# SECTION 704—CEMENT CONCRETE

## 704.1 GENERAL—

**(a) Description.** Furnish the indicated class of cement concrete according to the requirements of Table A. Cement concrete is a mixture of portland cement, fine aggregate, coarse aggregate, water and air-entraining admixture, with or without water reducing admixture, retarding admixture, or supplementary cementitious material (SCM)

The methods of producing concrete referred to in these Specifications are defined as follows:

**1. Plant Mixed Cement Concrete.** Concrete proportioned and mixed in either a stationary, commercial, and central plant or a stationary plant located near the project. Concrete is delivered to the work site by truck, agitator truck, or mixer truck.

**2. Truck Mixed Cement Concrete.** Concrete prepared by dry batching in a proportioning plant and placing the dry ingredients in a truck mixer. Measured water is then added to the truck drum from the plant water system and the concrete is mixed in the truck at the plant. Mixing is not allowed en-route to or at the work site.

**3. Volumetric Mixed Cement Concrete.** Concrete proportioned and mixed in a truck-mounted mobile mixer. The unit is capable of proportioning concrete ingredients from self-contained bins and mixing the materials with measured water in a self-contained mixer. The concrete is mixed and discharged at the work site.

**(b) Material.**

- Cement—Section 701
- Fine Aggregate, Type A—Section 703.1
- Coarse Aggregate, Type A, maximum size AASHTO No. 467, No. 57, No. 67 or No. 8 (Stone, Gravel, or Slag)—Section 703.2
- Coarse Aggregate, Type A Lightweight, Section 703.2(a) 6
- Water—Section 720.1
- Admixtures—Section 711.3
- Supplementary Cementitious Material (SCM)—Section 724

**Table A**
**Cement Concrete Criteria**

| Class of Concrete | Use | Cement Factor(2)(4) (lbs./cu. yd.) | | Maximum Water Cement Ratio(5) (lbs./lbs.) | Minimum Mix(1,7) Design Compressive Strength (psi) | | | | 28-Day Structural Design Compressive Strength (psi) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Days | | | | |
| | | Min. | Max. | | 3 | 7 | 28(8) | 56(8) | |
| AAAP | Bridge Deck | 560 | 640 | 0.45 | — | 3,000 | 4,000 | — | 4,000 |
| AAA(3) | Other | 634 | 752 | 0.43 | — | 3,600 | 4,500 | — | 4,000 |
| AAAP LW | Bridge Deck | 600 | 730 | 0.45 | --- | 3,000 | 4,000 | --- | 4,000 |
| AA | Slip Form Paving | 587 | 752 | 0.47 | — | 3,000 | 3,750 | — | 3,500 |
| AA | Paving | 587 | 752 | 0.47 | — | 3,000 | 3,750 | — | 3,500 |
| AA | Accelerated(6) | 587 | 800 | 0.47 | — | — | 3,750 | — | 3,500 |
| AA | Structures and Misc. | 587 | 752 | 0.47 | — | 3,000 | 3,750 | — | 3,500 |
| AA LW | | 587 | 752 | 0.47 | --- | 3,000 | 3,750 | --- | 3,000 |
| ASC(9) | | 587 | 846 | 0.47 | --- | --- | 4,000 | --- | 4000 |
| A | | 564 | 752 | 0.50 | — | 2,750 | 3,300 | — | 3,000 |
| C | | 394 | 658 | 0.66 | — | 1,500 | 2,000 | — | 2,000 |
| HES | | 752 | 846 | 0.40 | 3,000 | — | 3,750 | — | 3,500 |

(1) Test Procedures: Slump—AASHTO T 119; Compressive Strength—PTM No. 604, or Maturity Meter Method—PTM No. 640. The upper age limit and lower age limit are defined by the values listed for 7-day and 28-day compressive strength.
(2) For use in miscellaneous or structural concrete, if the Fineness Modulus (FM) is between 2.3 and 2.5, increase the minimum cement factor for the class of concrete 47 pounds per cubic yard. This requirement may be waived after adequate strength data is available and analyzed according to the mix-design section in ACI 211.
(3) AAA concrete is not allowed to be used for new bridge decks.
(4) For exception, see Section 704.1(c). Cement factor may be increased to a maximum of 690 pounds per cubic yard with the approval of the DME/DMM.
(5) If a portion of the cement is replaced by SCM, use a water to cement plus SCM ratio by weight. The minimum water cement ratio for AAAP is 0.40 pounds per pounds.
(6) For accelerated cement concrete, submit mix design, as specified, Section 704.1(c), having a minimum target value compressive strength of 1,500 pounds per square inch at 7 hours if tested according to PTM No. 604. (1,500 pounds per square inch at 7 hours is for mix design acceptance only). The required compressive strength for opening to traffic is specified in Section 501.3(q).
(7) Trial Mix Designs for Class AAAP, AAAP LW, ASC and all concrete paving mixtures are required to meet a minimum 28-day compressive strength overdesign requirement of 28-day Minimum Mix Design Compressive Strength plus 500 pounds per square inch.
(8) DME/DMM may accept mix designs based on the 56-day strength based on qualification testing.
(9) For accelerated structural cement concrete, submit mix design, as specified in Section 704.1(c), having a minimum target value compressive strength of 3,500 pounds per square inch at 24 hours and 3,000 pounds per square inch to open to traffic when tested according to PTM No. 604.

