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 proposed for use in construction. The test method is subdivided into Parts A and B. In Part A, the procedure appraises the quality of coarse aggregate and provides a numerical means in terms of a petrographic number (PN) of expressing and comparing the quality of material from the same or different sources. Part B outlines the procedure for petrographic identification of coarse aggregate extracted from either reclaimed asphalt pavement (RAP) or asphaltic concrete.

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, e.g., hardness, strength.

1.3 This test method is intended to be applied only to aggregate derived from natural mineral materials such as gravel and crushed bedrock. It is not intended for the assessment of quality or suitability of artificial or man-made materials. This may include, but is not limited to, industrial co-products such as slags and other recycled or reclaimed materials such as asphaltic concrete, Portland cement/hydraulic concrete, glass, ceramic whiteware etc. For the purposes of this test method, these materials are considered contaminants.

1.4 This system of evaluation of aggregate type and quality is based on laboratory studies and in-service performance for intended uses and prevailing conditions in Ontario. The factors may not apply under other conditions and in other areas.

2. RELEVANT DOCUMENTS

2.1 ASTM Standards

C 294, Standard Descriptive Nomenclature for Constituents of Concrete Aggregates.

C 295, Standard Guide for Petrographic Analysis of Aggregates for Concrete.

2.2 CSA Standards

A23.2-15A, Petrographic Examination of Aggregates

2.3 MTO Test Methods

LS-282, Method of Test for Quantitative Extraction of Asphalt Cement and Analysis of Extracted Aggregate from Bituminous Paving Mixtures

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

LS-602, Method of Test for Sieve Analysis of Aggregates

LS-616, Procedure for the Petrographic Analysis of Fine Aggregate

2.4 Hamblin, W. K. and Howard, J. D., Exercises in Physical Geology, Seventh Edition, MacMillan Publishing Company, New York, 1986, 191p.

2.5 Lane, E. W., Report of the Subcommittee on Sediment Terminology, Trans. Am. Geophys. Union, Vol. 28, pp. 936-938.

2.6 Rogers, C. A., Petrographic Examination of Aggregate and Concrete in Ontario, Engineering Materials Office, Ministry of Transportation, Report EM-91, 1989, 35p.

2.7 Rogers, C. A. and Mukherjee, P. K., Influence of Cementations in Sand from Fonthill on Durability and Strength of Concrete, Ministry of Transportation and Communications, Engineering Materials Office, Materials and Laboratory Services Section, Report MI-19, 11p.

2.8 Tucker, M. E., Sedimentary Rocks in the Field, Second Edition, John Wiley and Sons Ltd, 1996, 153p.

2.9 Wentworth, C. K., A Scale of Grade and Class Terms for Clastic Sediments, The Journal of Geology, Vol. 30, No. 5, 1922, pp. 377-392.

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 the Appendix and shown on MTO form PH-CC-343a : 03, 22, 06, 04, 05, 08, 07, 09, 10, 30, 29, 25, 34, 27, 28, 46, 56, 50, 55, 51, 48, 63, 81, 82, 73, 74, 86, 84, 97, 87, 32, and 64.

3.2 CARBONATE AGGREGATES: means rock particles composed predominantly of minerals containing the carbonate ion ($[CO_3]^{2-}$) in its chemical formula. The most abundant carbonate aggregates are limestones and dolostones, the former composed of the mineral calcite ($CaCO_3$) and the latter of dolomite ($Ca,Mg(CO_3)_2$). Carbonate aggregates include the following Type Numbers given in the Appendix and shown on form PH-CC-343a: 01, 20, 02, 21, 23, 35, 41, 42, 40, 24, 26, 43, 44, 49, and 45.

4. APPARATUS

4.1 HAND LENS: 10x magnification.

4.2 MAGNET

4.3 KNIFE: Good quality with a blade hardness of between 5½ and 6 on Moh's scale.

4.4 ANVIL & HAMMER: Suitable for breaking aggregate particles.

4.5 HYDROCHLORIC ACID: Technical grade, 5 % by volume.

4.6 BINOCULAR MICROSCOPE: 4x to 25x magnification or higher, with appropriate illumination source.

4.7 SCALE: Accurate to 0.1 g and of sufficient capacity.

PART A

5. PREPARATION OF SAMPLE

5.1 Examine the sample in the as-received condition and record any significant features regarding particles that may be affected by sample preparation such as soaking, washing and sieving.

