposed asphalt mix.

The portion of the coarse aggregate from the fine aggregate = 3000 x (10/100)
= 300.0 grams

Mass of blended coarse aggregates (A, B, & C) in the test sample = (3000.0 – 300.0)
= 2700.0 grams

Mass of Type A in the test sample = (2700.0)(2.600x50)/(2.600x50 + 2.685x30 + 2.750x20)
= 1321.8 grams

Mass of Type B in the test sample = (2700.0)(2.685x30)/(2.600x50 + 2.685x30 + 2.750x20)
= 819.0 grams

Mass of Type C in the test sample = (2700.0)(2.750x20)/(2.600x50 + 2.685x30 + 2.750x20)
= 559.2 grams

The total mass of tests sample = 300.0 + 1321.8 + 819.0 + 559.2 = 3000.0 grams

Ministry of Transportation Ontario

RELATIVE DENSITY AND ABSORPTION - COARSE AGGREGATE

LAB. NO.	SURFACE-DRY AGG. IN AIR MASS (B)	OVEN-DRY AGG. IN AIR MASS (A)	AGGREGATE IN WATER MASS (C)	LAB. NO.	SURFACE-DRY AGG. IN AIR MASS (B)	OVEN-DRY AGG. IN AIR MASS (A)	AGGREGATE IN WATER MASS (C)

PH-CC-331 90-01

DATE _____

OPERATOR _____

COMPUTED BY _____

Figure 1 Relative Density and Absorption – Coarse Aggregate Data Card

METHOD OF TEST FOR RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE

1. SCOPE

1.1 This method covers the determination of relative density (oven-dry and saturated-surface-dry), apparent relative density and absorption of fine aggregate.

2. RELEVANT DOCUMENTS

2.1 MTO LS-601

2.2 ASTM C 128

2.3 AASHTO T 84

3. DEFINITION

Fine aggregate – For the purpose of this test is all aggregate material passing the 4.75 mm sieve and predominantly coarser than the 75 µm sieve. This includes material passing the 4.75 mm sieve contained in the coarse aggregates.

4. SIGNIFICANCE AND USE

4.1 In addition to the Significance and Use given in the AASHTO procedure, further clarification is provided below in 4.2.

4.2 Bulk relative density is used in calculations of the VMA in asphalt mixtures. Slight biases in determining relative density may lead to inaccuracies in assessing the correct VMA. In order to minimize these inaccuracies, MTO has required the removal of fines from the fine aggregate for hot mix asphalt design purposes for over 40 years (Procedure 6.1). Procedure 6.2 has been developed for Super Pave mixture design. The procedure is intended to be used on the proposed blend of fine aggregates. In developing the actual blend of materials to be used in the mixture, the designer should use whatever technique of AASHTO T 84 they deem most accurate in determining the relative densities of the individual components, and then blend proportionately to create a test sample.

5. PROCEDURE

5.1 Procedures of AASHTO T 84 shall be followed, except as noted below, for the determination of relative density, apparent relative density, and absorption of fine aggregate. The period of soaking in water shall be 15-19 hours as specified by AASHTO (Note 1) except as noted below.

Note 1: The ASTM procedure specifies 24 ± 4 h of soaking.

5.2 If the aggregate contains material coarser than the 4.75 mm sieve, remove this material from the test sample. If the amount of material coarser than the 4.75 mm sieve is greater than 5% by mass of the sample, this material should be tested in LS-604. If the amount is less than 5% by mass, discard the material but assume that this material has the same density as the parent fine aggregate material in any calculations of density of the combined coarse and fine aggregates.

6. EXCEPTIONS TO AASHTO T 84

6.1 Individual fine aggregates for hydraulic cement concrete and for hot mix asphalt mixture design process

6.1.1 Obtain two representative sub-samples of approximately 1200 g of oven-dried fine aggregate by use of a sample splitter or by quartering.

6.1.2 Wash the samples over a 75 µm sieve in accordance with MTO LS-601, Method Of Test For Material Finer Than 75 µm Sieve In Mineral Aggregates By Washing, until all material passing the 75 µm sieve is removed.

6.1.3 Saturate the samples in water by immersion for 24 ± 4 hours for concrete fine aggregate and 15-19 hours for asphalt fine aggregate.

6.1.4 Test the two sub-samples. For the purpose of determining the saturated surface dry condition, where possible use the normal cone test.

6.1.5 If duplicate tests of relative density differ by more than 0.027, the materials shall be retested.

6.1.6 If duplicate tests of absorption differ by more than 0.31%, the materials shall be retested.

6.2 Blended fine aggregates for hot mix asphalt mixture design process (Note 2)

6.2.1 Make up a sample of approximately 2400 g of oven-dried fine aggregate. This is made by weighing up, in volume or mass proportion in which it will be used in the asphalt mixture, a representative sample from each fine aggregate. Material in the blended coarse aggregate(s) which is finer than 4.75 mm shall also be added in the proportion in which the coarse aggregate will be blended with the fine aggregate (Note 3) when the amount of material pass the 4.75 mm sieve in the blended coarse aggregate is greater than 5% by mass of the coarse aggregate. If the amount is less than 5% for the purposes of volume calculation, there is no need to test the pass 4.75 mm of

the total coarse aggregate. Assume that the pass 4.75 mm material from the coarse aggregate has the same density as that of the coarse aggregate.

6.2.2 Thoroughly mix the blended sample and split this combined sample into two sub-samples of approximately 1200 g and perform the test on each sub-sample. Reclaimed asphalt pavement materials (RAP) shall not be blended into the virgin fine aggregate test sample. RAP materials shall be tested separately.

Note 2: Testing of blended fine aggregate is carried out only when specified by the Owner.

Note 3: Example: The proposed asphalt mixture design will use two fine aggregates of essentially the same density, a natural sand and crusher screenings in the proportion of 1:2 by mass. In addition, the proportion of coarse aggregate will be 55% by mass and the coarse aggregate contains 12% by mass of material passing the 4.75 mm sieve. The proportion of fine aggregate from the coarse aggregate = 0.55 x 0.12% = 6.6% of the total fine aggregate. Proportion of virgin fine aggregate is therefore 100 - 6.6% = 93.4%. Proportion of natural sand = 93.4 x 1/3 = 31.1. Proportion of crusher screenings = 93.4 x 2/3 = 62.2. To make up a sample of 2400g, weigh out and combine the following masses of sample: Natural sand (2400g x 0.311%) = 746.4g; Crusher screenings (2400 x 0.622%) 1492.8g; Pass 4.75 mm material from coarse aggregate (2400 x 0.066%) 158.4g. The total mass of sample = 2397.6 g.

Note 4: If the densities of individual aggregates are within 0.02 of each other, the % by mass can be assumed to be the same as % by volume.

Note 5: If the densities of the individual fine aggregates used in the mix are significantly different, follow the example provided in Appendix B to prepare the test sample.

6.2.3 Wash each sub-sample over a 75 µm sieve in accordance with MTO LS-601, Method Of Test For Material Finer Than 75 µm Sieve In Mineral Aggregates By Washing, until all material passing the 75 µm sieve is removed.

6.2.4 Saturate the sub-samples in water by immersion for 15-19 hours.

6.2.5 Test the two sub-samples. For the purpose of determining the saturated surface dry condition, where possible use the normal cone test.

6.2.6 In cases where the fine aggregate slumps before the saturated surface dry condition is reached (normally fine aggregates with large amounts of material retained on the 2.36 and 1.18 mm sieves), remove the material coarser than the 2.36 mm sieve by dry sieving. Test the material pass

2.36 mm using the cone test. Test the material retained on the 2.36 mm sieve using procedure 4 of the test method using hard-finish paper towels (Note 6).

Note 6: Whatman No 541 filter paper may be suitable, is re-usable, and is available in approximately 500 x 500 mm sheets.

6.2.7 If duplicate tests of relative density differ by more than 0.027, the materials shall be retested.

6.2.8 If duplicate tests of absorption differ by more than 0.31%, the materials shall be retested.

6.3 Fine aggregates extracted from RAP for both Marshall and Super Pave mix design

6.3.1 Remove the asphalt from the RAP by solvent extraction with a suitable solvent. Soak the extracted aggregates in denatured methyl alcohol overnight, drain off the alcohol.

6.3.2 Wash the sample over a 75 µm sieve in accordance with MTO LS-601, Method of Test For Material Finer Than 75 µm Sieve In Mineral Aggregates By Washing, until all material passing the 75 µm sieve is removed. Use procedure B of the test method in which a wetting agent is used.

6.3.3 Follow the procedures of 6.1.

6.4 Combinations of virgin fine aggregate and RAP for both Marshall and SuperPave processes

6.4.1 Calculate the density of the fine aggregate in the asphalt mixture by using a calculation based on the density of the fine aggregate determined following 6.1 or 6.2 and the density of the RAP fine aggregate determined following 6.3. The calculation shall be based on the mass proportions of virgin fine aggregate to the mass proportion of fine aggregate contributed to the mixture by the RAP.

7. USE OF LABORATORY CONTROL AGGREGATE

7.1 Every ten samples, but at least every week in which a sample is tested, a sample of the standard reference aggregate shall also be tested. Material shall be taken from a stock supply of James Dick sand maintained by the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8 (Fax: 416-235-4101).

7.2 Control Chart Use: The percent loss of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the performance of the laboratory.

7.3 The mean absorption of the James Dick standard reference aggregate is 1.68%. Individual test data should not normally be greater than 2.05% or less than 1.31%.

7.4 The mean relative density (oven-dry) of the James Dick standard reference aggregate is 2.607. Individual test data should not normally be greater than 2.639 or less than 2.575.

8. REPORT

The report shall include the following:

8.1 Relative density values shall be reported to the nearest 0.001 and indicate the basis for relative density as either oven-dry (OD), saturated-surface dry (SSD) or apparent.

8.2 Report the absorption result to the nearest 0.01%.

8.3 When two determinations are made on a fine aggregate, the mean of the results shall be reported as the final "test result".