**1. Density of Material.** Except for admixtures, use the following material densities (unit weights) if proportioning cement concrete:

| **Type of Material** | **Density** |
|---|---|
| Water | 62.4 pounds per cubic foot |
| Cement | 94.0 pounds per cubic foot |
| Fine Aggregate | Based on bulk specific gravity as specified in Section 704.1(b)2 |
| Coarse Aggregate | |
| Stone or Gravel | Based on bulk specific gravity as specified in Section 704.1(b)2 |
| Slag | Based on field tests as specified in Section 704.1(b)2 |
| Lightweight | Based on bulk specific gravity as specified in Section 704.1(b)2 |
| SCM | Based on the LTS Tests |

**2. Specific Gravity of Aggregates.** For fine and coarse aggregates, use the bulk specific gravity (saturated, surface-dry basis) listed in Bulletin 14.

For lightweight aggregate use the bulk specific gravity value (saturated surface-dry basis) listed in Bulletin 14, or the SSD gravity provided by the lightweight aggregate if purchased. As an alternative, the producer may run the SSD test and absorption with District Materials unit present.

If slag is used, test at the site to determine its loose-struck unit weight, solid volume per cubic yard, and bulk specific gravity factor (saturated surface-dry basis). Establish the concrete proportions based on the bulk specific gravity factor determined by the test. Check the unit weight of the slag daily to maintain the established solid-volume proportions.

**3. Adjustment of Weight of Free Water.** Adjust the batch weight of the aggregate to compensate for the free water on the aggregate. Base this adjustment on tests of representative samples taken from aggregate stockpiles.

**4. Batching.** For plant and truck mixed cement concrete, batch by weight. For volumetric mixed cement concrete, batch by volume.

**(c) Design Basis.**

**1. General.** Compute and prepare concrete mix designs according to ACI 211. For AAAP, AA Paving, and AA Slip Form Paving mix designs, determine the aggregate gradation for the mix design according to PTM No. 528. This does not apply to AAAP with #8's. Base concrete mix designs on the materials to be used in the work.

Overdesign strengths will be a minimum of 1,000 pounds per square inch except for AAAP, AAAP LW, AA Paving, and ASC which will be 500 pounds per square inch.

Make trial mixtures for each class of concrete and mold and cure test specimens. If the requirements of Table A cannot be achieved, furnish other acceptable materials or make necessary changes in the mixing procedure to conform to the specified requirements. Notify the DME/DMM at least 3 days in advance of preparing trial mixtures.

At the start of construction, mix a full-sized batch using the type of mixer and the mixing procedure planned for the project. Use this batch to provide the basis for final adjustment of the accepted design.

Mixture qualifications testing of Anti-Washout concrete according to PTM No. 641 to determine the maximum loss and required anti-washout admixture dosage may be conducted at an accredited lab or by the ready-mix producer with oversight from a technical representative from the admixture supplier. Trial batching for determination and verification of other design requirements must be performed by the ready-mix producer as specified in Section 704.1(c). Document the test results from the mixture qualification testing on the mix design before submitting for Department review.

**2. Cement Factor.** For all classes of concrete, use the minimum cement factor (cement, blended cement, or cement and SCM(s) combined) specified in Table A, except as follows:

Portland cement may be replaced with SCM(s) provided the maximum replacement by mass percentages in Table G, Prevention Level Z are not exceeded. The maximum limit of the cement factor may be waived if SCM(s) is/are added to the mix provided the portland cement portion does not exceed the maximum cement factor specified.

For AAAP and AAAP LW cement concrete, replace Type I or Type II portland cement with SCM (silica fume, flyash or slag cement) weighing as much as or more than the portland cement replaced. The percentages of SCM applicable to AAAP concrete are as shown below. Limit SCM to not more than two of the three SCMs listed below in one mix design as long as one of the SCM supplements meets the minimum percentage of replacement.

Cement factor must include at least one of the following as a replacement for a portion of the cement:

| | |
|---|---|
| Slag Cement (Grade 100 or higher) | 25% (min) |
| Flyash (Type C or Type F) | 15% (min) |
| Silica Fume | 5%-10% |

**3. Air Content.** Design cement concrete to have an air content of 6.0% in the plastic state. Design AAAP and AA(pave) concrete mixes to have an air content of 7.0% in the plastic state. Obtain the air content through the addition of a solution of an air-entraining admixture as specified in Section 704.1(e)4. Use the quantity of air-entraining admixture necessary to maintain the plastic concrete air content, determined according to AASHTO T 152 (DO NOT APPLY AN AGGREGATE CORRECTION FACTOR) for stone and gravel and AASHTO T 196 (DO NOT APPLY AN AGGREGATE CORRECTION FACTOR for slag or lightweight coarse aggregate, within a tolerance of ± 1.5% during the work. The plastic concrete air content includes entrapped and entrained air.

If the hardened concrete exhibits deficiencies or the Representative suspects the hardened concrete to have deficiencies, and, if directed, determine the percent of entrained air in the hardened concrete according to PTM No. 623. Voids greater than 0.2 mils and less than 40 mils in their smallest dimension are considered entrained air. Voids 40 mils or more in diameter are considered entrapped air. The entrained air in the hardened concrete must be between 3.5% and 7.5%, inclusive. For AAAP and AA(pave) mixes, the entrained air in the hardened concrete must be between 4.5% and 8.5% inclusive.

**4. Mix Design Acceptance.** Submit a copy of each completed mix design to the Representative before its use in the work. The Department reserves the right to review all design through plant production before its use in Department work at no additional cost to the Department. The concrete design submitted for review is required to comply with the specified concrete class requirements, supported by slump, air content, and compressive strength test data according to ACI 211.

The Department will accept concrete designs based on the 7-day strength tests (Class High Early Strength (HES) may be accepted based on 3-day strength tests); however, conduct 28-day tests to show the potential of the design mix. The Department may also accept designs based on the 28-day tests.

