Standard Specification
For

Reclaimed Concrete Aggregate for Use As Coarse Aggregate in Portland Cement Concrete

1. SCOPE

1.1 This specification covers coarse aggregate derived from reclaimed concrete for use in Portland cement concrete. The specification is not intended for use when lightweight, high density, or other specialty Portland cement concrete applications are required. When aggregate materials are properly processed and manufactured to the requirements of this specification, combined and mixed in accordance with the appropriate requirements, and placed, consolidated, and cured properly, a Portland cement concrete structure of acceptable strength and durability can be produced. Introducing reclaimed concrete aggregate into Portland cement concrete, however, requires the use of quality control and quality assurance procedures to ensure that deleterious materials that might be present in the reclaimed concrete aggregate will not adversely impact the quality of the concrete product.

1.2 Portland cement concrete manufactured using reclaimed concrete aggregate shall be limited in use to concrete pavements, cement treated base courses, sidewalks, median barriers, curbing, and other non-structural applications unless alternative applications are approved by the specifying jurisdiction.

1.3 Since reclaimed concrete aggregate is a recycled material, various state and local jurisdiction laws and regulations may be applicable. The user of this specification is cautioned to contact state and local environmental and other local regulators to determine what requirements are appropriate.

Note 1 – The engineer is cautioned that the presence of deleterious materials in aggregates used in the production of Portland cement concrete could adversely affect concrete setting time and/or strength, and could also induce expansive reactions that could result in premature deterioration of the concrete structure. As a result, strict quality control and quality assurance procedures are required to ensure that reclaimed concrete aggregate material used as coarse aggregate in the production of Portland cement concrete will not adversely affect the quality of the concrete product. Recommended approaches are outlined in AASHTO Standard Practice R 18-97.

Note 2 – The engineer is cautioned that coarse reclaimed concrete aggregate may contain air entrained concrete mortar and, therefore, may be highly absorptive and can exhibit low and highly variable specific gravity values. Utilizing highly absorptive aggregates (coarse and fine) that do not exhibit consistent specific gravity values in Portland cement concrete can adversely affect the weighing and batching process in the concrete production operation. Further discussions of this issue are presented in Appendix X1.

Note 3 – The engineer is cautioned that some reclaimed concrete aggregate materials may yield higher than expected soundness loss values when subjected to conventional sulfate soundness testing methods. Such testing methods may not be reliable for reclaimed concrete aggregate soundness testing. Further discussion of this topic is presented in Section 6.2 and Appendix X2.

Note 4 – The engineer is cautioned to ensure that reclaimed concrete source materials are not contaminated with extraneous solid waste or hazardous materials. Methods and criteria for examining and approving reclaimed concrete materials prior to use should be established by the specifying jurisdiction.

2. DEFINITIONS

2.1 The definition of concrete and concrete aggregate terms used in this specification are provided in ASTM C 125. The term "reclaimed concrete aggregate" as used in this specification shall mean coarse aggregate material derived from the crushing, processing, and classification of Portland cement concrete construction debris recovered from roadways, sidewalks, buildings, bridges, and other sources.

3. REFERENCED DOCUMENTS

3.1 AASHTO Standards:

M 43 Sizes of Coarse Aggregate for Highway Construction
M 80 Coarse Aggregate for Portland Cement Concrete
T 103 Soundness of Aggregates by Freezing and Thawing
T 260 Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials
T 299 Rapid Method to Determine the Presence of Potentially Alkali Reactive Aggregates
T 303 Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars due to Alkali-Silica Reaction
New York State Department of Transportation Test Method NY 703-08, "Standard Test Method for Resistance of Coarse Aggregate to Freezing and Thawing."
Ontario Ministry of Transportation Test Method LS 614, "Freezing and Thawing of Coarse Aggregate."
Ontario Ministry of Transportation Test Method LS 618, Micro Deval.