8.4 When a sample has been separated on the 2.36 mm sieve and the density and absorption of the retained 2.36 mm material determined separately from the pass 2.36 mm material, this shall be noted and the individual and weighted mean densities and absorptions reported together with the calculation.

8.5 When fine aggregate extracted from RAP has been tested and the density combined with that of the virgin fine aggregate, the individual densities and absorptions of the extracted RAP aggregate and virgin fine aggregate shall be reported. The weighted mean density and absorption shall also be reported together with the calculation.

8.6 The percent absorption and relative density of the last twenty samples of reference material on control charts.

APPENDIX A

Non-Mandatory Information

Discussion on sources of bias in determining absorption and relative density

It has been found that there are significant differences in density when washed versus unwashed fine aggregate densities are compared. This is thought to be due to the fines retained in fine aggregate affecting the assessment of the saturated surface dry condition. This was thought to be caused by some weak cementing action of the fines (Woolf, 1936). Recent work has shown that fines may cause the formation of agglomerations of fine aggregate particles prior to attaining the saturated surface dry condition. These agglomerations have a higher porosity and lower density than that of the constituent particles. The point of saturated surface dryness is that of the agglomerations and not of the individual particles. The effect is most pronounced with crusher screenings containing over 6 or 7% fines (pass 75 μm sieve) but may occur with all materials containing fines greater than about 4%. Following the conventional AASHTO method, where fines

are not removed, nearly always results in a higher absorption and a lower bulk relative density compared with the MTO procedure where fines are removed prior to determining the saturated surface dry condition. It should be noted that the original procedure was developed for concrete sands, which are nearly always of low fines content. The test has been subsequently adopted for use on manufactured sands and screenings. The Ministry of Transportation adopted a modified test where fines were removed prior to testing in the 1960's.

In studies (Rogers, 1980) of the comparison of bulk relative density of 26 samples of coarse aggregate and companion crusher screenings, it was found that the screenings on average had almost the same density (screenings were on average 0.003 more dense) as that of the corresponding coarse aggregate and had slightly higher average absorption (by approx 0.1%). This study was done using a test in which the fines were removed by washing prior to determining density. It was thought that the modified test (removal of fines by washing) gave a good approximation of likely density of the screenings. There was one notable exception to this, which was with vuggy, porous dolostones (Silurian reefal dolostone of the Niagara Escarpment). In this case, the process of crushing removes vugs and reduces porosity so that the screenings (2.772) were on average about 0.11 more dense than the coarse aggregate (2.662) and had half as much absorption (1.57%-0.74%). Further crushing to remove all pores would theoretically result in a density close to that of the density of the dolomite mineral (2.86).

A limited study of the difference in values obtained between immersing the sample versus mixing in 6% water and allowing to stand for 24 hours was conducted in 2004 by MTO. In repeated tests (n = 11) on one fine aggregate, it was found that the 6% water method, on average, resulted in higher absorption by 0.23% (1.80% versus 1.58%) and relative density was 0.17 less compared to the sand that was immersed in water.

REFERENCES

Woolf, D.O., *The cone method for determining the absorption by sand*, ASTM Proceedings, vol. 36, pp. 411-425, 1936.

Rogers, C.A., *Precision and accuracy of the test for absorption and relative density of fine aggregate, Ontario Ministry of Transportation, Soils and Aggregates Section, unpublished report (file no. 3162-2-4-605), 19 pages, 1980.*

APPENDIX B

Development of Equations for Preparation of Test Samples with Different Densities

The equation is derived for an asphalt mix consisting of two types of fine aggregates with different densities and fine aggregate from the coarse aggregate. The coarse aggregate in the mix Pc% and the coarse aggregate contain P_f% by mass of material finer than 4.75 mm. The mass of fine aggregate No. 1 in the blended portion M_1 in grams and P_1% by volume. The fine aggregate No. 2 has a mass of M_2 and P_2% by volume.

Percentage of fine aggregate from the coarse aggregate = $\left(\frac{P_f}{100}\right)P_c$

Mass of fine aggregate from coarse aggregate M_f in grams = $(M_t)\left(\frac{P_f}{100}\right)\left(\frac{P_c}{100}\right)$

Mass of blended fine aggregates (No. 1 & No. 2) in the test sample = $(M_t - M_f)$ grams

$$P_1 + P_2 = 100$$

$$M_1 = G_1V_1 \text{ and } M_2 = G_2V_2$$

$$(V_1)/(V_2) = (P_1)/(P_2)$$

$$M_1 + M_2 = (M_t - M_f)$$

Where, G and V are the bulk specific gravity and volume of fine aggregates No. 1 and No. 2, respectively.

Manipulation of the above equations yields masses M_1 and M_2 of fine aggregates in the test sample.

$$M_1 = (M_t - M_f)\left[\frac{(P_1G_1)}{(P_1G_1 + P_2G_2)}\right] \text{ and}$$

$$M_2 = (M_t - M_f)\left[\frac{(P_2G_2)}{(P_1G_1 + P_2G_2)}\right]$$

Example: The proposed asphalt mix will use two fine aggregates, a natural sand and crusher screenings in the proportion of 33%-67% by volume. The bulk specific gravity of natural sand and screenings are 2.650 and 2.750, respectively. The coarse aggregate portion of the mix will be 55% by mass and the coarse aggregate contain 12% by mass of material finer than 4.75 mm. Prepare 2400 grams of test sample in the proportion of fine aggregates expected in the proposed asphalt mix.

The portion of the fine aggregate from the coarse aggregate = 2400 x(12/100) x (55/100)
= 158.5 grams

Mass of blended fine aggregates (No. 1 & No. 2) in the test sample = (2400 – 158.5)
= 2241.5 grams

Mass of natural sand in the test sample = (2241.5)(2.65x33)/(2.650x33 + 2.750x67)
= 721.5 grams

Mass of screenings in the test sample = (2241.5)(2.75x67)/(2.650x33 + 2.750x67)
= 1520.0 grams

The total mass of tests sample = 158.5 + 721.5 + 1520. 0 = 2400.0 grams

Ministry of Transportation
Ontario

RELATIVE DENSITY & ABSORPTION - FINE AGGREGATE

LAB NO.	TEMP °C	FLASK		MASS OF FLASK + SAND	MASS OF SAT. SUR. DRY SAND IN AIR B	MASS OF SAND + FLASK + WATER	MASS OF WATER ADDED W	VOLUME OF FLASK V	MASS OF DRY SAND IN AIR A
		NO.	MASS						

PH-CC-332 78-06

DATE _____

OPERATOR _____

COMPUTED BY _____

Figure 1 Relative Density and Absorption – Fine Aggregate Data Card

METHOD OF TEST FOR SOUNDNESS OF AGGREGATES BY USE OF MAGNESIUM SULPHATE

1. SCOPE

1.1 This method covers the testing of aggregates to determine their resistance to disintegration in saturated solutions of magnesium sulphate. It furnishes information helpful in judging the soundness of aggregates subject to weathering action, particularly when adequate information is not available from service records.

2. RELEVANT DOCUMENTS

2.1 ASTM C 88

2.2 CSA-A23.2-9A

3. APPARATUS

3.1 SULPHATE TANK: A suitably constructed three-compartment tank, one compartment for solution make-up, one for the test solution, and the third for washing the completed test samples. The test solution compartment shall contain suitable refrigeration and heating units capable of controlling the temperature of the magnesium sulphate solution within ± 1.0°C of the required temperature.

Note 1: Immersion type mercury contact thermo-regulators reading to 0.05°C controlling Jumo electronic relays are suitable for this purpose.

3.2 SIEVES: With square openings of the following sizes conforming to OPSS specifications, Table 1.

Table 1

Coarse Series	Fine Series
4.75 mm	300 µm
9.50 mm	600 µm
13.2 mm	1.18 mm
16.0 mm	2.36 mm
19.0 mm	4.75 mm

3.3 WIRE BASKETS: For immersing the samples of aggregates in the solution. The baskets shall bear a number or other means of identification. The baskets shall be made of copper wire or stainless steel and of appropriate mesh size for the aggregate under test (19 - 9.5 mm aggregate use sieve mesh 6.7 mm, 9.5 - 4.75 mm aggregate use sieve mesh 2.36 mm).

3.4 BALANCES: For fine aggregate, a balance or scale accurate within 0.1 g over the range required for this test; for coarse aggregate, a balance or scale accurate within 0.1% or 1 g, whichever is greater, over the range required for this test.

3.5 MECHANICAL CONVECTION OVEN: The oven shall be capable of being heated continuously at 110 ± 5.0°C , and the rate of evaporation at this range of temperature shall be at least 25 g/h for 4 h, during which period the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from one-litre Griffin low-form beakers, each initially containing 500 g of water at a temperature of 21 ± 2.0°C, placed at each corner and the centre of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

3.6 HYDROMETER: Capable of determining the relative density of the test solution, conforming to the requirements of ASTM E100 for ASTM Hydrometers.

3.7 LABORATORY CONTROL AGGREGATE: A supply of standard Brechin Quarry No. 2 coarse aggregate is available from the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Ontario M3M 1J8, Fax (416) 235-4101.

4. PREPARATION OF SOLUTION

4.1 Prepare a saturated solution of magnesium sulphate by dissolving a U.S.P. or equal grade of the salt in water at a temperature of 40 ± 3.0°C . Add sufficient salt of either the anhydrous ($MgSO_4$) or the crystalline ($MgSO_4\_7H_2O$, Epsom salt) form to ensure saturation and the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool 21 ± 1.0°C. Again stir and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly and determine the relative density of the solution. When used, the solution shall have a relative density not less than 1.295 nor more than 1.308. Discard a discoloured solution or filter it and check for relative density.

Note 2: For the solution, 350 g of anhydrous salt or 1230 g of heptahydrate per litre of water are sufficient for saturation at 23°C . However, since these salts are not completely stable, with the heptahydrate being the more stable of the two, and since it is desirable that an excess of crystals be present, it is recommended that the heptahydrate be used and in an amount of not less than 1400 g/L of water.