Design AAAP cement concrete mixtures to achieve slow strength gain. Adjust component proportions with an objective of attaining a 28-day to 7-day compressive strength ratio during mix design greater than or equal to 1.20. A PennDOT inspector will witness the compressive strength tests. The 1.20 ratio is for mix design purposes only and not to be utilized as an acceptance factor during production. In no case will the Department accept any mixture during design which fails to meet a minimum 28-day to 7-day compressive strength ratio of 1.20.

Additional criteria for mix design acceptance of AAAP concrete are as follows:

The producer is required to complete the following tests before mix design submittal and approval.

- **Permeability** – Design the concrete mixture to meet a target permeability of 2,000 coulombs after a 56-day curing period according to with AASHTO T 277 or AASHTO T 358, not to exceed 2,800 coulombs.
- **Shrinkage (Microstrain)** – The 28-day shrinkage according to ASTM C157 is not to exceed 500 microstrain unless approved up to 550 microstrains by the DME/DMM. Wet cure specimens in the lab for 14 days before beginning the 28-day shrinkage testing (42 total days).

If permeability and shrinkage testing have been met for AAAP with #57's, these tests are not required for AAAP with #8's, provided the aggregates are from the same source.

A higher-class concrete may be used in place of an indicated lower-class concrete if the higher-class concrete conforms to all the requirements of the indicated lower class, and if approved by the Department.

**5. Lightweight Cement Concrete (AAAP LW and AA LW).** Compute and prepare concrete mix designs according to ACI 211.2. Design lightweight cement concrete to have a range of Equilibrium Density of 110 pounds per cubic feet to 117 pounds per cubic feet with a target of 115 pounds per cubic feet, when tested according to ASTM C567

Supply the following information to the District Materials Unit at least two weeks before conducting trial mixes:

- Approximate absolute volume of coarse aggregate (cubic feet)
- Suggested coarse aggregate factor (CAF) (pounds per cubic yard)
- Oven-dry loose weight of coarse aggregate (pounds per cubic feet)
- Specific gravity factor
- Percent absorption

Store and use lightweight aggregates in a stable, uniform, saturated condition to ensure the aggregate, if batched, is at a moisture greater than saturated surface dry (SSD). Use the same source of aggregates and mix design throughout the entire project.

Plastic density can be used for field acceptance once a correlation between plastic density and equilibrium density is established. Equilibrium density as measured according to ASTM C567.

Entrained air content can be determined by the unit weight method according to ASTM C138. Once established, a correlation between air content as tested according to ASTM C 173 and the unit weight method can be made.

**6. Sulfate Resistance Concrete**. Design sulfate resistant concrete according to ACI 201.2.

**(d) Testing and Acceptance.**

**1. QC Plan.** Prepare a QC Plan as specified in Section 106.03 and submit it for review before the start of the project and at least annually thereafter. Include in the QC Plan testing frequencies and action points to initiate corrective measures. Do not start work until the Department has reviewed the QC Plan. Furnish a copy of the QC Plan to be maintained in the Department's project field office.

**1.a Field Operation QC Plan.** Prepare a field operation QC Plan for the Representative’s review, as outlined on Form CS-704, to evaluate concrete field operation. Submit the field operation QC Plan at the Pre-construction conference or at least 2 weeks before the first concrete pour. Describe the construction equipment, personnel, and methods necessary to construct and test concrete courses for all structural elements. Include testing frequencies and action points to initiate corrective measures. Do not establish action points at either the upper or lower specification limits.

**2. Concrete Technician.** Provide, and assign to the work, a concrete technician properly instructed and trained to develop the concrete design, to control the quality and gradation of aggregates used, to perform required concrete tests, and to control the operations and concrete deliveries so the completed mixture conforms to the specifications at the point of placement.

The Department's concrete plant Inspector will not allow concrete considered unacceptable to be shipped to the project. The Inspector will not assume, by act or by word, any responsibility for batch control adjustments; calculations; or for setting of dials, gauges, scales, or meters. Failure of the Inspector to reject unacceptable concrete will not relieve the Contractor's obligation to provide concrete conforming to the specifications.

**2.a Concrete Field Testing Technician.** Provide, and assign to the work during placement of material, a PennDOT certified field testing technician, meeting the requirements according to Publication 536, to perform the required acceptance testing. The technician must carry a valid PennDOT certification card during placement of material.

**3. Testing Facilities and Equipment.** Provide sufficient thermometers, air meters conforming to AASHTO T 196 and T 152, and slump cones conforming to AASHTO T 119 for each separate project operation as needed. In the presence of the Inspector, calibrate all air meters a maximum 2 weeks before beginning concrete placement. Recalibrate all air meters, in the presence of the Inspector, every 2 weeks during concrete placement. Have back-up equipment available to ensure no tests are missed. Provide sufficient 6-inch by 12-inch cylinder molds and tight-fitting domed caps (PTM No. 611) for QC, acceptance, verification, and QA samples. Provide sufficient incidental equipment such as wheelbarrows, shovels, and scoops as needed.

Provide acceptable means to conduct compressive strength testing using a compression machine and capping device conforming to PTM No. 604. Provide a curing tank conforming to PTM No. 611. Provide curing boxes, or other acceptable equipment, conforming to PTM No. 611 and capable of maintaining the air temperature immediately adjacent to the field-cured cylinders in the range of 60F to 80F for the first 24 ± 2 hours. Provide sufficient high-low thermometers or other temperature recording devices to monitor the temperatures next to the test cylinders. If required, cap cylinders at the testing site under the Representative’s supervision.