3.2 ASTM Standards:

C 125 Terminology Relating to Concrete and Concrete Aggregates
C 289 Potential Reactivity of Aggregates (Chemical Method)
C 295 Petrographic Examination of Aggregates for Concrete
C 342 Potential Volume Change of Cement Aggregate Combinations
C 441 Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete Due to the Alkali Aggregate Reaction
C 586 Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates
C 856 Petrographic Examination of Hardened Concrete
C 666 Resistance of Concrete to Rapid Freezing and Thawing
C 1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction

4. ORDERING INFORMATION

4.1 The purchaser or specifier shall include the following information in the purchase order or contract documents:
4.1.1 Reference to this specification and year of issue,
4.1.2 Grading to be furnished (AASHTO Size No.) (Section 5.1),
4.1.3 Soundness testing requirement (Section 6.2),
4.1.4 Class designation of aggregate (Table 1)
4.1.5 Whether the restriction on reactive materials applies (Section 6.3),
4.1.6 Additional testing requirements, and
4.1.7 Any exceptions or additions to this specification.

5. GRADING AND PROPORTIONS

5.1 Coarse reclaimed concrete aggregate shall either conform to the coarse aggregate gradation requirements prescribed in AASHTO M 43 for the size number specified in the contract documents, or shall conform to the coarse aggregate gradation requirements of the specifying jurisdiction.

Note 5 – Where coarse aggregate size numbers like 357 or 467 of AASHTO M 43 or other size numbers that exhibit a range of particle size distributions that can result in aggregate segregation are used, the aggregate should be furnished in at least two separate sizes.

5.2 If the contractor/supplier wishes to use combinations of reclaimed concrete aggregate or reclaimed concrete aggregate and other approved aggregate materials, a request shall be made to the engineer for approval. The percentage of combined materials shall be established as part of a pre-submitted blended aggregate combination. At the engineer's discretion, revised Portland cement concrete mix designs shall be required when percentages of materials change.

5.3 If reclaimed concrete aggregate is blended with other approved aggregates, this shall be accomplished by mechanical interlock blending or belt blending to ensure uniform proportioning. Other methods of blending shall be permissible if it can be demonstrated to the engineer that the alternate blending method will prevent segregation.

6. PHYSICAL PROPERTIES

6.1 Reclaimed concrete aggregate shall comply with the Los Angeles abrasion or Micro Deval test requirements for the various class designations shown in Table 1.

6.2 Reclaimed concrete aggregate soundness testing shall be required at the discretion of the engineer. Appendix X2 lists alternative soundness test methods and acceptance criteria (see Note 3 and Appendix X2).

6.3 Reclaimed concrete aggregate for use in concrete that will be subject to in-service wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are reactive with alkali components in the cement in an amount sufficient to cause excessive expansion of mortar or concrete, except that if such materials are present in injurious amounts, the coarse aggregate may be used with a Portland cement containing less than 0.6 percent alkalies calculated as sodium oxide equivalent or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. Alkali reactivity shall be testing in accordance with AASHTO T 303 when alkali silica reaction is suspected, in accordance with ASTM C 586 when alkali carbonate reaction is suspected, or in accordance with other equivalent test methods approved by the specifying jurisdiction. A listing of alternative test methods that are available is presented in Appendix X3.

6.4 Reclaimed concrete aggregate for use in concrete that will be subjected to freeze-thaw action shall not contain aggregate components that expand and result in D-cracking of the concrete. When potential D-cracking is suspected by the specifying jurisdiction, the reclaimed concrete aggregate shall be tested in accordance with ASTM C 666 or other equivalent method and shall meet the acceptance requirements of that jurisdiction.

6.5 Reclaimed concrete aggregate shall meet the flat and elongated particle requirements of the specifying jurisdiction.

6.6 Reclaimed concrete aggregate shall be saturated with water for a time period that is sufficient to saturate all particles, prior to introducing the reclaimed concrete aggregate into a Portland cement mix, by means of a water sprinkling system or another approved method. At the time of batching, the reclaimed concrete aggregate shall contain water in excess of the saturated surface dry condition. Provision shall also be made for the free drainage of excess water.