Note 3: Freshly mixed sulphate solutions have low pH values which may result in a higher loss of material for aggregates containing carbonate minerals. When testing these types of materials, the

pH value of freshly mixed solutions should be checked for pH (with either a pH meter or pH paper, range 5 - 7) and neutralized by the addition of a suitable additive.

5. PREPARATION OF SAMPLE

5.1 FINE AGGREGATE: Fine aggregate for the test shall be passed through a 4.75 mm sieve. The test sample shall be obtained from the materials to be tested by use of a sample splitter or the method of quartering and shall weigh approximately 2500 g. The sample is then washed on a 300 µm sieve and dried to a constant mass. The sample is separated into the sizes shown in Table 2 by sieving in a mechanical sieve shaker for a period of 8 to 12 minutes. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal (in general, a 110 to 120 g sample will be sufficient). The samples are then re-sieved to refusal on the same sieves using a mechanical sieve shaker for a period of 12 min. Weigh samples consisting of 100 ± 0.1 g from each of the separated fractions after final sieving and place in separate containers for the test.

Note 4: Sieving to 'refusal' means that no particles pass the sieve during 1 minute of continuous sieving. No hand manipulation of particles is allowed.

Table 2

Passing Sieve	Retained on Sieve
600 µm	300 µm
1.18 mm	600 µm
2.36 mm	1.18 mm
4.75 mm	2.36 mm

Should the sample have less than 30% retained on the 300 µm sieve, it is deemed to be too fine and no test is done on any fraction. If any fraction constitutes less than 5% of the sample, it shall not be tested.

5.2 COARSE AGGREGATE: Coarse aggregate for test shall consist of material from which sizes finer than the 4.75 mm sieve have been removed. Separate the sample into the different sizes shown in Table 3 by sieving to refusal. Weigh out quantities of the different sizes shown in Table 3. If any fraction constitutes less than 5% of the sample, it shall not be tested.

Table 3

Pass	Retained	Mass, g
9.5 mm	4.75 mm	300
19.0 mm	9.5 mm	1000
Consisting of:		
13.2 mm	9.5 mm	330
19.0 mm	13.2 mm	670
37.5 mm	19 mm	1500
Consisting of:		
26.5 mm	19 mm	500
37.5 mm	26.5 mm	1000
63 mm	37.5 mm	5000
Consisting of:		
53 mm	37.5 mm	2000
63 mm	53 mm	3000

6. PROCEDURE

6.1 FINE AGGREGATE: Place each fraction in a separate suitable wire basket.

6.2 COARSE AGGREGATE: Place the 9.5 mm to 4.75 mm fraction in a suitable wire basket. Place the combined 19.0 mm to 9.5 mm fraction in another wire basket. Place combined fractions larger than 19 mm in one or more baskets as required.

6.3 STORAGE OF SAMPLES IN SOLUTION: Immerse the samples in the prepared solution of magnesium sulphate for not less than 16 h or more than 18 h in such a manner that the solution covers them to a depth of at least 15 mm. Maintain the samples immersed in the solution at a temperature of 21 ± 1.0°C for the immersion period. The volume of solution shall be at least 20 times greater than the total sample volume.

6.4 DRYING SAMPLES AFTER IMMERSION: After the immersion period, remove the samples from the solution, drain for 30 ± 5 min. and place in drying oven. Dry at 110 ± 5.0°C until constant mass has been achieved, usually 6 to 8 h. Drying time may be established as follows: with oven containing the maximum sample load expected, check the loss in mass of samples by removing and weighing them in the baskets, without cooling, at intervals of 2 to 4 h. Make enough checks to establish required drying time for the least favourable oven location and sample condition. Constant mass will be considered to be achieved when the loss is less than 0.1% of sample mass in 4 h of drying. When constant mass is achieved, allow samples to cool to room temperature and immerse in solution.

Note 5: As the number of cycles progresses, the drying time required increases due to loss of drying efficiency because of the accumulation of salt adhering to particles, increase of surface area due to breakdown, and differences in surface area due to particle sizes.

6.5 NUMBER OF CYCLES: Repeat the process of alternate immersion and drying for 5 cycles.

7. QUANTITATIVE EXAMINATION

7.1 After completion of the final cycle, and after the sample has cooled, wash the sample free from the magnesium sulphate as determined by the reaction of the wash water with a 3% (by mass) barium chloride ($BaCl_2$). Wash by circulating hot tap water (40 to 60°C) in their containers. A continuous flow of fresh hot water shall be maintained throughout the washing period. In the washing operation, the sample shall not be subjected to impact or abrasion that may tend to break up particles. After the magnesium sulphate has been removed, dry the samples to a constant weight at 110 ± 5.0°C.

7.2 FINE AGGREGATE: Sieve the fine aggregate over the same sieve on which it was retained before the test, nesting the sieves so that the finest is on the top and the coarsest is on the bottom. Sieve in a mechanical sieve shaker for a period of twelve minutes. Weigh the material retained on each sieve and record each amount on the Fine Aggregate Report Card (Figure 1).

7.3 COARSE AGGREGATE: Sieve material larger than 63 mm over the same sieve on which it was retained before the test. Sieve the sample of pass 63 mm retained 37.5 mm material over the 37.5 mm sieve. Sieve the sample of pass 37.5 mm retained 19 mm material over the 19 mm sieve. Sieve the sample of pass 19.0 mm retained 9.5 mm material over the 9.5 mm sieve. Sieve the sample of pass 9.5 mm retained 4.75 mm over the 4.75 mm sieve. Sieve only sufficiently to assure that all undersize material passes the sieves. Weigh the material retained on each sieve and record each amount on the Coarse Aggregate Report Card (Figure 2).

8. QUALITATIVE EXAMINATION

8.1 A qualitative examination may be done on coarse aggregate samples to determine the mode of breakdown, i.e. splitting, disintegration, crumbling, cracking, flaking, etc. This examination is not done routinely by MTO. Samples are held in storage for some time after the test. If there are conflicting or "surprising" results in this test, the samples may be recalled and examined in an effort to resolve problems of this nature.

9. CALCULATION

9.1 Calculate the percent loss for each fraction in the magnesium sulphate soundness test as follows:

$$\text{percent loss} = \frac{\text{original mass - mass retained after test}}{\text{original mass}} \times 100$$

9.1.1 Calculate the percent loss to one decimal place.

9.2 Calculate the percent loss for each fraction as the product of the percentage (based on the "as-received" coarse aggregate sample mass or "as-received" fine aggregate sample mass) of each fraction and the percent loss for that fraction.

9.2.1 Calculate the weighted average value of the as-received sample as the sum of the weighted average value for each fraction divided by 100.

9.2.2 For the purpose of calculating the weighted average, consider any sizes (not tested) that contain less than 5% of the as-received sample to have the same values as the average of the next smaller and the next larger size or if one of these sizes is missing, to have the same value as the next larger or smaller size, whichever is present. For fine aggregates, sizes smaller than the 300 µm sieve shall be assumed to have zero percent loss.

10. USE OF LABORATORY CONTROL AGGREGATE

10.1 Every ten samples, but at least every week in which a sample is tested, a sample of the standard reference aggregate shall also be tested. The material shall be tested on the 19.0 mm to the 9.5 mm and 9.5 mm to 4.75 mm gradings. For the purposes of calculating a weighted average loss, assume the 19.0 mm fraction constitutes 67% of the sample and the 9.5 mm to 4.75 mm fraction constitutes 33% of the sample.

10.2 Control Chart Use: The weighted average loss of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the performance of the laboratory.

10.3 The mean loss of the Brechin Quarry No. 2 standard reference aggregate is 13.2% (MERO-002 & 008, 2003 & 2004). Individual test data should not normally be greater than 18.4% or less than 8.0%.

11. REPORT

The report shall include the following:

11.1 The weighted average loss of the reference sample, tested closest to the time at which the aggregate sample was tested, to one decimal place.

11.2 The weighted average loss of the last twenty samples of reference material on a control chart.

11.3 Report the loss in percent of each fraction of the sample tested to 0.1%.

11.4 Report the weighted loss in percent of the sample tested to the nearest 0.1%.

12. PRECAUTIONS

12.1 Wire baskets shall be examined after each test for defects in the mesh.

12.2 Extreme care must be taken when immersing the fine aggregate samples as often some of the particles float on the solution due to surface tension. Carefully, with the fingers, sink these particles into their baskets when this happens.

Ministry of Transportation Ontario

$Mg\ SO_4$ SOUNDNESS
FINE AGGREGATE

RUN NO. _____

LAB. NO.	DATE REQ'D.	BASKET NO.	2.36 mm	1.18 mm	600 µm	300 µm

REMARKS:

PH-CC-336 78-06

Figure 1 Fine Aggregate Data Card

Ministry of Transportation Ontario

$MgSO_4$ SOUNDNESS COARSE AGGREGATE

RUN NO._____

LAB. NO.	BASKET	DUE DATE	GRADING	MASS RETAINED ON			
				37.5 mm	19.0 mm	9.5 mm	4.75 mm

PH-CC-335 88-06

Figure 2 Coarse Aggregate Data Card

METHOD OF TEST FOR DETERMINATION OF PERCENT FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE

1. SCOPE

1.1 This method covers the determination of the percentage of flat and elongated particles in processed coarse aggregate, retained on the 4.75 mm sieve by measurement of individual particles.

2. RELEVANT DOCUMENTS

2.1 ASTM D 4791

2.2 CSA-A 23.2-13A

3. DEFINITION

3.1 FLAT AND ELONGATED pieces shall be those particles whose greatest dimension in the longitudinal axis, compared to the least dimension in a plane perpendicular to the longitudinal axis, exceeds a ratio of 4:1.

4. APPARATUS

4.1 BALANCE: A balance having a capacity of 5000 g and readable to 1.0 g or less.

4.2 CALIPERS: Proportional (Figure-of-eight) calipers in which the ratio of the opening at one end to the other is 4:1.

Note: The proportional calipers must be checked periodically to ensure that the 4:1 ratio is maintained throughout the range of opening.