If using the maturity method to estimate concrete compressive strength, provide one or more maturity meters and a sufficient number of temperature sensors conforming to PTM No. 640. Note: Casting concrete cylinders according to PTM 611 is recommended in case maturity meter equipment malfunctions.

Maintain all equipment used for testing in an operable condition. Using an independent agency acceptable to the Department, calibrate scales, balances, and the compression machine at least once per year. Recalibrate the compression machine whenever it is relocated. Maintain accurate records of calibration. If the compression machine is out of tolerance or malfunctions, return it to working order within 24 hours or supply a back-up machine until the problem is corrected.

Provide the necessary facilities for inspection, including a plant office as specified in Section 714.5(a), with the exception of a minimum floor space of 120 square feet.

**4. QC Testing.** Perform QC testing according to the reviewed QC Plan and as follows:

**4.a QC Sampling and Testing of Plastic Concrete.** Select an appropriate slump target value and range that will provide a workable mix for the construction element. The Contractor's technician must have a copy of the Department reviewed QC Plan in their possession during testing and must be aware of the target slump for the structural element being placed. Do not exceed the following slump upper limits:

| **Type of Mix** | **Slump Upper Limit** |
|---|---|
| without water reducing admixtures | 5 inches |
| with water reducing admixtures | 6 1/2 inches |
| with high range water reducing admixtures (superplasticizers) | 8 inches |
| mixes specified in Section 704.1(h) (except tremie concrete as specified in Section 1001.2(j)) | 2 1/2 inches |
| AAAP (regardless of admixtures used) | 5 1/2 inches |
| AAAP LW (regardless of admixtures used) | 6 inches |

Perform plastic concrete slump, air, density (for AAAP LW and AA LW) and temperature tests on the first three consecutive trucks at the beginning of concrete placement operations or after a significant stoppage such as plant or equipment breakdown to determine if material control has been established. Material control is established when all test results of concrete slump, air, and temperature for three consecutive trucks are determined to be within the established action points. Obtain samples of fresh concrete according to PTM No. 601. Perform slump tests according to AASHTO T 119, air content tests according to AASHTO T 152 (DO NOT APPLY AN AGGREGATE CORRECTION FACTOR) or T 196 (DO NOT APPLY AN AGGREGATE CORRECTION FACTOR) (AASHTO T196 for AAAP LW and AA LW), temperature tests according to ASTM C1064, and density testing according to AASHTO T 121(for AAAP LW and AA LW) Report test data to the concrete technician promptly in order to facilitate necessary changes. Continue testing consecutive trucks until material control is established. Once material control is established, the frequency of testing may be reduced to a minimum of one test per 50 cubic yards. Select concrete batches for sampling according to the reviewed QC Plan or as directed by the Inspector. Notify the Inspector if sampling and QC testing are to be performed. The Inspector will witness the sampling and QC testing. If a QC test fails to conform to the specified requirements or exceeds the upper or lower action points included in the reviewed QC Plan, increase the testing frequency to every truck until material control has been reestablished.

Maintain the cement concrete consistency within 1 1/2 inches of the selected target slump value (target range). If the upper slump limit is exceeded on any slump test, the Contractor's technician shall reject the cement concrete. If any slump test result falls outside the target range and has not exceeded the upper limit, immediately perform the air content and temperature tests. If the air content and concrete temperature is within the specified limits, the Contractor may incorporate the material into the work provided a full set of quality control and acceptance cylinders are molded in addition to the cylinders made for the originally selected PTM No. 1 sample location, for compressive strength testing according to PTM No. 611 and PTM No. 604. If one or more truckloads of cement concrete exceeds the slump target range, make additional quality control and acceptance cylinders from each truck. Use the lowest compressive strength cylinders for acceptance of the lot.

Do not incorporate concrete into the work that does not conform to the specified requirements.

**4.b QC Compressive Strength Test Cylinders.** From the same sample of concrete selected for acceptance testing as specified in Section 704.1(d)5, mold a sufficient number of concrete QC cylinders to be tested for 3-day or 7-day compressive strength, 14-day compressive strength (AAAP), 28-day compressive strength, form removal strength, and loading strengths, as specified.

If using the maturity method to estimate concrete compressive strength, mold two or more cylindrical specimens for temperature history recording and embed a temperature sensor at the vertical and horizontal center of the cylindrical specimen and activate the maturity meter or data acquisition equipment to record the temperature history for the 3-day, 7-day, 14-day (AAAP), 28-day, and, as required, 56-day compressive strength analysis.

Field cure cylinders according to PTM No. 611, Section 11.2, for the specified curing period. After concrete curing is discontinued, QC cylinders may be relocated to a preapproved, acceptable, secure area, to protect them from damage. Provide maintenance and security for the area at no additional cost to the Department. The secure area must be easily accessible for inspection at all times. Continue to provide the same field cure and protection from the elements on all surfaces of the cylinders as that provided for the in-place concrete the cylinders represent until the cylinders are tested for compressive strength. Remove cylinders from molds at the same time formwork is removed.

Perform QC testing for 3-day or 7-day compressive strength, 14-day compressive strength (AAAP), 28-day compressive strength, and form removal and loading strengths according to PTM No. 611. If using the maturity method to estimate concrete compressive strength, perform QC testing using the procedure to estimate in place strength according to PTM No. 640. Do not use the maturity method for determining acceptance strength, typically at 28 days. Notify the Inspector when QC testing is to be performed. The Inspector will witness the QC testing.

Unless otherwise directed, use QC test results for 3-day or 7-day compressive strength and form removal and loading compressive strength to determine whether to place additional concrete in areas that will be impacted by the lot of concrete represented by the QC cylinders. Acceptable QC compressive strength test results do not relieve the Contractor's responsibility for providing concrete conforming to the 28-day minimum mix design compressive strength acceptance requirements as specified in Section 704.1(d)5.