5.2 Determine the gradation of the coarse aggregate portion (material retained on the 4.75 mm sieve) according to LS-602. Record the percentage of each fraction of the as-received sample as a percentage of the total coarse aggregate on MTO form PH-CC-343a (see Appendix).

5.3 Weigh out representative quantities of the different sizes present in the sample to the minimum masses shown below:

Pass	Retained	Minimum 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	13.2 mm	1500
13.2 mm	9.5 mm	500
9.5 mm	4.75 mm	200

5.4 Begin the examination on the coarsest fraction that comprises at least 10 percent of the coarse aggregate portion of the sample. Continue with examination of progressively finer fractions until at least 90 percent of the coarse aggregate portion of the sample has been examined.

5.5 Consider all material retained on the 19 mm as a single fraction with the quantity of material to be examined determined by the largest sieve through which all the aggregate passes, e.g., if 100% of the aggregate passes the 53 mm sieve, then the fraction of material retained on the 19 mm sieve will consist of 5000 g. Proportion the quantity of material within this fraction according to the coarse aggregate gradation of the as-received sample.

6. TEST PROCEDURE

6.1 Follow the procedure given below for each fraction to be examined.

6.2 Spread the sample out on a clean tray or other clean, flat working surface.

6.3 Visually examine the sample for angularity and shape characteristics and make an estimate of the percentage of crushed particles. Record the information on MTO form PH-CC-343a. .

6.4 Examine all aggregate particles for coatings (such as clay), cementations and encrustations which may affect bond with asphalt or Portland/hydraulic cements. Note the type of coating and the degree of adhesion to the aggregate and record this in the Additional Information section on MTO form PH-CC-343a.

6.5 Separate all particles that may break down in water or with normal handling, e.g., clay balls. Classify these particles according to paragraph 6.9 below (do not soak).

6.6 Wash the remaining material to remove clay and dust coatings. Place the washed material in a bowl or other suitable container and cover with water. Soak the sample for a minimum of 12 hours.

Note 1: Soaking will cause particles with clay, shale, shaley, slightly shaley or micaceous content to soften, making them easier to recognize.

6.7 Pour off the water from the sample. Remove the sample from the bowl and spread it out on a clean tray or other clean, flat working surface covered with either paper or a cloth towel to absorb excess water.

6.8 Examine and classify each particle into separate groups according to rock type and quality using the information provided in the Appendix.

Note 2: MTO form PH-CC-343a only provides listing of the most common rock type and quality designations that may be expected and is not exhaustive. MTO form PH-CC-343a may be amended with additional rock types from the Appendix as applicable.

Note 3: Index tests and a microscopic examination are usually sufficient to classify an aggregate particle. If not, refer the particle to a Petrographer for additional information and identification, i.e., possibly requiring a detailed petrographic study.

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

6.9.1 Scratch hardness

6.9.2 Strength

6.9.3 Density

6.9.4 Shape

6.9.5 Texture

6.9.6 Colour

6.9.7 Mineralogy

6.9.8 Structure

6.9.9 Reaction with hydrochloric acid

6.9.10 Weathering

6.9.11 Magnetism

6.10 On completion of the examination, record the mass of classified particles to the nearest 0.1 g in the appropriate columns shown on MTO form PH-CC-343a.

6.11 Repeat the procedure for the next fraction.

7. CALCULATIONS

7.1 For each fraction, calculate the percentage of each rock type to the nearest 0.1 percent. Calculate the percentage of good, fair, poor and deleterious particles as a percentage of the entire sample (including contaminants).

7.2 Calculate the PN for each fraction as the sum of the products of the percentage of each petrographic category (good, fair, poor and deleterious) and the appropriate factor (1, 3, 6, and 10, respectively).

Note 4: Do not include contaminant particles when calculating the PN or the weighted average PN.

7.3 When the test is performed on more than one fraction, calculate a weighted average PN as follows: compute the percentage of each fraction of the coarse aggregate portion of the as-received sample. Multiply each of these calculated percentages for each of the fractions by their respective petrographic numbers for those fractions. Divide the sum of the products by 100. Enter the information in the appropriate sections of MTO form PH-CC-343a.