5. PREPARATION OF TEST SAMPLE

5.1 Prepare the coarse aggregate according to LS-600.

5.2 Dry the sample sufficiently to obtain a clean separation of particles on the 4.75 mm sieve.

5.3 Separate the sample by sieving according to LS-602 into one or more of the individual fractions indicated in Table 1.

5.4 Prepare the test sample from each coarse aggregate fraction representing at least 5 % or more of the submitted sample according to the minimum masses shown in Table 1.

Note: the test sample only needs to be prepared from those coarse aggregate fractions representing at least five percent or more of the submitted sample. Maintain each fraction of the test sample in separate sizes.

5.5 When the test sample contains a mixture of natural aggregate, recovered crushed concrete, recovered asphaltic material, glass and/or ceramic material, the size of test sample shall be increased so that the amount of natural aggregate and recovered crushed concrete in the test sample meets the requirements of Table 1.

Table 1 – Sample Preparation

Coarse Aggregate Fraction		Mass (minimum), g
Passing	Retained	
37.5 mm	26.5 mm	3000
26.5 mm	19.0 mm	2000
19.0 mm	13.2 mm	1250
13.2 mm	9.5 mm	500
9.5 mm	6.7 mm	200
6.7 mm	4.75 mm	75

5.6 Weigh and record the mass of material of each fraction to the nearest 1 g.

6. TEST PROCEDURE

6.1 Spread each test fraction on a clean, flat surface large enough to permit individual particles to be easily inspected.

6.2 For each fraction, separate the particles of each test fraction by means of calipers into: (i) flat and elongated, and; (ii) cubical particles. Set the caliper on the maximum particle length and then check whether the least particle dimension will completely pass through the opening at the small end of the caliper.

6.3 Weigh and record the mass of each flat and elongated and cubical portion of the fraction to the nearest 1 g. Table 2 is a laboratory worksheet for recording test data and calculations

7. CALCULATION

7.1 Calculate the percent of flat and elongated particles in each test fraction (to one decimal place) as follows:

$$\% \text{ Flat \& Elongated} = \frac{A}{A+B} \times 100$$

Where A = mass of flat and elongated particles

B = mass of cubical particles

7.2 Calculate the percent of flat and elongated particles weighted average value for each fraction as follows: Multiply the percentage (based on the as received coarse aggregate sample mass) of each fraction and the percent flat and elongated particles for that fraction.

7.3 Calculate the percent of flat and elongated particles of the as-received sample as the sum of the weighted average value for each fraction divided by 100.

7.4 For the purpose of calculating the weighted average, consider any fraction (not tested) containing less then 5% of the as-received sample to have a value equal to the average of the next smaller and the next larger fractions. If one of these sizes is missing, assign the same value as the next larger or smaller fraction, whichever is present.

8. REPORTING OF RESULTS

8.1 Report the percent flat and elongated of each fraction of the test sample to the nearest whole percent.

8.2 Report the weighted average percent flat and elongated of the test sample to the nearest whole percent.

9. GENERAL NOTES

9.1 Material used in this test may be reused if insufficient material is available for all the required tests

.

Table 2. Percent Flat and Elongated Particles Worksheet (all masses in grams)

Sample No.: _____ **Date:** _____

Test Sample Fraction	Mass of Original Fraction (g)	% of Original Fraction[1]	Flat & Elongated Particles Mass (A)	Cubical Particles Mass (B)	% Flat and Elongated Particles (%FE)	
					Per fraction $\frac{A}{A+B}$ x 100	Weighted per fraction[2]
37.5 – 26.5 mm						
26.5 – 19.0 mm						
19.0 – 13.2 mm						
13.2 – 9.5 mm						
9.5 – 6.7 mm						
6.7 – 4.75 mm						
				% FE particles, Weighted Average (ΣWeighted per fraction) ÷ 100		

Notes:
1. As determined by LS-602
2. = %FE (per fraction) x % of original fraction

Remarks: _____

_____

_____

Operator: _____

PROCEDURE FOR THE PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE

1. SCOPE

1.1 This procedure outlines the method to be employed in the petrographic analysis of coarse aggregate. The procedure appraises the quality of coarse aggregate, and provides a numerical means (in terms of a petrographic number, or P.N.) of expressing and comparing the quality of samples from the same or different sources.

1.2 This procedure does not attempt to describe the techniques used in the geological classification of the aggregate particles, since it is assumed that the examination will be performed by persons qualified to do so by experience and training. The subsequent classification of aggregate particles into quality types employs index tests related to their strength. Sets of reference samples for the petrographic analysis can be obtained from the Petrographer, Soils and Aggregates Section, Engineering Materials Office, 1201 Wilson Ave., Downsview, Ontario, M3M 1J8.

2. RELEVANT DOCUMENTS

2.1 ASTM C 294, C 295

2.2 MTO LS-602, LS-616

2.3 EM - 91, Petrographic Examination of Aggregate and Concrete in Ontario, Engineering Materials Office, Ministry of Transportation.

3. DEFINITION

3.1 Siliceous Aggregates: means rock particles containing or composed of silica (SiO_2) or minerals with silica in the crystal structure as silicate (SiO_4). Siliceous aggregates include the following Type Numbers given in Figure 1 and Table 1: 03, 22, 06, 04, 05, 08, 07, 09, 10, 30, 29, 25, 34, 27, 28, 46, 56, 50, 55, 51, 48, 63, 71, 81, 82, 73, 74, 33, 86, 84, 97, 87, 32, and 64.

4. APPARATUS

4.1 HAND LENS: 10x magnification.

4.2 ALNICO MAGNET.

4.3 POCKET KNIFE: Good quality with a blade hardness of between 5.5 and 6 on Moh's scale.

4.4 ANVIL & HAMMER: Suitable for breaking aggregate particles.

4.5 HYDROCHLORIC ACID: Technical grade, 5 % by volume, in polyethylene squeeze-type bottle with spout.

4.6 STEREOSCOPIC MICROSCOPE: 4x to 25x final magnification, with illumination source.

4.7 BALANCE: Accurate to 0.1 g and of sufficient capacity,

4.8 LIGHT SOURCE: Capable of providing excellent illumination of working area.

5. PREPARATION OF SAMPLE

5.1 A representative sample of oven dried aggregate shall be prepared to the following approximate masses:

Pass	Retained	Approx. Mass, g
75 mm	19.0 mm	10,000
53 mm	19.0 mm	5000
37.5 mm	19.0 mm	4000
26.5 mm	19.0 mm	3000
19.0mm	9.5 mm	1000
13.2 mm	9.5 mm	500
9.5 mm	6.7 mm	200
6.7 mm	4.75 mm	75

Note 1: Generally this examination is performed on the pass 19.0 mm retained 9.5 mm material (full fraction), which should consist of pass 19.0 mm retained 16.0 mm, pass 16.0 mm retained 13.2 mm and pass 13.2 mm retained 9.5 mm material proportioned according to the sieve analysis of the aggregate. The pass 13.2 mm retained 9.5 mm material should not exceed 500 g in weight. If the full fraction constitutes less than about 68.5 percent of the sample, the pass 9.5 mm retained 6.7 mm fraction shall also be examined. If these fractions together constitute less than about 68.5 percent of the sample, the pass 6.7 mm retained 4.75 mm fraction shall also be examined. Each sieve size examined should contain a minimum of 200 particles.

6. TEST PROCEDURE

6.1 The sample shall be spread on a tray or other flat working surface.

6.2 If required, the sample shall be examined visually for angularity and shape characteristics and an estimate made and noted of the percentage of crushed, as well as flat and elongated, particles.

6.3 The aggregate shall be examined for coatings (such as clay), cementations and encrustations which may affect the bond with Portland cement paste or asphalt cement. The type of coating and the degree of adhesion to the aggregate shall be noted.

6.4 If clay balls or other particles, which may break down in water or with normal handling are present, these particles shall be separated out.

6.5 The sample shall be washed to remove clay and dust coatings. In addition, when the sample contains carbonates and or metavolcanics it shall be soaked for a period of at least one hour. Following immersion, each particle shall be quickly surface dried and then examined, and tested for scratch.

Note 2: Soaking will cause clay, shale, and shaley, slightly shaley or micaceous particles to soften, making recognition easier.

6.6 The washed sample shall be spread on a flat surface covered with paper or cloth towel to absorb excess water.

6.7 Each particle in the sample shall be classified into a rock type listed on Form PH-CC-343 (Figure 1) or the supplementary rock type list (Table 1). A guide is provided as an appendix to this procedure.

Note 3: Index tests and microscopic examination will usually be sufficient to classify a rock particle. If not, the particle shall be referred to a petrographer for identification (possibly requiring detailed petrographic study).

6.8 In the classification of each particle, the following features may be relevant:

6.8.1 Strength; features such as fossils and clay or shale partings (including stylolites) may constitute weaknesses.

6.8.2 Relative Density.

6.8.3 Shape.

6.8.4 Texture, including porosity and cementation.

6.8.5 Colour.

6.8.6 Mineralogy.

6.8.7 Structure, including bedding and foliation.

6.8.8 Effervescence with acid.

6.8.9 State of weathering.

6.8.10 Magnetism.

6.9 On the completion of the examination, each group of classified particles shall be weighed to the nearest 0.1 g and the weights recorded on Form PH-CC-343 (Figure 1). If any rock types are present which are not found on this form, the category in which they shall be recorded will be found in the supplementary rock type list (Table 1).

7. CALCULATION

7.1 The percentage of each rock type shall be calculated to the nearest 0.1 percent. The percentages of good, fair, poor and deleterious particles shall be calculated. The sum of the sub-totals shall be 100 percent.

7.2 The petrographic number of aggregates for use in hot mix asphalt, surface treatment and concrete shall be calculated as the sum of the products of the percentage of each petrographic category (good, fair, poor and deleterious) and the appropriate factor for each category (1,3,6, and 10, respectively).