For AAAP and Prevention Level Z mixes, in addition to the samples required above, mold two concrete cylinders and cure them under QC conditions for 56 days. After 56 days test the two cylinders for compressive strength and report the compressive strengths.

**4.b.1 3-Day or 7-Day or 14-Day (AAAP) QC Compressive Strength.** If the average 3-day (HES concrete only) or average 7-day QC compressive strength test result is greater than or equal to the minimum mix design compressive strength requirement specified in Table A, the Contractor may discontinue the field cure on the lot of concrete represented by the QC cylinders unless otherwise directed. If the average 14-day (AAAP) QC compressive strength test result is greater than or equal to 3,500 pounds per square inch, the Contractor may discontinue the field cure on the lot of concrete represented by the QC cylinders, unless otherwise directed.

If the average 3-day (HES concrete only) or average 7-day QC compressive strength test result is less than the minimum mix design compressive strength requirement specified in Table A, continue the field cure on the lot of concrete represented by the QC cylinders until the specified 28-day minimum mix design compressive strength is obtained, or for a maximum of 28 days. If the average14-day (AAAP) QC compressive strength test result is less than 3,500 pounds per square inch, continue the field cure on the lot of concrete represented by the QC cylinders, until the specified 28-day minimum mix design compressive strength is obtained, or for a maximum of 28 days.

**4.b.2 28-Day QC Compressive Strength.** If the average 28-day QC compressive strength test result is greater than or equal to the 28-day minimum mix design compressive strength specified in Table A, acceptance of the concrete lot will be based on the compressive strength testing of acceptance cylinders as specified in Section 704.1(d)5.

If the average 28-day QC compressive strength test result is less than the 28-day minimum mix design compressive strength specified in Table A, but greater than or equal to the 28-day structural design compressive strength specified in Table A, acceptance of the concrete lot will be based on the compressive strength testing of acceptance cylinders as specified in Section 704.1(d)5, and as follows:

- Perform an investigation of procedures for material sampling, testing, and concrete cylinder molding and curing, and evaluate the concrete mix design and specification compliance to determine possible causes for the QC test result not meeting the specified minimum mix design compressive strength.

- Implement corrective actions as required.

- Submit an investigation report to the District Executive within 10 working days for review and approval.

If the average 28-day QC compressive strength test result is less than the 28-day structural design compressive strength specified in Table A, acceptance of the concrete lot will be based on compressive strength testing of cores obtained from the lot of concrete represented by the QC cylinders as specified in Section 110.10(d).

**5. Acceptance Testing**. Determine the lot size, or portion thereof for partial lots, for material acceptance according to Table B. Establish new lots daily for each class of concrete. Lots must be specific to a particular structural element, except for incidental concrete items. The Contractor may use a lot combining structural elements if allowed in writing before concrete placement and if the following conditions are met:

- The total volume is 100 cubic yards or less.
- The combined structural elements are constructed using the same mix design concrete.
- The combined structural elements are cured using identical curing methods and conditions.

Cylinders (and cores if necessary) for this lot will represent all the combined elements.

**TABLE B**
**Lot Size for Concrete Acceptance**

| Construction Area | Lot Size |
|---|---|
| Structural Concrete | 100 cu. yd. |
| Pavement Concrete | 500 cu. yd. |
| Pavement Patching Concrete | 200 cu. yd. |
| Incidental Concrete | 100 cu. yd. |

The Representative will select sample locations for acceptance testing according to PTM No. 1 (n=1). Perform sampling and testing for acceptance in the presence of the Representative. Obtain samples of fresh concrete at the point of placement according to PTM No. 601. Perform concrete temperature tests. Perform air content tests according to AASHTO T 196 or T 152. Reject all concrete not conforming to the specification requirements at the point of placement.

If the results of plastic concrete testing conform to the specification requirements, mold a sufficient number of acceptance cylinders according to PTM No. 611 from the same sample of concrete taken for slump, air content, and temperature determination. Standard cure acceptance cylinders according to PTM No. 611, Section 11.1, for 28 days and 56 days (AAAP and Prevention Level Z) at an acceptable location. Conduct 28-day and 56-day (AAAP and Prevention Level Z mixtures only) compressive strength testing of two acceptance cylinders according to PTM No. 604. If for any reason two testable acceptance cylinders are not available for compressive strength testing, obtain two cores of the representative concrete within 3 working days as directed, and at no additional cost to the Department. Conduct 28-day compressive strength testing of the cores according to PTM No. 604.

The Department will accept the lot of concrete if the average 28-day acceptance cylinder compressive strength test result is greater than or equal to the 28-day minimum mix design compressive strength specified in Table A and if the average 28-day QC compressive strength requirements specified in Section 704.1(d)4.b have been met.

If the average 28-day acceptance cylinder compressive strength test result is less than the 28-day minimum mix design compressive strength specified in Table A, acceptance of the concrete lot will be based on the procedures as specified in Section 110.10.

**6. Verification Testing.** The Representative will perform verification testing on the initial acceptance sample for each type of concrete specified in Table B and a minimum of one verification test for every ten acceptance samples thereafter. Verification testing will consist of testing for temperature, air content, and compressive strength. Verification tests will be performed on concrete from the same sample used for acceptance testing.

The Representative will obtain the temperature of the sample concurrently with the acceptance sample. Immediately after an acceptable air content test result for acceptance is obtained, the Representative will test the sample for air content according to AASHTO T 196 or T 152 using the same air meter.