7.4 For the purpose of calculating the weighted average PN, consider any sizes of the coarse aggregate fractions that were not tested to have the same value as the next larger or smaller size fraction, whichever is present.

8. REPORTING OF RESULTS

8.1 Include the following in the examination report (MTO form PH-CC-343a):

8.1.1 Information regarding contract, aggregate, source and sampling as applicable.

8.1.2 Contact information of the testing laboratory and the sample number.

8.1.3 The date the examination was completed and the name of the analyst performing the examination.

8.1.4 The coarse aggregate gradation of the as-received sample.

8.1.5 The masses of each type (including contaminants) to one decimal place for each fraction tested.

8.1.6 The percentages (to the nearest 0.1 percent) of each type and of good, fair, poor and deleterious particles for each fraction tested.

8.1.6 The PN for each fraction tested (to the nearest whole number).

8.1.7 The weighted average PN (to the nearest whole number), when the test is performed on more than one fraction.

8.1.8 Other information as required, such as the percentage of individual or combined rock types or contaminants by mass, e.g., percent by mass of carbonate or siliceous aggregate rock types.

9. GENERAL NOTES

9.1 In the event that there are a number of highly absorptive aggregate particles, air-dry the particles before weighing so that excess water absorbed during washing/soaking will not significantly influence the mass.

9.2 Petrographic factors used for classification take only the physical properties of the aggregate into account. The possibility of the aggregate producing excessive expansion through alkali-aggregate reactions or other adverse reactions and/or staining in asphaltic or hydraulic cement concretes due to the presence of components such as silica or siliceous minerals, sulphide minerals, free lime, free magnesia, or gypsum is not considered here.

PART B

10. SAMPLE PREPARATION

10.1 Extract sufficient aggregate material from the RAP or asphaltic concrete using LS-282, or as specified in the contract documents, to obtain a minimum of 1 kg of clean, dry, coarse aggregate. Examine the material for residual asphalt cement and if present, repeat the extraction.

10.2 Determine the gradation of the extracted aggregate according to procedures given in LS-602.

10.3 Prepare individual fractions from the coarse aggregate proportion as shown in the following table:

Pass	Retained	Minimum Mass, g
-	9.5 mm	entire sample
9.5 mm	4.75 mm	200

Note 5: Where the mass of the pass 9.5 mm/retained 4.75 mm fraction is more than 25% of the mass shown in this table, reduce the mass by splitting to meet this requirement.

11. PROCEDURE

11.1 Follow the procedure given below for each sieve fraction to be examined.

11.2 Place the material in a bowl or other suitable container and cover with water. Soak for a minimum of 12 hours.

11.3 Pour off the water from the sample. Remove the sample from the bowl and spread it out on a clean tray or other clean, flat working surface covered with either paper or a cloth towel to absorb excess water.

11.4 Examine and classify each particle according to rock type, mineral type or material and quality using the information provided in the Appendix. Refer to Part A, 6.9 of this test method for relevant features.

Note 6: Classify each rock, mineral and material type individually, e.g., granite, diorite, gabbro, gneiss, schist, sandstone. DO NOT group rock types together into broad classifications, e.g., granite-diorite-gabbro.

11.5 Determine the appropriate Category for each rock type, mineral type or material identified and record the classification as a separate entry on MTO form PH-CC-343b (Appendix).

Note 7: Rock type quartzite (formerly Category 4) is now included in Category 1.

11.6 Upon the completion of the examination, weigh and record the mass of each group of classified particles to the nearest 0.1 g. Enter this information on MTO form PH-CC-343b.

12. CALCULATIONS

12.1 Calculate the proportion of each different rock, mineral or material type tested as percentage of each sieve fraction tested as follows:

12.1.1 For each fraction, calculate the percentage of each different rock, mineral or material type by dividing the mass of individual types by the total mass of the tested fraction and multiply by 100.

12.1.2 For each category, sum the individual masses of each type tested. Divide this sum by the total mass of the tested fraction and multiply by 100.