7.3 If the material is to be used for granular base or sub-base, a correction shall be applied which reflects the differing environmental conditions in which the material is used. The percentage of each rock type shall be multiplied by the appropriate correction factor (0, 2, 3, 5, 7, or 9) shown on Form PH-CC-343 and the supplementary rock type list. The sum of the values obtained shall be subtracted from the petrographic number for hot mix asphalt, surface treatment and concrete to obtain the corrected petrographic number for granular use.

Note 4: The use of a petrographic number to classify aggregate for use in granular base and sub-base has been discontinued by MTO.

7.4.1 When the test is performed on more than one size fraction, a weighted average petrographic number shall be calculated by multiplying the percentage (based on the 'as received' coarse aggregate sample grading) of each sieve fraction by the petrographic number for that fraction, adding these products, and dividing by 100.

7.4.2 For the purpose of calculating the weighted average, any fractions (not tested) that contain less than 5 percent of the 'as received' sample shall be considered to have the same value as the average of the next smaller and the next larger fraction or, if one of these fractions is missing, to have the same value as the next larger or smaller fraction, whichever is present.

8. REPORTING OF RESULTS

8.1 The report of the examination should include the following:

8.1.1 The aggregate source name, location, and Mineral Aggregate Inventory Data Bank (MAIDB) number.

8.1.2 The laboratory sample number.

8.1.3 The date, the fraction examined, and the name of the analyst.

8.1.4 The percentages (to the nearest 0.1 percent) of each rock type and of good, fair, poor, and deleterious particles.

8.1.5 The petrographic numbers (to the nearest whole number) for hot mix asphalt, surface treatment and concrete, and for granular base and sub-base.

8.1.6 The weighted average petrographic numbers (to the nearest whole number), when the test is performed on more than one size fraction.

8.1.7 When required, the percent by mass of siliceous aggregate.

9. GENERAL NOTES

9.1 In the event that there are a number of particularly absorptive particles, they should be dried before weighing so that water absorbed during washing will not significantly influence the mass.

9.2.1 Due to the time-consuming nature of petrographic examination on the smaller coarse aggregate sizes, a shorter procedure is usually used.

9.2.2 A full petrographic examination shall always be performed on the largest aggregate size of a sample. If smaller sizes are also to be tested, they may be separated into the petrographic categories 'good' and 'deleterious' without separation into individual rock types. The nature of the material in the 'good' and 'deleterious' categories will normally be apparent from the complete petrographic analysis on the largest size. Those particles that fall into the 'fair' and 'poor' categories must be separated into their individual rock types.

9.2.3 If the nature of the 'good' and 'deleterious' material is questionable, a full petrographic analysis of the smaller sizes must be performed.

9.3 The factors applied to each rock type are based on laboratory studies and in-service performance for the intended use and prevailing conditions in Ontario. These factors may not apply under other conditions and in other areas. The factors are subject to periodic review, and shall be changed when necessary to reflect current experience.

9.4 The petrographic factors take only physical properties into account. The possibility of the aggregate being alkali-reactive in concrete is not considered.

10. PRECISION

10.1 The petrographic number of a stockpile of coarse aggregate varies by up to 20 on either side of the mean (19 times out of 20).

Ministry of Transportation Ontario

COARSE AGGREGATE PETROGRAPHIC ANALYSIS – MTO LS609

SOURCE NAME _____ MAIDB NO. _____

LOCATION _____ LAB. NO. _____

DATE _____ FRACTION _____ ANALYST _____

TYPE	TYPE NO.	MASS	%	GRANULAR CORRECTION	
CARBONATE (hard; silty, hard)	01			–	–
CARBONATE (surf. weath.; silty, surf. weath.; med. hard; silty, med. hard)	20			–	–
CARBONATE (sandy, hard or medium hard)	02			–	–
CARBONATE (slightly cherty: <5% chert)	21			–	–
MARBLE (hard or medium hard)	23			–	–
CONGLOMERATE-SANDSTONE-ARKOSE (hard)	03			–	–
CONGLOMERATE-SANDSTONE-ARKOSE (medium hard)	22			–	–
GREYWACKE-ARGILLITE (hard or medium hard)	06			–	–
GNEISS-AMPHIBOLITE-SCHIST (hard)	04			–	–
QUARTZITE	05			–	–
GRANITE-DIORITE-GABBRO (hard)	08			–	–
VOLCANIC (hard or medium hard)	07			–	–
TRAP (≤20% sulphide)	09			–	–
QUARTZ (vein or pegmatitic)	10			–	–
TOTAL GOOD AGGREGATE	–			–	–
CARBONATE (soft; silty, soft; slightly shaley)	35			X2	
CARBONATE (soft, pitted)	41			X2	
CARBONATE (deeply weathered; silty, deeply weathered)	42			–	–
CARBONATE (sandy, soft)	40			X2	
MARBLE (brittle)	24			X2	
CHERT-CHERTY CARBONATE (<20% leached chert)	26			X2	
CONGLOMERATE-SANDSTONE-ARKOSE (brittle)	30			X2	
GREYWACKE (brittle)	29			X2	
ENCRUSTATION	52			X2	
GNEISS-AMPHIBOLITE-SCHIST(brittle)	25			X2	
ARGILLITE (medium soft)	34			X2	
GRANITE-DIORITE-GABBRO (brittle)	27			X2	
VOLCANIC (soft)	28			X2	
TOTAL FAIR AGGREGATE	–			–	–
CARBONATE (shaley; clayey; silty, clayey)	43			–	–
CARBONATE (ochreous; sandy, ochreous)	44			–	–
MARBLE (friable)	49			X3	
CHERT-CHERTY CARBONATE (≥20% leached chert)	45			X5	
CONGLOMERATE-SANDSTONE-ARKOSE (friable)	46			X3	
SILTSTONE	56			X3	
CEMENTATION (partial)	53			X3	
CEMENTATION (total)	54			–	–
GNEISS-AMPHIBOLITE (friable)	50			X3	
SCHIST (soft)	55			X3	
GRANITE-DIORITE-GABBRO (friable)	51			X3	
VOLCANIC (very soft, porous)	48			X3	
TOTAL POOR AGGREGATE	–			–	–
OCHRE	60			–	–
SHALE	61			–	–
CLAY	62			–	–
VOLCANIC-GNEISS-SCHIST (decomposed)	63			–	–
TOTAL DELETERIOUS AGGREGATE	–			–	–
		TOTALS			

% GOOD _____ x 1 = _____

% FAIR _____ x 3 = _____

% POOR _____ x 6 = _____

% DELETERIOUS _____ x 10 = _____

EST. PERCENT CRUSHED	
EST. PERCENT FLAT AND ELONGATED	

HOT MIX, SURF. TREATMENT AND CONCRETE P.N.	

CORRECTED GRANULAR P.N.	

PH-CC-343 93-06

Made from recovered materials

Figure 1 MTO Form PH-CC-343

Table 1 Supplementary Rock Type List

CATEGORY	TYPE	TYPE NUMBER	CORRECTION FOR GRANULAR
GOOD	IRON FORMATION (hard; sl. weath.)	71	-
	GYPSITE (< 10 % gypsum)	77	-
	SEDIMENT: SIBLEY GROUP (hard)	80	-
	FLINT/JASPER	81	-
FAIR	SULPHIDE	72	-
	IRON FORMATION (mod. weathered)	82	-
	VOLCANIC (glassy)	73	X2
	VOLCANIC (ochreous)	74	X2
	TRAP (21-74 % sulphide)	33	X2
	SEDIMENT: SIBLEY GROUP (med. hard)	83	-
POOR	GYPSITE (10-49 % gypsum)	78	X3
	ARGILLITE-TUFFITE-SLATE (soft)	86	-
	IRON FORMATION (highly weathered)	84	-
	SEDIMENT: SIBLEY GROUP (soft)	85	-
	GREYWACKE (friable)	97	X3

DELETERIOUS	IRON FORMATION (decomposed)	87	-
	ARGILLITE-TUFFITE-SLATE (very soft)	32	-
	GYPSITE (> 49 % gypsum)	79	-
	SEDIMENT: SIBLEY GROUP (very soft)	88	-
	SLAG-GLASS (in non-slag aggregate)	92	X9
	COAL-COKE-CINDER	31	X7
	TALC	64	-

APPENDIX
TO PROCEDURE FOR THE
PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE
(TYPE DESCRIPTIONS)

DISCUSSION

In the petrographic analysis, aggregate particles are initially subjected to a geological classification. Particles are then categorized into types, using descriptors such as 'hard', 'soft', 'brittle', 'friable', 'surface weathered', 'deeply weathered', 'decomposed', etc. For the purposes of standardization, descriptions of the various types are presented in this appendix.

Index tests related to the strength of the aggregate particles, such as scratching, scraping, peeling and plucking using a knife blade, are employed in this classification. Scratching, scraping, and peeling determine the application of hardness descriptors; and plucking determines the application of descriptors such as 'brittle'and 'friable'. Each rock group, such as carbonate, sandy carbonate, marble, volcanic, gneiss, etc., is described separately so as to highlight the decreasing quality of the group through categories 'good' to 'deleterious'. This enables an aggregate to be classified on a systematic basis.

Due to the subjective nature of this test method, descriptions of types contained in this appendix should be considered only as a guideline. The petrographic examination is largely dependent on the experience of the analyst and, where possible, should be complemented by routine tests and/or performance data. In specific cases (especially those of rocks whose performance is unfamiliar to the analyst) additional testing including the study of thin sections may be necessary. A freeze-thaw test conducted on medium hard and slightly shaley carbonate can be used to determine if the shale seams are planes of weakness, and therefore whether or not the particles are classified correctly; the material should be immersed in a 3 % sodium chloride solution in a pan and subjected to five cycles, each cycle consisting of approximately 16 hours of freezing followed by approximately 8 hours of thawing at room temperature.