The Representative will mold two verification cylinders according to PTM No. 611. Standard cure the verification cylinders along with the acceptance cylinders according to PTM No. 611, Section 11.1, for 28 days. Conduct 28-day compressive strength testing of the verification cylinders according to PTM No. 604 in the presence of the Representative. Conduct the testing at the same time the acceptance cylinders are tested and using the same equipment.

Verification test results will be compared to the associated acceptance test results and will not be used to determine acceptance of the lot. If there is a difference in test results of more than 5F for temperature, 1.0% for air content, or 500 pounds per square inch for compressive strength, the Representative will immediately review the testing procedures, equipment, and personnel used in the acceptance testing and implement corrective measures to ensure the tests are performed within the prescribed tolerances. The Representative will record the acceptance test results, the verification test results and applicable corrective measures in the Concrete Inspector's Daily Record Book, Form CS-472.

**7. QA Testing.** The CMD QA personnel will obtain QA samples as part of the operation review process according to the QA Manual, Publication 25.

QA personnel will select concrete to be sampled. Obtain samples of fresh concrete at the point of placement according to PTM No. 601. Perform concrete temperature tests adjacent to those conducted by QA personnel. Perform air content tests according to AASHTO T 196 or T 152 with the air meter used for acceptance testing and the backup air meter. Immediately report all test results to the QA personnel. Reject all concrete not conforming to the specification requirements at the point of placement.

QA personnel will immediately perform an independent assurance evaluation of the temperature and air content test results. If the difference in test results is more than 5F for temperature or 1.0% for air content, the Representative will immediately review the testing procedures, equipment, and personnel used in the acceptance testing and implement corrective measures to ensure the tests are performed within the prescribed tolerances.

Mold five QA cylinders from the selected sample according to PTM No. 611. Field cure the QA cylinders according to PTM No. 611, Section 11.2, for the specified curing period for the structural element the cylinders represent. After curing of the in-place concrete is discontinued, QA cylinders may be relocated to a pre-approved, acceptable, secure area, to protect them from damage. Provide maintenance and security for the area at no additional cost to the Department. The secure area must be easily accessible for inspection at all times. Continue to provide the same field cure and protection from the elements on all surfaces of the cylinders as that provided for the in-place concrete the cylinders represent until the cylinders are tested for 28-day compressive strength.

Conduct 28-day compressive strength testing on two QA cylinders according to PTM No. 604 using the same equipment used for acceptance and verification testing.

The Representative will forward the remaining three QA cylinders to the LTS for 28-day compressive strength testing according to PTM No. 604 and hardened air content testing according to PTM No. 623. Furnish packaging material and package cylinders under the direction and supervision of the Representative. Place the cylinders in individual containers cushioned with suitable material to prevent damage during shipment. The total weight of each container, cylinder and cushioning material must not exceed 50 pounds.

QA personnel will perform an independent assurance evaluation of the 28-day compressive strength test results. If the difference between the test results of the cylinders tested at the project site and the cylinders tested at the LTS is more than 500 pounds per square inch, the Representative will immediately review the testing procedures, equipment, and personnel used in the acceptance testing and implement corrective measures to ensure the tests are performed within the prescribed tolerances.

**(e) Measurement of Material.**

**1. Cement.** AASHTO M 157 and as follows:

For plant and truck mixed concrete, measure by weight. The Contractor may measure the weight of the cement separately in an enclosed compartment in the aggregate hopper. The Contractor may measure the weight of the cement and discharge it simultaneously with the aggregates, except as specified in Section 106.05(c).

For volumetric mixed concrete, measure by volume.

**2. Aggregates.** AASHTO M 157 and as follows:

For plant or truck mixed concrete, measure by weight unless otherwise allowed. Base measurements on the material weight-volume relationship, as specified in Section 704.1(b)1.

For volumetric mixed concrete, measure by volume.

**3. Water.** AASHTO M 157 except as follows:

Use water-measuring systems capable of discharging the total quantity of measured water into the plant or truck mixer drum in a time not greater than one-fourth of the specified mixing time. For truck mixed concrete, do not add water from the truck water system. Add water only from the plant water measuring system.

**4. Admixtures.** Incorporate the air-entraining admixture solution into the batch with the mixing water using a suitable visual measuring device. If another type of admixture is used with an air-entraining admixture, add it in solution to another portion of the mix water, as directed, by an additional suitable visual measuring device, except high range water reducing and anti-washout admixtures will be added according to the manufacturer's recommendations.

Equip the measuring device with interlocks to prevent discharging during the charge cycle and to prevent charging during the discharging cycle. Provide a means to calibrate the measuring device to within ±3%.

Dispense the air-entraining admixture solution into the batch from a bulk supply tank. For paving, and if directed, provide a bulk supply tank containing sufficient solution for the entire day's concreting operations.

On the dispensing system, provide device(s) capable of detecting and indicating the presence or absence of admixture flow. Agitate admixtures, as required, to insure consistency of the solution.

**5. SCM.** If the use of SCM is allowed by the specification, add separately and measure cumulatively as specified in Section 704.1(e)1.

**(f) Mixing Conditions.**

**1. During Cool and Cold Weather.** If concrete is to be placed at air temperatures below 40F, or if the local weather bureau forecasts air temperatures to descend to 40F or lower at any time during the 24-hour period following concrete placement, use an acceptable method to ensure the aggregate is free of frozen lumps and at a temperature of not less than 40F or more than 100F at the time of charging into the mixer. Heat mixing water, if necessary, but do not exceed 150F. Do not allow water with a temperature above 90F to come in contact with the cement until the cement has been mixed with the aggregates.