12.2 Calculate the weighted average of each different rock, mineral or material type tested and for each category as a percentage of the total sample as follows:

12.2.1 For each type, multiply the percentages within each fraction obtained in 12.1.1 by the portion represented by that fraction as determined by coarse aggregate gradation of the as-received sample.

13. REPORTING OF RESULTS

13.1 Include the following in the examination report (MTO form PH-CC-343b):

13.1.1 Information regarding contract, aggregate, source and sampling as applicable.

13.1.2 Contact information of the testing laboratory and the sample number.

13.1.3 The date the examination was completed and the name of the analyst performing the examination.

13.2 The coarse aggregate gradation of the as-received sample, as determined by LS-602.

13.3 For each fraction tested, report the following:

13.3.1 The percentage of the same fraction in the as received sample.

13.3.2 The mass of each different rock, mineral or material type recorded to one decimal place.

13.3.3 The percentage of each different rock, mineral or material type to one decimal place.

13.3.4 For each Category, the total mass of each rock, mineral or material type found within that Category and the percentage that it represents in the tested fraction.

13.4 The weighted average percentage that each different rock, mineral or material type represents in the as-received sample.

13.5 The weighted average percentage that all the components within each designated Category represents in the as-received sample.

APPENDIX
ROCK AND QUALITY TYPE DESCRIPTIONS FOR THE PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE

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 typically encountered in Ontario are presented in this appendix. The list is not exhaustive, and rock type names that are more descriptive or detailed may be used at the discretion of, or in consultation with a Petrographer (see Note 2). Prior to this, every attempt should first be made to classify aggregate particles within the framework provided.

Index tests related to the strength of the aggregate particles, e.g., scratching, scraping, peeling and plucking using a knife blade, are employed in this classification. Scratching, scraping, and peeling determine the application of hardness descriptors. Plucking determines the application of descriptors such as 'brittle' and 'friable'. Each rock group, e.g., carbonate, sandy carbonate, marble, volcanic and gneiss, 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, X-ray diffraction analysis, chemical analysis and scanning electron microscopy may be necessary. For example, 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; can be peeled with difficulty

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

Note 8: Use of the term "pitted" should be reserved for concavities developed on the aggregate particle surface that are due to chemical and/or physical weathering. "Pitted" as a descriptor refers to having marked concavities not related to the texture of the rock in which it appears or to differential weathering. For example, certain hard and medium-hard dolostones in Ontario, e.g,. Amabel Formation may have vugs or open pore spaces that are an intrinsic part of the rock. , These open spaces are not classified as pits or "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 (very soft): contains between 33 and 75 percent very low strength material; can be scraped and peeled with ease

43. Carbonate (very soft, deeply weathered): contains between 33 and 75 percent very low strength deeply weathered material

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

64. Carbonate (very weak): 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.

64. Carbonate (very weak, deeply weathered): 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.

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

Note 9: Sand-sized quartz grains are those ranging between 63 µm and 2 mm in size (see Table 2).

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 1 for petrographic classification, and Note 8)

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

Note 10: Scratching the surface of shaley carbonates may produce a bitumen odour; shale seams or laminations may be discernable (see Table 1) or have a mottled appearance when wet, typically light and dark tones usually grey, but also grey brown.

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): particle contains 5 to 100 percent chert. Of the chert that is present, the leached variety constitutes less than 20 percent of the particle. Leached chert is absorptive and will generally stick to the tongue.

POOR

45. Chert-Cherty Carbonate (≥20 % leached chert): particle contains 20 percent or more of the leached variety of chert. Leached chert is absorptive and will generally stick to the tongue.

Note 11: Hardness of chert is equivalent to that of crystalline quartz, therefore when scratched it will leave a metallic streak produced from the knife blade.

Note 12: Additional characteristics of chert include conchoidal fracture. Lustre may range from waxy or vitreous (unleached) to dull and porcelainous, with a similar appearance to that of freshly broken ceramic or pottery (leached and semi-leached).

Note 13: The classification of semi-leached chert as leached chert or unleached chert should be based on the rate of absorption. Absorptive chert (leached) will generally stick to the tongue.

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)

Note 14: Identification of sandstone versus quartzite. Sandstone: raspy sound to barely discernable when scratched; grains generally appear subrounded to rounded; rock may break or fracture across individual grains or around them; individual grains are discernable when viewed through a hand lens.