CARBONATE, SILTY CARBONATE, SILTSTONE, AND CLAY

GOOD

1. Carbonate (hard): high strength; can be scratched (relatively thin scratch); typically unweathered
1. Carbonate (silty, hard): high strength; can be scratched; (relatively thin scratch); raspy sound when scratched; commonly greenish grey; typically unweathered
20. Carbonate (medium hard): high strength; can be scratched (relatively thick scratch)
20. Carbonate (silty, medium hard): high strength; can be scratched (relatively thick scratch); raspy sound when scratched; commonly greenish grey

20. Carbonate (surface weathered): mainly high strength; can be scratched; no more than 33 percent of particle consists of medium to low strength weathered material

20. Carbonate (silty, surface weathered): mainly high strength; can be scratched; raspy sound when scratched; commonly greenish grey; no more than 33 percent of particle consists of medium to low strength weathered material

FAIR

35. Carbonate (soft): medium strength; uniform consistency; can be scratched and scraped with ease; cannot be peeled

35. Carbonate (silty, soft): medium strength; can be scratched with ease and scraped with some difficulty; may contain minor low strength zones which can be scraped with ease; raspy sound when scratched; commonly greenish grey

41. Carbonate (soft, pitted): medium strength; can be scratched with ease and scraped with some difficulty; moderately pitted

42. Carbonate (deeply weathered): more than 33 percent of particle consists of medium to low strength weathered material

42. Carbonate (silty, deeply weathered): more than 33 percent of particle consists of medium to low strength weathered material; raspy sound when scratched; commonly greenish grey

POOR

43. Carbonate (clayey): contains between 33 and 75 percent very low strength material; can be scraped and peeled with ease

43. Carbonate (silty, clayey): contains between 33 and 75 percent very low strength material; can be scraped and peeled with ease; raspy sound when scratched

44. Carbonate (ochreous): contains between 33 and 75 percent ochreous material

56. Siltstone: fissile (tends to separate readily along thin bedding planes on which mica flakes can commonly be seen); medium to low strength; poorly cemented; friable (many pieces can be plucked easily from particle)

DELETERIOUS

62. Clay: greater than 75 percent of particle consists of very low strength material; can be peeled with ease and at times can be broken with the fingers or cut completely through; includes kaolin

SANDY CARBONATE

GOOD

2. Carbonate (sandy, hard or medium hard): high strength (matrix material may be slightly weaker than quartz grains); can be scratched with some difficulty; raspy sound when scratched; ranges from no weathering to thin surface weathering; contains 5 to 49 percent sand-sized quartz grains

FAIR

40. Carbonate (sandy, soft): medium strength; can be scratched with ease and scraped with some difficulty; may contain minor low strength zones which can be scraped with ease; raspy sound when scratched; contains 5 to 49 percent sand-sized quartz grains

POOR

44. Carbonate (sandy, ochreous): contains between 33 and 75 percent ochreous material; contains 5 to 49 percent sand-sized quartz grains

MARBLE

GOOD

23. Marble (hard or medium hard): high strength; can be scratched; intact (edges and corners cannot be plucked)

FAIR

24. Marble (brittle): medium strength; can be scratched with ease and scraped with some difficulty; brittle (edges and corners can be plucked); may have partial to total thin surface weathering

POOR

49. Marble (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles totally when plucked); includes cleavable calcite

SHALEY CARBONATE AND SHALE (See Table 2 for petrographic classification)

GOOD

20. Carbonate (medium hard): high strength; can be scratched (relatively thick scratch)

FAIR

35. Carbonate (slightly shaley): medium strength; can be scratched with ease and scraped with some difficulty; generally shows grey or brown (sometimes greasy) streak when scratched

POOR

43. Carbonate (shaley): low strength; can be scraped with ease and peeled with some difficulty; generally shows grey, brown or black (sometimes greasy) streak when scratched

DELETERIOUS

61. Shale: low to very low strength; can be scraped and peeled with ease; sometimes greasy to touch

CHERT AND CHERTY CARBONATE

GOOD

21. Carbonate (slightly cherty: <5 % chert): high strength; hard and/or slightly weathered carbonate; particle contains less than 5 percent chert

FAIR

26. Chert-Cherty Carbonate (<20 % leached chert): high strength; hard and/or slightly weathered carbonate; particle contains 5 percent or more chert, but less than 20 percent of the particle is leached (i.e., absorptive) chert which can generally stick to the tongue

POOR

45. Chert-Cherty Carbonate (≥20 % leached chert): high to medium strength; particle contains 20 percent or more leached (i.e., absorptive) chert, which can generally stick to the tongue

Note 5: The classification of semi-leached chert as leached chert or unleached chert should be based on the rate of absorption.

CONGLOMERATE-SANDSTONE-ARKOSE

GOOD

3. Conglomerate-Sandstone-Arkose (hard): high strength; cannot be scratched; intact (edges and corners cannot be plucked)

22. Conglomerate-Sandstone-Arkose (medium hard): high strength; generally cannot be scratched, although cementing material may be scratched with some difficulty; some edges and corners can be plucked with difficulty

FAIR

30. Conglomerate-Sandstone-Arkose (brittle): medium to high strength; generally cannot be scratched, although cementing material may be scratched with moderate ease; brittle (edges and corners can be plucked)

POOR

46. Conglomerate-Sandstone-Arkose (friable): low strength; generally poorly cemented; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles totally when plucked)

QUARTZITE

GOOD

5. Quartzite: very high strength; cannot be scratched

GNEISS-AMPHIBOLITE-SCHIST

GOOD

4. Gneiss-Amphibolite-Schist (hard): mainly very high strength; generally cannot be scratched; minor medium to high strength (e.g., micaceous and chloritic) zones which can be scratched and scraped with some difficulty; may have partial thin surface weathering

FAIR

25. Gneiss-Amphibolite (brittle): mainly medium to high strength; generally cannot be scratched; brittle (edges and corners can be plucked); minor medium to low strength zones which can be plucked with ease; may have partial to total, thin, surface weathering

25. Schist (brittle): medium strength; can be scratched with moderate ease; brittle (edges and corners can be plucked); may contain minor more friable zones which can be plucked and scraped with ease

POOR

50. Gneiss-Amphibolite (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)

55. Schist (soft): low strength; can be scraped and plucked with ease; contains chloritic and/or micaceous zones which can be peeled with ease

DELETERIOUS

63. Schist (decomposed): very low strength; can be crumbled with the fingers; high mica or chlorite content; low quartz and feldspar content

63. Gneiss (decomposed): very low strength; can be crumbled with the fingers; high mica content; low quartz and feldspar content

GREYWACKE-ARGILLITE-TUFFITE-SLATE

GOOD

6. Greywacke (hard or medium hard): high strength; can be scratched with difficulty; some edges and corners can be plucked with difficulty

6. Argillite (hard or medium hard): high to very high strength; can be scratched with difficulty

FAIR

29. Greywacke (brittle): medium to high strength; can be scratched with moderate ease and scraped with some difficulty; brittle (edges and corners can be plucked)

34. Argillite (medium soft): medium strength; can be scratched with moderate ease and scraped with some difficulty

POOR

97. Greywacke (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)

86. Argillite-Tuffite-Slate (soft): low to medium strength; can be scratched and scraped with ease; fissile (particle breaks along closely spaced fractures, and shatters when struck by a hammer); generally characterized by length to thickness ratio less than 4 to 1

DELETERIOUS

32. Argillite-Tuffite-Slate (vey soft): low to very low strength; can be scraped and peeled with ease; very fissile (particle breaks readily along very closely spaced fractures, and shatters easily when struck by a hammer); rusty weathering stains penetrate into the particle; generally characterized by length to thickness ratio greater than 4 to 1

GRANITE-DIORITE-GABBRO

GOOD

8. Granite-Diorite-Gabbro (hard): mainly very high strength; generally cannot be scratched; minor medium strength (e.g., micaceous and chloritic) zones which can be scratched and scraped with some difficulty; may have partial thin surface weathering

FAIR

27. Granite-Diorite-Gabbro (brittle): mainly medium to high strength; generally cannot be scratched; brittle (edges and corners can be plucked); minor medium to low strength zones which can be plucked with ease; may have partial to total thin surface weathering

POOR

51. Granite-Diorite-Gabbro (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)

TRAP (INCLUDES VERY HARD BASALT AND FINE GRAINED DIABASE/GABBRO)

GOOD

9. Trap (20 % sulphide): very high strength; faint scratch may be possible; fine grained; dark coloured; unweathered; may contain magnetite, hard epidote, garnet, and/or up to 20 % sulphide minerals such as pyrite

FAIR

33. Trap (21-74 % sulphide): very high strength; faint scratch may be possible; fine grained; dark coloured; generally unweathered; contains 21 to 74 percent sulphide minerals such as pyrite; may contain magnetite, hard epidote, and/or garnet

ENCRUSTATION

FAIR

52. Encrustation: 33 percent or more of particle is covered by a coating, usually calcium carbonate (25 percent in the case of a thick coating)

CEMENTATION

POOR

53. Cementation (partial): a group of particles cemented together, usually by calcium carbonate; one dominant host particle
54. Cementation (total): a group of particles cemented together, usually by calcium carbonate; no dominant host particle

VOLCANIC

GOOD

7. Volcanic (hard or medium hard): mainly very high strength; generally cannot be scratched; minor medium to high strength zones which can be scratched and scraped with some difficulty; may have partial, thin, surface weathering

FAIR

28. Volcanic (soft): medium strength; can be scratched with moderate ease and scraped with some difficulty; may contain minor low strength zones which can be gouged
73. Volcanic (glassy): cannot be scratched; conchoidal to semi-conchoidal fracture; includes obsidian
74. Volcanic (ochreous): contains between 25 and 50 percent ochreous material

POOR

48. Volcanic (very soft): low strength; can be scraped with ease and peeled with some difficulty; may contain up to 75 percent ochre
48. Volcanic (porous): porous; low strength; can be scratched and scraped with ease; may contain up to 75 percent ochre

DELETERIOUS

63. Volcanic (decomposed): very low strength; can be peeled with ease and crumbled with fingers

FLINT/JASPER AND IRON FORMATION

GOOD

71. Iron Formation (hard): high strength; cannot be scratched; unweathered

71. Iron Formation (slightly weathered): mainly high strength; can be scratched with difficulty; less than 5 percent of particle consists of penetrating zones of low to medium strength weathered material which can be scraped or gouged; may have partial to total thin surface weathering (rusty stains)

81. Flint/Jasper: high strength; cannot be scratched

FAIR

82. Iron Formation (moderately weathered): mainly medium to high strength; can be scratched with difficulty; outer crust can be scraped and plucked with difficulty; contains between 5 and 25 percent penetrating zones of low to medium strength weathered material which can be scraped or gouged

POOR

84. Iron Formation (highly weathered): contains between 25 and 75 percent low strength weathered material which can be scraped or gouged with ease; outer crust containing medium to low strength zones can be scraped and plucked with moderate ease; inner core may have appearance of ochre or pumice

DELETERIOUS

87. Iron Formation (decomposed): low to very low strength; greater than 75 percent of particle consists of low strength weathered material which can be scraped, peeled or gouged with ease

Note 6: Fissile iron formation should be included in the Greywacke-Argillite-Tuffite-Slate group.