**2. During Hot Weather.** In hot weather, cool the aggregates and the mixing water as necessary to maintain the concrete temperature from 50F to 90F at the time of placement. For bridge deck concrete placement, maintain the concrete temperature from 50F to 80F at the time of placement. For accelerated concrete placement, maintain the concrete temperature from 50F to 100F at the time of placement.

**3. Retarding Admixtures.** The Contractor may use retarding admixtures, or may be directed to use retarding admixtures, if any of the following conditions are anticipated:

- rapid drying of the concrete as a result of low humidity
- high winds
- high air temperatures

Introduce the retarder into the concrete mixture as specified in Section 704.1(e)4. Adjust the proportions of the design as necessary but do not use the retarder to replace any portion of the specified volume of cement.

Use a retarder available in sufficient quantities to provide the required degree of retardation under the prevailing weather conditions at the time of concrete placement.

**(g) Mix Designs Using Potentially Reactive Aggregate.**

**1. Definition of Terms.**

**1.a Alkalis.** Oxides of sodium and potassium generally derived from Portland cement, but may also be available to concrete from other sources such as; admixtures, de-icing salts, and, in rare instances, aggregates. Alkalis are calculated according to AASHTO M 85.

**1.b SCM.** A siliceous or siliceous and aluminous material that possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. The term "SCM," includes flyash, slag cement, silica fume, and metakaolin.

1.c **Lithium Nitrate Admixtures.** A lithium nitrate admixture as listed in Bulletin 15.

**1.d Alkali-Aggregate Reaction.** A chemical reaction in concrete between alkalis and certain constituents of some aggregates. The products of this reaction, under certain conditions, may cause deleterious expansion within the concrete.

**1.e Alkali-Silica Reaction.** An alkali-aggregate reaction involving certain siliceous aggregates and some calcareous aggregates containing certain forms of silica.(1)

Note (1)—Siliceous substances known to react with alkalis are as follows: opal; chalcedony as a constituent of chert in carbonate rock or sand and gravel particles; tridymite and cristobalite, which are high temperature forms of silica found in andesite or rhyolite; acid glasses containing more than 65% silica; or intermediate glasses containing between 55% and 65% silica. Other siliceous substances that are potentially reactive with alkalis are strained quartz as a constituent of granite or granite gneiss and clay minerals as a constituent of graywackes, argillites, phyllites, and siltstones.

**1.e.1. Determining Aggregate Reactivity.**

**1.e.1.a. Field Performance History.** Field performance history according to AASHTO R 80, Section 6.1 of an aggregate may be used to establish the potential to contribute to deleterious ASR with the approval of the DME/DMM.

**1.e.1.b Petrographic Examination.** Petrography may be used to classify an aggregate as potentially reactive, but expansion testing is required to determine the extent of potential reactivity and the appropriate level of prevention.

**1.e.1.c. Expansion Testing.** Aggregates will be tested according to ASTM C1293 or AASHTO T 303 and listed in Bulletin 14. ASTM C1293 test results will be used to determine the reactivity level of an aggregate. Unless it is a new source, the AASTHO T 303 results will be used until ASTM C1293 testing is completed by the Department. The reactivity class of the aggregate will be used to determine the required level of prevention. If using aggregates with different reactivity levels, the highest reactivity level will be used for mitigation. If the expansion result for a coarse aggregate size is not listed in Bulletin 14, use of the expansion result from another coarse aggregate size listed in Bulletin 14 from the same source will be acceptable.

Use aggregates deemed potentially reactive only with cements or cement-SCM combinations as specified in Section 704.1(g)3. If one or both of the aggregates (coarse or fine) used in a mix is reactive, mitigation is required as specified in Section 704.1(g)3. This requirement applies to all concrete used in paving or permanent structures on Department projects, including latex modified overlays and precast and prestress concrete products.

For new Type A aggregate sources which do not have LTS expansion listed, LTS will initially perform AASHTO T 303 to determine the reactivity class. Any new source with an expansion that indicates the aggregate is non-reactive (R0) will initially be listed with an expansion of 0.11% (R1) requiring ASR mitigation until ASTM C1293 testing by LTS is completed.

Sources will be tested on a 5-year cycle according to ASTM C1293. Testing will be performed by LTS. If the new test results change the mitigation level of the aggregates, mix designs must be started immediately and all designs must be completed within 90 days of receiving test results.

**2. Selecting Preventive Measures for Alkali-Silica Reaction.**

**2.a Using the Concrete Prism Test (ASTM C1293) to Evaluate Preventive Measures.**

**2.a.1 Mixture Qualification.** The concrete prism test may be used to evaluate the efficacy of SCMs or blended cements or both used with volumetric SCM replacements less than those specified in Section 704.1(g)2.c as a prescriptive remediation method and for all mixtures utilizing remediation with either metakaolin or a lithium nitrate admixture. If lithium nitrate admixtures are used, the admixture must be added to the mix water and necessary corrections made to account for the water in the admixture. If the expansion of concrete prisms is less than 0.04 percent after 2 years, the preventive measure will be deemed effective with the reactive aggregate(s).

For mixtures qualified using the preventive measure, substitutions of the cement (type for type), or SCM(s), type for type will be allowed provided the alkali limits as specified in Section 704.1(g)3 are not exceeded. Substitution of aggregates using the preventive measure is prohibited.

**2.b Steps for Selecting Preventive Measures for Alkali Silica Reaction.**

**2.b.1** Determine the level of prevention by considering the reactivity class of the aggregate(s), classification of the structure type, and the associated risk level.

**2.b.1.a Aggregate Reactivity.** The degree of alkali silica reactivity of an aggregate will be determined as specified in Section 704.1(g).1.d.1.c and as indicated in Table C.