QUARTZITE

GOOD

5. Quartzite: very high strength; cannot be scratched

Note 15: Identification of sandstone versus quartzite. Quartzite is generally nonfoliated. Individual quartz grains within the rock tend to be interlocked, stretched, deformed and fused together making them barely discernable to indiscernible when viewed through a hand lens. The rock tends to break or fracture randomly across the grains. Quartz is the principal mineral, but some quartzite may contain as much as 40% other minerals such as mica. Although generally nonfoliated, the presence of mica and/or interbedded argillaceous material may lead to areas with slaty cleavage or relict bedding which can locally impart a planar element to the rock.

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 (very 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

Note 16: Greywacke is argillaceous sandstone that is characterized by sand-sized mineral and rock fragments in a clay sized matrix. In Ontario, greywacke is generally hard, medium-grained, dark grey in colour, and consists of a mixture of poorly sorted angular grains of quartz, feldspar, ferromagnesian minerals and other rock fragments in an abundant matrix that is very fine-grained (muddy). Greywacke generally does not react with acid, and when scratched it will leave a metallic streak produced from the knife blade.

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: very high strength; faint scratch may be possible; fine grained; dark coloured; unweathered; may contain magnetite, hard epidote, garnet

ENCRUSTATION AND CEMENTATION

FAIR

52. Encrustation: 25 percent or more of particle is covered by a coating, usually calcium carbonate

52. Cementation (partial): cementations and encrustations form between 5 and 20% of the total particle surface area or total particle volume (whichever is exceeded first), where the host particle is judged to be of good to fair quality. See Table 3.

CEMENTATION

POOR

53. Cementation (partial): a group of particles cemented together, usually by calcium carbonate; one dominant host particle. See Table 3.

54. Cementation (total): a group of particles cemented together, usually by calcium carbonate; no dominant host particle. See Table 3.

Note 17: Encrustation and cementation rock types refer to those occurring in and formed by natural processes. Particles such as reclaimed concrete material (RCM), reclaimed asphalt pavement (RAP), or particles containing residual asphalt from an incomplete extraction process should not be included within the encrustation or cementation rock types. These materials should be classed as contaminants.

VOLCANIC AND METAVOLCANIC

GOOD

7. Volcanic and metavolcanic (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, non-foliated to weak schistosity; felsic, intermediate through mafic composition

7. Mafic Metavolcanic - Greenstone (hard or medium hard): generally fine grained to aphanitic, non-foliated to weak schistosity discernable; can be scratched with some difficulty (surficial or thin scratch only; deep scratch not possible); some difficulty in producing powder by scratching

FAIR

28. Volcanic and metavolcanic (soft): medium strength; can be scratched with moderate ease and scraped with some difficulty; may contain minor low strength zones which can be gouged, non-foliated to moderate schistosity; felsic, intermediate through mafic composition

28. Mafic Metavolcanic - Greenstone (soft): medium strength; can be scratched with moderate ease and scraped with some difficulty (deep scratch possible, powder produced by scratching); may contain minor medium to low strength zones; generally foliated with weak to moderate schistosity discernable

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; felsic, intermediate through mafic composition

48. Volcanic (porous): porous; low strength; can be scratched and scraped with ease; may contain up to 75 percent ochre; felsic, intermediate through mafic composition

DELETERIOUS

63. Volcanic (decomposed): very low strength; can be peeled with ease and crumbled with fingers; felsic, intermediate through mafic composition

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 18: 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

GYPSUM AND ANHYDRITE

GOOD

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

POOR

78. Gypsum (10-49 % gypsum): contains between 10 and 49 percent gypsum and/or anhydrite

DELETERIOUS

79. Gypsum (> 49 % gypsum): contains between 49 and 100 percent gypsum and/or anhydrite

SIBLEY GROUP SEDIMENTARY ROCKS

GOOD

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

FAIR

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

POOR

85. Sedimentary Rock: 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. Sedimentary Rock: Sibley Group (very soft): low to very low strength; can be scraped and peeled with ease

Note 19: The Sibley Group is a group of three Proterozoic sedimentary rock formations: Rossport Formation, Kama Hill Formation and Pass Lake Formation that occur in the Thunder Bay – South Lake Nipigon - Nipigon area. The distribution of the Sibley Group is limited to bedrock outcrops in these geographic areas and in the surficial deposits that overlie, and are proximal to these areas. Sibley Group terminology is usually only applied where the user is aware of the location and geology of the source and is familiar with utilization of the terminology.