7. DELETERIOUS SUBSTANCES

7.1 Reclaimed concrete aggregate shall not contain: clay lumps and friable particles, chert, and coal and lignite or other deleterious substances that exceed the maximum allowable amounts listed in Table 1.

Table 1: Limits for Deleterious Substances and Physical Property Requirements Of Coarse Aggregate for Concrete
Maximum Allowable Percent[a]

Class Designation[b]	Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)[c]	Sum of Clay Lumps, Friable Particles and Chert (Less Than 2.40 sp gr SSD)[c]	Other Deleterious Substances[d]	Coal and Lignite	Durability Requirements[e]	Sodium Sulfate Soundness (5 cycles)[f]
A	3.0	3.0	3.0	0.3	0.5	Los Angeles	d
B	5.0	5.0	5.0	0.3	0.5	Abrasion or	d
C	5.0	8.0	8.0	0.3	0.5	Micro Deval	d

[a] The engineer may supplement the requirements of Table 1 by placing limits on the amount of deleterious substances or physical properties in accordance with local experience and practice.

[b] Aggregate conforming to the requirements for the various classes designated in Table 1 should generally be suitable for the following uses:

Typical Uses (Suggested)	Weathering Exposure	Class of Aggregate
Concrete pavements, cement treated base courses, sidewalks, median barriers, curbing, and other non-structural applications where a moderate number of popouts can be tolerated	Severe Moderate Negligible	A B C

The purchaser or specifier must indicate the class of aggregate to be furnished, as the degree of weathering exposure is not precisely defined.

[c] These limitations apply only to aggregates in which chert appears as an impurity. They are not applicable to gravels that are predominantly chert. Limitations on soundness of such aggregates must be based on service records in the environment in which they are used.

[d] Other deleterious substances include adherent fines, vegetable matter, plastics, plaster, paper, gypsum board, metals, fabrics, wood, brick, tile, glass, and bituminous materials. The percentages of these materials shall be determined in accordance with ASTM C 295 or other equivalent method approved by the specifying jurisdiction.

[e] The engineer shall require either Los Angeles abrasion testing or Micro Deval testing. The acceptance criteria shall be 50 percent maximum loss for Los Angeles abrasion testing and 13 percent maximum loss for Micro Deval testing.

[f] See Appendix X2 for recommended soundness test methods and acceptance criteria.

7.2 Reclaimed concrete aggregate shall not contain more than 1.0 percent by mass of material finer than the 75-µm (No. 200) sieve. This maximum quantity may be increased to 1.5 percent by mass if the fines are derived from the aggregate crushing process.

7.3 Reclaimed concrete aggregate when sampled and tested according to AASHTO Standard T260 shall not contain chloride ion in excess of 0.6 lbs of chloride ion per cubic yard of Portland cement concrete.

Note 6 – The engineer may select stockpiling as an approach to assist in qualitatively and quantitatively identifying the presence of deleterious materials. Stockpiling can also be used as a means to qualitatively assess the uniformity of the material. When such an approach is used, the stockpile may represent all or part of the material to be used on a project, and should be constructed in a manner that will minimize segregation and permit visual examination and representative sampling of the material.

8. METHODS OF SAMPLING AND TESTING

8.1 Sample and test the aggregates in accordance with the following methods of the American Association of State Highway and Transportation Officials, except as otherwise provided in this specification.

8.1.1 Sampling T 2.
8.1.2 Amount of Material Finer than 75-µm (No. 200) Sieve T 11.
8.1.3 Unit Weight and Voids in Aggregate T 19.
8.1.4 Grading T 27.
8.1.5 Specific Gravity and Absorption of Coarse Aggregate T 85.
8.1.6 Abrasion T 96.
8.1.7 Soundness T 103 or T 104.
8.1.8 Clay Lumps and Friable Particles T 112.
8.1.9 Lightweight Pieces in Aggregate T 113.

APPENDICES

X1. Specific Gravity and Water Absorption

X1.1 The specific gravity of reclaimed concrete aggregate from different sources can be expected to vary. Such fluctuations in specific gravity properties are undesirable in a concrete aggregate material. Since Portland cement concrete is batched on the principle of weighing the components, the effect on the volume of material measured when the specific gravity varies may be significant. These potential variations can affect the yield of the mix, the cement factor, and the engineering properties of the Portland cement concrete mixture.