OCHRE

DELETERIOUS

60. Ochre: greater than 75 percent of particle consists of ochre

GYPSITE

GOOD

77. Gypsite (< 10 % gypsum): less than 10 percent of particle consists of gypsum; host rock should be used for particle classification if it is not good aggregate

POOR

78. Gypsite (10-49 % gypsum): contains between 10 and 49 percent gypsum

DELETERIOUS

79. Gypsite (> 49 % gypsum): contains between 49 and 100 percent gypsum

SEDIMENT: SIBLEY GROUP

GOOD

80. Sediment: Sibley Group (hard): high strength; very difficult to scratch; scratching does not produce powder

FAIR

83. Sediment: Sibley Group (medium hard): high strength; can be scratched (surficial scratch only; deep scratch not possible); powder produced by scratching

POOR

85. Sediment: Sibley Group (soft): medium strength; can be scratched with ease (deep scratch possible); powders easily; ranges from scraped with difficulty to scraped with ease

DELETERIOUS

88. Sediment: Sibley Group (very soft): low to very low strength; can be scraped and peeled with ease

QUARTZ

GOOD

10. Quartz (vein or pegmatitic): does not include quartzite

TALC

DELETERIOUS

64. Talc: sectile; greasy to touch

SULPHIDE

FAIR

72. Sulphide: particle contains at least 75 percent sulphide minerals such as pyrite, marcasite, and chalcopyrite

COAL-COKE-CINDER

DELETERIOUS

31. Coal-Coke-Cinder

SLAG-GLASS

DELETERIOUS

92. Slag-Glass (in non-slag aggregate)

Category	Type	Color	Description
Good	Carbonate (medium hard) Particles with a thin shale coating on one face; no more than one intraparticle shale seam Equidimensional particles with one to three intraparticle shale seams and elongated particles with one or two intraparticle shale seams Equidimensional particles with a thin shale coating on two faces; no intraparticle shale seams	Becoming generally darker ▼	High strength; can be scratched
Fair	Carbonate (slightly shaley) Particles with a thick shale coating on one major face; no intraparticle shale seams Elongated particles with a thin shale coating on two faces; no intraparticle shale seams Equidimensional particles with a thin shale coating on two faces; one to two intraparticle shale seams Equidimensional particles with a thin shale coating on one face; two to three intraparticle shale seams Equidimensional particles with four intraparticle shale seams Elongated particles with three intraparticle shale seams		Medium strength; can be scratched with ease and scraped with some difficulty; generally shows grey or brown (sometimes greasy) streak when scratched
Poor	Carbonate (shaley) Particles extensively interbedded with shale or particles with uniform shaley (argillaceous) content throughout		Low strength; can be scraped with ease and peeled with some difficulty; generally shows grey, brown or black (sometimes greasy) streak when scratched
Deleterious	Shale Particles totally shale		Low to very low strength; can be scraped and peeled with ease; sometimes greasy to touch

Table 2 Petrographic Classification of Shale-Bearing Carbonate and Shale

METHOD OF TEST FOR VOLUME OF VOIDS (RIGDEN VOIDS) IN COMPACTED FILLER OR FINES

I. SCOPE

This test procedure describes a method for determining the void volume in a dry-compacted mineral filler or fines (the so-called Rigden voids). The test method is based upon the assumption that the densest packing maximum bulk density of fines can be obtained by compacting the dry fines in a mold. This method is modified from that presented in NAPA Information Series 127. This test requires further development. Comments and suggestions from users should be forwarded to Chris Rogers, Soils and Aggregates Section, Room 220, Building C, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8.

2. APPLICABLE DOCUMENTS

ASTM C 188 Specific Gravity of Hydraulic Cement

ASTM D 422 Particle Size Analysis of Soils

ASTM D 854 Specific Gravity of Soils

ASTM E 11 Specification for Wire-Cloth Sieves for Testing Purposes

NAPA Information Series 127, Evaluation of Baghouse Fines for Hot Mix Asphalt

3. SUMMARY OF METHOD

In this test method, the volume of the voids in a dry-compacted bed of mineral dust (the so-called Rigden voids) is determined by compacting the dust in a small mold.

4. DEFINITIONS

4.1 Maximum packing occurs when the particles are packed together in their minimum volume with a minimum void volume. Maximum packing results in a maximum bulk density.

4.2 The bulk density of the compacted fines is defined as the dry weight of the fines divided by the bulk volume of the compacted fines. The bulk volume includes the sum of the solid volume of the fines particles and the volume of the voids between the particles.

4.3 The density of the fines is defined as the dry weight of the fines divided by the solid volume of the fines particles. This density can be obtained from ASTM Test Method C 188 or D 854, or another appropriate test method.

5. SIGNIFICANCE

The void volume in dry compacted fines (Rigden voids) is sensitive to changes in gradation and other properties of the fines and, therefore, the dry compaction test has been proposed as a test for monitoring the uniformity of the fines collected in HMA facilities. Rigden voids can also be used to estimate the stiffening effect of the fines when mixed with asphalt cement.

6. APPARATUS

6.1 Compaction Hammer: A compaction hammer, as shown in Figure A-1, is required to compact the fines into the test mold. The fines are compacted in one layer, using 25 blows of the hammer.

6.2 Test Mold: A test mold or sample holder, as shown in Figure A-1, is required for measuring the volume of the compacted bed of fines.

6.3 CompactIon Pedestal: A circular steel block, 25.4 $\pm$ 2 mm thick, 100-130 mm diameter, is used as a base for placing the test mold.

6.4 Thickness Measuring System: A dial gauge with 0.002 mm gradations is required for measuring the thickness of the compacted bed of fines.

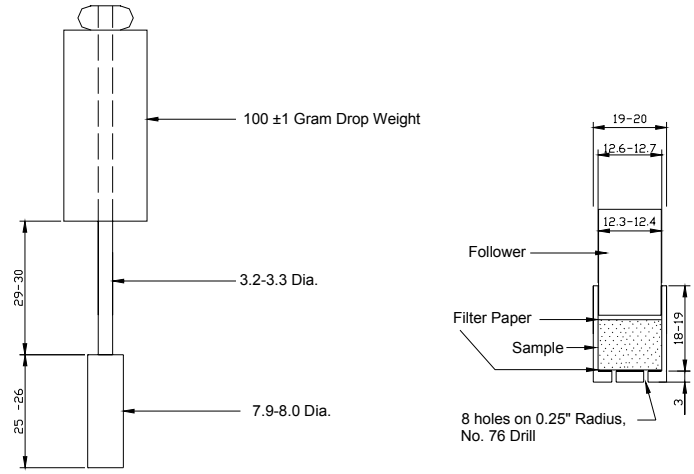
6.5 Filter Membrane: Small 12.7 mm diameter disks cut from a medium grade filter paper. A round cutting tool can be used for this purpose.

6.6 Tweezers: Tweezers are needed for handling the filter disks.

6.7 75 µm Sieve: A 75-µm sieve meeting the requirements of ASTM E 11 is needed to remove the particles larger than 75 µm.

6.8 Balance or Scale: A balance or scale rated to 200 grams and readable to 0.01 gram is required.

Compaction Hammer and Sampler Holder



Compaction Hammer Sampler Holder

All Dimensions are in mm

7. Sampling and Sample Preparation

The fines may be obtained from a primary or secondary dust collector, the coarse or fine aggregate, or the aggregate extracted from a mixture. Obtain a 2-kg sample and reduce by suitable means to a specimen of 10 g. Particles larger than 75 µm should be removed by sieving. Dry sieving is usually adequate if several sieves coarser than the 75-µm sieve are placed above the No. 200 sieve during the sieving operation to avoid overloading the 75-µm sieve. Wet sieving should be avoided because the fine particles tend to stick together after they are dried.

8. Procedure

8.1 Use the cutting tool to cut a number of 12.7 mm diameter filter disks. Place two of these disks in the bottom of the sample cup, place the follower over the top of the disks, and seat the follower on the filter disks using firm finger pressure. Insert the entire assembly under the dial gauge. Record the dial gauge reading as t_1.

8.2 Weigh the empty mold, two filter disks, and the follower, and record the mass as W_1. Remove the follower and the two filter disks.

8.3 Place a filter disk in the bottom of the sample cup, making certain that it is centered and firmly in place at the bottom of the mold. Select a representative sample of minus 75 µm fines that weighs approximately 1.0–1.3 grams. Carefully place the fines in the sample cup over the top of the filter disk. Place a second filter disk over the top of the fines and use the follower and firm hand

pressure to seat the disk on top of the fines. This procedure will result in some initial compaction of the fines and is to be expected.

8.4 Remove the follower, place the sample cup on the steel base plate, and apply 25 blows with the compaction hammer. Use caution during the compaction process to be certain that the mold is seated firmly on the compaction pedestal, the drop weight falls its full height, and the drop weight falls freely.

8.5 Remove the compaction hammer and insert the follower on top of the compacted fines and filter disk. Insert the entire assembly under the dial gauge and record the dial gauge reading, t_2. Weigh the entire mold assembly and record as the mass W_2.