QUARTZ

GOOD

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

FELDSPAR

GOOD

11. Feldspar (vein or pegmatitic):

TALC

DELETERIOUS

64. Talc: sectile; greasy to touch

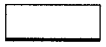
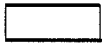
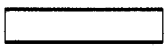
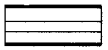
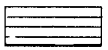
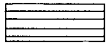
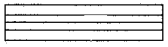
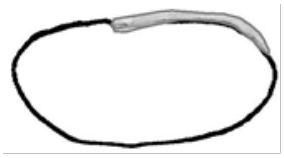
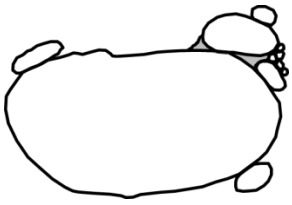
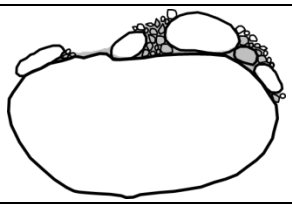
Category	Type	Color	Description
Good	Carbonate (medium hard)  Particles with a thin shale coating on one face; no more than one intraparticle shale seam  Equidimensional particles with one to three intraparticle shale seams and elongated particles with one or two intraparticle shale seams  Equidimensional 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
	Shale		Low to very low strength; can be
Deleterious	 Particles totally shale		scraped and peeled with ease; sometimes greasy to touch

Table 1. Petrographic Classification of Shale-Bearing Carbonate and Shale

Table 2. Terms for grain size classes and siliclastic rock types, modified from Tucker (1996), Wentworth (1922), and Lane et al. (1947).

Grade Name	Size	Rock Type	
Boulder	Over 256 mm	Conglomerates (rounded clasts) and Breccias (angular clasts)	
Cobble	64-256 mm		
Pebble	4-64 mm		
Granule	2-4 mm		
Very coarse grained sand	1-2 mm	Sandstone	
Coarse grained sand	0.5-1 mm		
Medium grained sand	0.25-0.5 mm		
Fine grained sand	0.125-0.25 mm		
Very fine grained sand	0.0625-0.125 mm		
Silt	0.004-0.0625 mm	Siltstone	Mudrocks
Clay (mud)	Less than 0.004 mm	Claystone	

Table 3. Classification of Cementations and Encrustation.

Rock Type	Type No.	Illustration/Example Sketch	Quality Category	Description
Encrustation	52		Fair	25% or more of the surface area of the particle is covered by a mineral coating. The mineral coating is deposited through the action of groundwaters and typically consists of calcium carbonate, silicate minerals or iron hydroxides. Classify particle as an encrustation (rock type 52) if the host rock particle is judged to be of good to fair quality. This is irrespective of coating thickness. If the host particle is judged to be of poor or deleterious quality, the particle shall be classified according to the host particle rock type. Example: if an encrusted particle is composed of 'siltstone' (poor quality) then the particle shall be classed as siltstone (rock type 56), not as an encrustation (rock type 52).
Cementation (Total)	54		Poor	A conglomeration of particles that is bound together by natural cement. The cement is deposited through the action of ground waters and typically consists of calcium carbonate, silicate minerals or iron hydroxides.
Classify according to host rock particle type			Can be good, fair, poor or deleterious quality	Where cementations cover less than 5% of the host particle surface or form less than 5% of total particle volume (whichever is exceeded first) classify the particle according to its host particle rock type and NOT as a cementation. Example: cementations cover <5% of a medium hard limestone particle (rock type 20). In this case, the particle shall be classified according to the host rock lithology and quality classification and not as a cementation, i.e. rock type 20.
Cementation (Partial)	52		Fair	Partial Cementation, Fair Category: cementations and encrustations form between 5 and 20% of the total particle surface area or total particle volume (whichever is exceeded first), where the host particle is judged to be of good to fair quality. If the host particle is judged to be of poor or deleterious quality, the particle shall be classified as rock type 53.
Cementation (Partial)	53		Poor	Partial Cementation, Poor Category: cementations and encrustations form greater than 20% of the total particle surface area or total particle volume (whichever is exceeded first), where the host particle is judged to be of good to poor quality.