X1.1.1 A technique to control the variability of specific gravity properties of reclaimed concrete aggregate is to use the source approval method. In this approach the state or other jurisdiction specifies what materials within the limits of the project are suitable for recycling into reclaimed concrete aggregate. The concrete to be recycled generally contains aggregate from one source, where little variation in specific gravity can be expected.

X1.1.2 An alternative to the source approval approach is for the engineer to monitor the physical properties of the fresh Portland cement concrete, including yield, to determine if specific gravity variations result in property changes. Standard practices of adjusting batch weights to correct yield should be followed. A ±3.0% variation in yield should require batch weight adjustments.

X1.2 Reclaimed concrete aggregate can be expected to exhibit higher and more variable water absorption properties than conventional aggregates. This is due to the presence of a highly absorptive mortar component of the original concrete material adhering to the aggregate particles.

X1.2.1 The primary effect on the quality of the Portland cement concrete manufactured using aggregate with high water absorptive properties is to draw the free water that is present in the mortar of the fresh concrete into the pore structure of the aggregate. The net effect of this process is to reduce the water in the mortar, thus resulting in an early setting of the concrete and an early loss in workability.

X1.2.2 Since the fine portion (material passing the 2.36-mm (No. 8) sieve) of reclaimed concrete aggregate will contain the predominant fraction of high absorption material in the recycled concrete aggregate, eliminating the fine portion from the source material can be utilized as a means to mitigate this problem.

X1.2.3 High absorption problems can be further mitigated by requiring that coarse reclaimed concrete aggregate be saturated with water to at least the saturated surface dry condition prior to mixing with cement and water. During this process steps must also be taken to ensure that excess water readily drains from the reclaimed concrete aggregate material. This process ensures that the internal voids in the aggregate particles are filled with water at the time of batching of the Portland cement concrete, eliminating any additional water demand.

X2. Soundness Testing of Reclaimed Concrete Aggregate

X2.1 Reclaimed concrete aggregate can be susceptible to sulfate attack when tested for soundness using sodium sulfate or magnesium sulfate solutions, resulting in higher than expected soundness loss values, (particularly when sodium sulfate solution is used in the test procedure). Sulfate solution test methods (AASHTO T 104) may be applied if local experience has shown these methods to be acceptable, however, alternative approaches may be used. When the state or other jurisdiction elects to use sodium or magnesium sulfate testing, the acceptance limits for these two tests are typically 12% and 18%, respectively.

X3. Methods for Evaluating Potential Reactivity of an Aggregate

X3.1 A number of methods for detecting potential reactivity have been proposed. However, they do not provide quantitative information on the degree of reactivity to be expected or tolerated in service. Therefore, the evaluation of the potential reactivity of an aggregate must be based upon judgment and on the interpretation of test data and examination of concrete structures containing a combination of fine and coarse aggregates and cements for use in the new work. A listing of suggested test methods follows:

X3.1.1 AASHTO T 299 – Rapid Identification of Alkali Silica Reaction Products in Concrete – This rapid test method is intended to be used in conjunction with other tests to determine the presence of alkali-silica reaction products in hardened Portland cement concrete. A solution of uranyl acetate is applied to the fractured surface of hardened Portland cement concrete. The reagent reacts with the sodium- and potassium-rich ASR gel present on the fractured surface of the concrete in such a manner that the uranium ions are absorbed by these gels. If sodium- and potassium-rich ASR gels are present on the fractured surface of the uranyl-acetate treated concrete, the areas in which the gel is concentrated will effloresce a bright yellow-green. However, both expansive and non-expansive sodium- and potassium-rich ASR gels will effloresce after exposure to a uranyl-acetate solution. This test, therefore, can only be used as an indicator that ASR may be present. A positive test then indicates that further evaluation is required. If sodium silicates are present the light will effloresce. The use of this test method may be restricted by local environmental requirements because of the use of a uranyl-acetate solution.