8.6 The specific gravity of the fines solids is required to complete the calculations. If the specific gravity of the fines solids is not known, it will be necessary to measure it using ASTM procedure C188 or D854. Caution: The specific gravity of the fines solids may not be the same as for the other aggregate fractions. Although kerosene has been used as a liquid for determining specific gravity, water can also be used without adversely affecting the accuracy of the results.

9. Calculations

9.1 Notation

r	=	Radius of mold (mm)
G_{fs}	=	Specific gravity of the fines solids
t	=	Thickness of compacted sample (mm)
t_1	=	Initial dial gauge reading (mm)
t_2	=	Final dial gauge reading (mm)
V_{fB}	=	Bulk volume of compacted fines sample (cm^3)
V_{fS}	=	Volume of fines solids (cm^3)
RV	=	Volume of voids in compacted fines or Rigden voids (cm^3)
$\% RV$	=	Volume of voids in compacted fines expressed as percentage of bulk volume
W_{fs}	=	Mass of dry fines solids to nearest 0.01g (g)
γ_w	=	Density (unit weight) of water (1.00 g/cm^3)

9.2 Compacted Dust

9.2.1 Calculate the bulk volume of the compacted fines V_{fB}, as follows:

$$V_{fB} = \pi \times r^2 \times t$$

where:

r = radius of mold (mm)

t = $t_2 - t_1$ sample thickness (mm)

9.2.2 Calculate the volume of the fines solids V_{fS}, as follows:

$$V_{fS} = \frac{W_{fs}}{\gamma x G_{fs}} \quad cm^3$$

where:

W_{fs} = $W_2 - W_1$, mass of compacted fines (grams)

γ = unit weight of water (1.000g/cm^3)

G_{fs} = specific gravity of the fines solids as determined from the ASTM C 188 or D 854, or another suitable test method

9.2.3 Calculate the volume of the voids in compacted fines, RV (Rigden voids), as follows:

$$RV = V_{fB} - V_{fS}$$

9.2.4 Calculate the percentage of voids in the compacted fines (Rigden voids) as follows:

$$\% RV_{fs} = \frac{V_{fB} - V_{fS}}{V_{fB}} \times 100$$

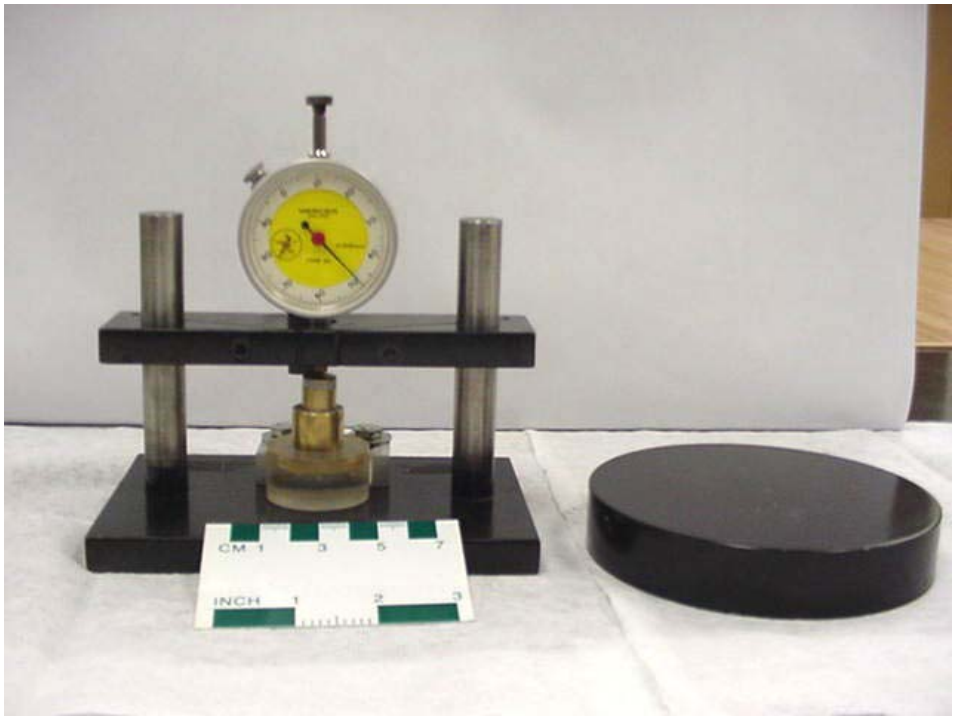


Figure 1 Rigden Voids Apparatus

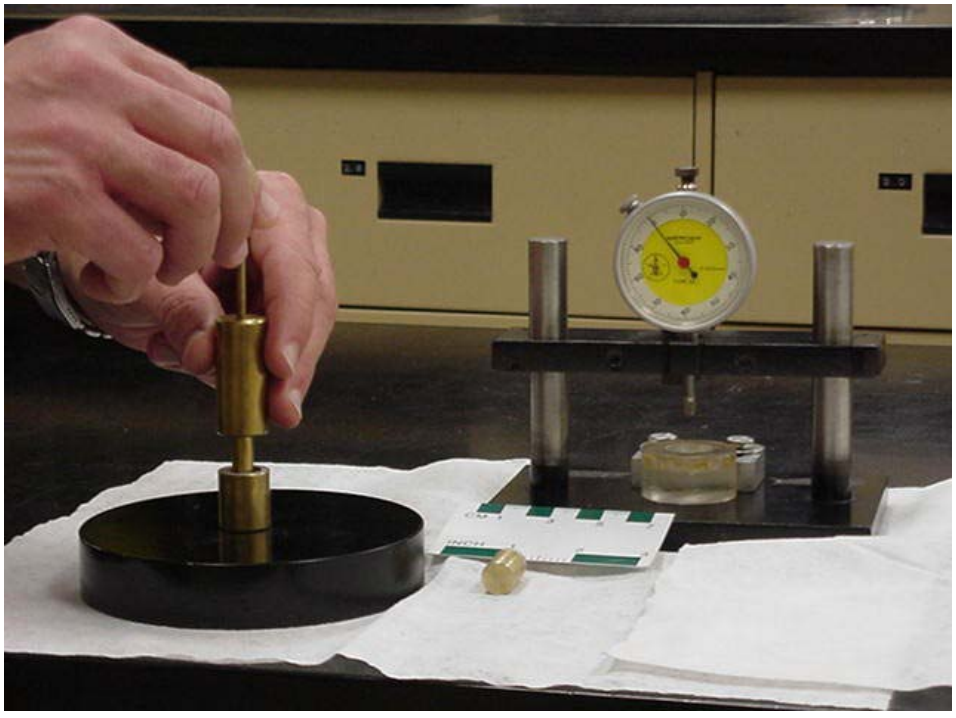


Figure 2 Compaction of Baghouse Fines

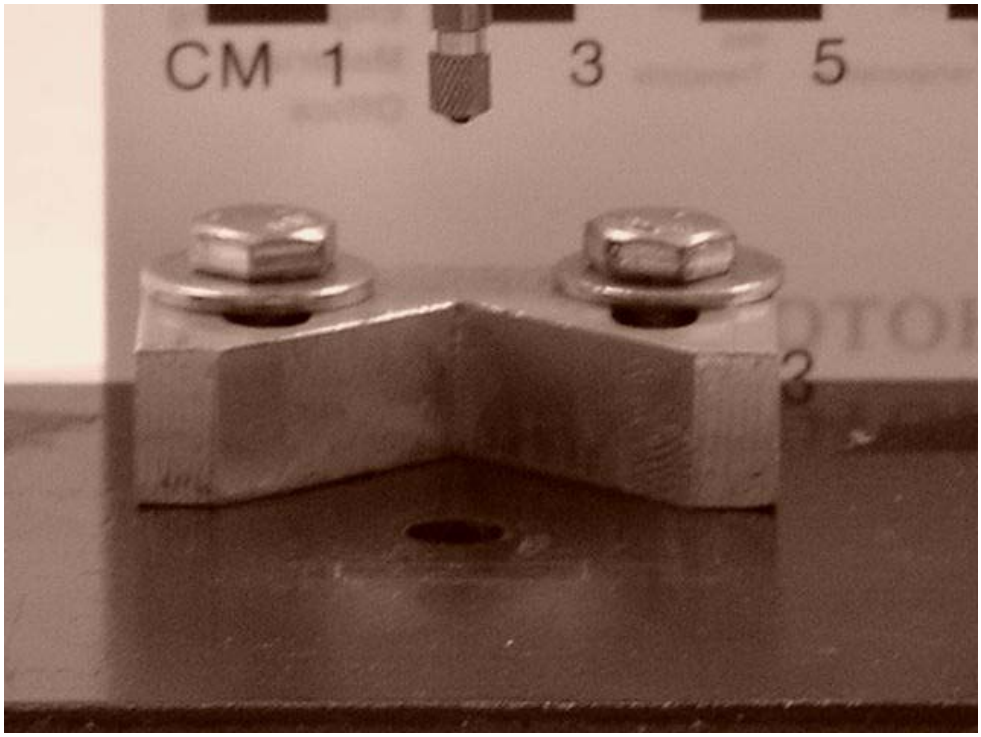


Figure 3 V Notch on Base

METHOD OF TEST FOR
UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

1. SCOPE

1.1 This method describes the determination of the loose uncompacted void content of fine aggregate. AASHTO T 304 describes three procedures for determining void content. For the purposes of determining compliance with "Superpave" consensus properties MTO has chosen to use Method A of the procedure.

Note: ASTM C 1252 is the same as AASHTO T 304 in all important respects.

2. PROCEDURE

2.1 Follow the test method (Method A) described in AASHTO T 304 except as noted below.

2.2 In determining the bulk dry specific gravity (relative density) of the fine aggregate follow MTO LS-605. It is critical that the fines be removed from the fine aggregate test portion prior to determination of density. Determine the density of the graded sample and do not use the individual size fraction method of clause 9.4 of T 304.