Ontario

LS-609 (Part A) - Coarse Aggregate Petrographic Analysis (Petrographic Number, PN)

SAMPLE #:	**ANALYST:**		**DATE TESTED:**
TESTING LAB:	**TEL:**	**FAX:**	**LAB #:**
SAMPLED BY:	**DATE SAMPLED:**		**SAMPLE TYPE:**
SOURCE NAME:	**SOURCE LOCATION:**		**MAIDB #:**
AGGREGATE TYPE:	**AGGREGATE PRODUCT:**		**LOT #:** / **SUBLOT #:**
CONTRACT:	**CONTRACT LOCATION/HWY.:**		**CONTRACTOR:**

TYPE	TYPE No.	/ R19		P19.0 / R13.2		P13.2 / R9.5		P 9.5 / R4.75		Weighted Composition (%)
		Mass (g)	% of Fraction	Mass (g)	% of Fraction	Mass (g)	% of Fraction	Mass (g)	% of Fraction	
CARBONATE (hard; silty, hard)	01									
CARBONATE (surface weathering; silty, surface weathering; medium hard; silty, medium 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 (hard)	09									
QUARTZ (vein or pegmatitic)	10									
TOTAL GOOD AGGREGATE	–									
CARBONATE (soft; silty, soft; slightly shaley)	35									
CARBONATE (soft; pitted)	41									
CARBONATE (deeply weathered; silty, deeply weathered)	42									
CARBONATE (sandy, soft)	40									
MARBLE (brittle)	24									
CHERT – CHERTY CARBONATE (< 20% leached chert)	26									
CONGLOMERATE – SANDSTONE – ARKOSE (brittle)	30									
GREYWACKE (brittle)	29									
ENCRUSTATION	52									
GNEISS – AMPHIBOLITE – SCHIST (brittle)	25									
ARGILLITE (medium soft)	34									
GRANITE – DIORITE – GABBRO (brittle)	27									
VOLCANIC (soft)	28									
TOTAL FAIR AGGREGATE	–									
CARBONATE (shaley; clayey; silty, clayey)	43									
CARBONATE (ochreous; sandy, ochreous)	44									
MARBLE (friable)	49									
CHERT – CHERTY CARBONATE (≥ 20% leached chert)	45									
CONGLOMERATE – SANDSTONE – ARKOSE (friable)	46									
SILTSTONE	56									
CEMENTATION (partial)	53									
CEMENTATION (total)	54									
GNEISS – AMPHIBOLITE (friable)	50									
SCHIST (soft)	55									
GRANITE – DIORITE – GABBRO (friable)	51									
VOLCANIC (very soft, porous)	48									
TOTAL POOR AGGREGATE	–									
OCHRE	60									
SHALE	61									
CLAY	62									
VOLCANIC – GNEISS – SCHIST (decomposed)	63									
TOTAL DELETERIOUS AGGREGATE	–									
Estimate % Crushed = .	**TOTALS**									
	CONTAMINANTS (Not included in PN calculations)									
	Totals (with contaminants)									

Additional Information:									**Weighted Average PN**
	% GOOD	X 1 =		X 1 =		X 1 =		X 1 =	
	% FAIR	X 3 =		X 3 =		X 3 =		X 3 =	
	% POOR	X 6 =		X 6 =		X 6 =		X 6 =	
	% DELETERIOUS	X 10 =		X 10 =		X 10 =		X 10 =	
	PN =								

COARSE AGGREGATE GRADATION OF AS-RECEIVED SAMPLE, % RETAINED

P75.0/R53.0	P53.0 /R37.5	P37.5 / R26.5	P26.5 / R19.0	P19.0 / R13.2	P13.2 / R9.5	P 9.5 / R4.75

Ontario **LS-609 (Part B) - Coarse Aggregate Petrographic Analysis on Aggregate Extracted From Asphaltic Concrete or RAP**