X3.1.2 AASHTO T 303 – Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction – In this 16-day test, hardened mortar bars consisting of Portland cement and the crushed suspect aggregate are subjected to submersion in a standard sodium hydroxide solution.

The specimens are measured both before and after the 16-day submersion in the solution. If the specimens expand more than 0.10% there is a strong probability that reactive aggregates are present.

X3.1.3 ASTM Recommended Practice C 295 – Certain materials are known to be reactive with the alkalies in cements. These include the following forms of silica: opal, chalcedony, tridymite, and cristobalite; intermediate to acid (silica-rich) volcanic glass such as is likely to occur in rhyolite, andesite, or dacite; certain constituents of some phyllites. Determination of the presence and quantities of these materials by petrographic examination is helpful in evaluating potential alkali reactivity. Some of these materials render an aggregate deleteriously reactive when present in quantities as small as 1.0 percent or even less.

X3.1.4 ASTM C 289 – This test method covers chemical determination of the potential reactivity of an aggregate with alkalis in Portland cement concrete as indicated by the amount of reaction during 24 hours at 80°C between 1N sodium hydroxide solution and aggregate that has been crushed and sieved to pass a 300-µm (No. 50) sieve and be retained on a 150-µm (No. 100) sieve. Test results from ASTM C 289, which indicate that the aggregate is non-reactive, should not be used as a final determination that the aggregate is indeed non-reactive. Many aggregates which react very slowly to cause deleterious expansion from alkali-silica reactivity have tested as non-reactive in ASTM C 289. In addition to ASTM C 289, the aggregate should be subjected to at least one of the following additional tests: ASTM C 295, ASTM C 1293, or AASHTO T 303.

X3.1.5 ASTM C 342 – This test method is intended primarily for research concerning the potential expansion of cement-aggregate combinations subjected to variations of temperature and water saturation during storage under prescribed conditions of test. Its use is mainly by those interested in research on aggregates that are found in parts of Kansas, Nebraska, Iowa, and possibly other adjoining states.

X3.1.6 ASTM C 441 – Mineral Admixtures to Prevent Alkali Silica Reaction – There are a number of mineral admixtures that when added to plastic Portland cement concrete will prevent the reaction of alkali silica reactive aggregates with free alkalis in the Portland cement. This procedure may be used to measure the effectiveness of mineral admixtures.

X3.1.7 ASTM C 586 – Potential Reactivity of Carbonate Aggregates – The reaction of the dolomite in certain carbonate rocks with alkalies in Portland cement paste has been found to be associated with deleterious expansion of concrete containing such rocks as coarse aggregate. Carbonate rock capable of such reactions possess a characteristic texture and composition. The characteristic texture is that in which large crystals of dolomite are scattered in a finer-grained matrix of calcite and clay. The characteristic composition is that in which the carbonate portion consists of substantial amounts of both dolomite and calcite, and the acid-insoluble residue contains a significant amount of clay. Except in certain areas, such rocks are of relatively infrequent occurrence and seldom make up a significant proportion of the material present in a deposit of rock being considered for use in making aggregate for concrete. This method has been successfully used in (1) research and (2) preliminary screening of aggregate sources to indicate the presence of material with a potential for deleterious expansions when used in concrete.

X3.1.8 ASTM C 666 – This test method applies freeze-thaw cycling to hardened concrete samples. The object of the test is to determine the potential of the aggregate used in the concrete to expand as a result of freeze-thaw action. This test method is widely used in the mid-western states to determine the potential of aggregates to cause D-cracking in Portland cement concrete.

X3.1.9 ASTM C 856 – Petrographic Examination of Hardened Concrete – An effective method of determining the nature of aggregate materials to react with alkali components of Portland cement to form alkali silica reaction products is to perform a petrographic analysis of hardened Portland cement concrete.

The suspect concrete material is cut with a diamond saw into slices that are called thin sections. The thin sections are then studied with a petrographic microscope to determine if a reaction has taken place. When a reaction has occurred a halo-like ring will appear around the reacting particle.