LAB SAMPLE #:	**ANALYST:**		**DATE TESTED:**
TESTING LAB:	**TEL:**	**FAX:**	**LAB #:**
SAMPLED BY:	**SAMPLE TYPE:**	**DATE SAMPLED:**	**AS-RECEIVED SAMPLE MASS (g):**
SAMPLING LOCATION/SOURCE:	**MIX TYPE:**	**LOT/SUBLOT :**	**QUANTITY (TONNES):**
CONTRACT:	**LOCATION/HIGHWAY:**		**CONTRACTOR:**

TYPE[3,4]	**FRACTION**				**Weighted Average (%)**
	P____ / R9.5		**P 9.5 / R4.75**		
	% of As-Received Sample		**% of As-Received Sample**		
CATEGORY 1 : SILICEOUS ROCK TYPES AND MINERALS (Hard to Medium Hard) [3,4]	**Mass (g)**	**% of Fraction**	**Mass (g)**	**% of Fraction**	
TOTAL CATEGORY 1:					

CATEGORY 2 : CARBONATE ROCK TYPES AND MINERALS[4]	**Mass (g)**	**% of Fraction**	**Mass (g)**	**% of Fraction**	**Weighted Average (%)**
TOTAL CATEGORY 2:					

CATEGORY 3 : CONTAMINANTS[3,4]	**Mass (g)**	**% of Fraction**	**Mass (g)**	**% of Fraction**	**Weighted Average (%)**
TOTAL CATEGORY 3:					

CATEGORY 4: NOW INCLUDED IN CATEGORY 1

CATEGORY 5 : NON-CARBONATES & NON-CONTAMINANTS (Fair, Poor or Deleterious) [3,4]	**Mass (g)**	**% of Fraction**	**Mass (g)**	**% of Fraction**	**Weighted Average (%)**
TOTAL CATEGORY 5:					
TOTALS:					

Coarse Aggregate Gradation of the As-Received Sample, % Retained

P37.5/R26.5	**P26.5/R19.0**	**P19.0/R12.5**	**P12.5/R9.5**	**P9.5/R4.75**

PH-CC-343b 15-01

Notes:

1. *If the aggregates are from a sample of asphaltic concrete, identify where the asphaltic concrete was sampled. If the aggregates are from a sample of RAP, identify the source of the RAP, including where the RAP was milled.*
2. *Identify the mix type where applicable, i.e., Superpave FC1, Superpave FC2, SMA 9.5, etc.*
3. *Classify rock types on a detailed basis and list each rock type, mineral type or material type individually and on separate lines for Categories 1, 3 and 5 only, e.g., "granite", "gabbro", "quartzite", "feldspar". DO NOT group rock types together into broad classifications, e.g. granite-diorite-gabbro on the same line.*
4. *Each category shall include the rock, mineral and material types described below:*
   a. *CATEGORY 1: SILICEOUS ROCK TYPES AND MINERALS (Hard to Medium Hard) includes rock types 3, 4, 5, 6, 7, 8, 9, & 22 as well as any other medium to hard, competent (i.e. not brittle, friable or platy), siliceous rock types and the minerals that they may be comprised of such as quartz, feldspar and the amphiboles.*
   b. *CATEGORY 2: CARBONATE ROCK TYPES AND MINERALS includes rock types 1, 2, 20, 21, 23, 24, 26, 35, 40, 41, 42, 43, 44, 45, & 49 and any other carbonate rock and/or mineral types not listed here.*
   c. *CATEGORY 3: CONTAMINANTS includes but is not limited to clay and soluble minerals, clay lumps, earth, wood, crack sealant as well as all waste materials such as gypsum, plaster, gypsum/plastic wallboard, hydraulic cement concrete, clay brick, tile, coal, fly ash, cardboard, paper, metals, slags, glass, ceramics, soluble minerals, paint, rubber, etc.*
   d. *CATEGORY 5: NON-CARBONATES & NON-CONTAMINANTS (Fair, Poor or Deleterious) includes rock type 80, all fair, poor or deleterious rocks and minerals, as well as any other materials that do not fall under CATEGORIES 1, 2 or 3.*