**Table C**
**Classification of Aggregate Reactivity**

| Aggregate Reactivity Class | Description of Aggregate Reactivity | 1-Year Expansion in ASTM C1293 (percent) | 14-d Expansion in AASHTO T 303 (percent) |
|---|---|---|---|
| R0 | Non-reactive | ≤ 0.04 | ≤ 0.10 |
| R1 | Moderately reactive | >0.04 to ≤ 0.12 | >0.10 to ≤ 0.30 |
| R2 | Highly Reactive | >0.12 to ≤0.24 | >0.30 to ≤0.45 |
| R3 | Very Highly Reactive | >0.24 | >0.45 |

**2.b.1.b Risk of ASR.** Determine the level of ASR risk occurring in a structure by considering the aggregate reactivity class in Table D.

**Table D**
**Level of ASR Risk**

| **Aggregate Reactivity Class** | R0 | R1 | R2 | R3 |
|---|---|---|---|---|
| **Level of ASR Risk** | Risk Level 1 | Risk Level 2 | Risk Level 3 | Risk Level 4 |

**2.b.1.c Level of Prevention.** The level of prevention is determined from Table E by determining the risk of ASR from Table D together with the class of structure from Table F.

**Table E**
**Determining the Level of Prevention**

| Level of ASR Risk | Classification of Structure | | |
|---|---|---|---|
| | S1 | S2 | S3 |
| Risk Level 1 | V | V | V |
| Risk Level 2 | V | W | X |
| Risk Level 3 | W | X | Y |
| Risk Level 4 | X | Y | Z |

**Table F**
**Structure Classification**

| Structure Class | Consequences | Acceptability of ASR | Structure/Asset Type | Sections |
|---|---|---|---|---|
| S1 | Safety and future maintenance consequences small or negligible | Some deterioration from ASR may be tolerated | Temporary structures. Inside buildings. Structures or assets that will never be exposed to water | 620, 621, 624, 627, 628 643, 644, 859, 874, 930, 932, 934, 952, 953, and 1005 |
| S2 | Some minor safety, future maintenance consequences if major deterioration were to occur | Moderate risk of ASR acceptable | Sidewalks, curbs and gutters, inlet tops, concrete barrier and parapet. Typically structures with service lives of less than 40 years | 303, 501, 505, 506, 516, 518, 523, 524, 525, 528, 540, 545, 605,607, 615, 618, 622, 623, 630, 633, 640, 641, 658, 667, 673, 674, 675, 676, 678, 714, 852, 875, 910, 948, 951, 1001, 1025, 1040, 1042, 1043, 1086, 1201, 1210, 1230, and Miscellaneous Precast Concrete |
| S3 | Significant safety and future maintenance or replacement consequences if major deterioration were to occur | Minimal risk of ASR acceptable | All other structures. Service lives of 40 to 75 years anticipated. | 530, 1001, 1006, 1031, 1032, 1040, 1080, 1085, 1107, MSE walls, Concrete Bridge components, and Arch Structures |

**2.c Minimum Levels of Supplementary Cementitious Materials (SCM) based on Level of Prevention.** Utilize a minimum mass replacement level from Table G below.

**Table G**
**Minimum Replacement Level of SCM (percentage by mass of cementitious material [12])**

| Type of SCM[1] | Alkali Level of SCM (% Na2Oe) [2], [3] | Level V[4] | Level W | Level X | Level Y | Level Z[5], [11] |
|---|---|---|---|---|---|---|
| Class F or C flyash[6] | ≤ 3.0 | – | 15 | 20 | 25 | 35 |
| Class F or C flyash[6] | >3.0 to ≤ 4.5 | – | 20 | 25 | 30 | 40 |
| Slag Cement | ≤ 1.0 | – | 25 | 35 | 50 | 65 |
| Silica Fume[7], [8], [9], [10] | ≤ 1.0 | – | 1.2 x LBA | 1.5 x LBA | 1.8 x LBA | 2.4 x LBA |

**Notes:**

(1) The SCM may be added directly to the mixture, be a blended cement, or a combination of a blended cement and a SCM.
(2) Where combinations of Class C and Class F are used, the alkalinity of the Class C flyash may exceed 4.5% provided the calculated alkalinity of the combination, based on the mass replacement, does not exceed 4.5%
(3) If two or more SCMs (including SCMs in blended cements) are used in combination, the minimum mass replacement levels given in Table G for the individual SCMs may be reduced provided the sum of the parts of each SCM is greater than or equal to one. For example, if silica fume and slag are used together, the silica fume level may be reduced to one-third of the minimum silica fume level given in the table provided the slag level is at least two-thirds of the minimum slag level required.
(4) No remediation is required at prevention Level V unless otherwise indicated by specification, e.g. Section 530.
(5) The alkali level of the concrete may be limited as specified in Section 704.1(g) 2.c.1
(6) The CaO must be limited to a maximum of 18%.
(7) The SiO must be greater than or equal to 85%
(8) The minimum level of silica fume is calculated based on the alkali (Na2Oe) content of the concrete contributed by the Portland cement and expressed in LBA (lbs./cy) by multiplying the cement content of the concrete in lbs./cy by the alkali content of the cement divided by 100. For example, for a concrete containing 500 lbs./cy with an alkali content of 0.81% Na2Oe, the value of LBA = 500 x 0.81/100 = 4.05 lbs./cy. For this concrete, the minimum replacement level of silica fume for Level Y is 1.8 x 4.05 = 7.3 percent.
(9) Regardless of the calculated value, the minimum level of silica fume should not be less than 7 percent if it is the only method of prevention.
(10) It is impractical to modify a mix design frequently during production based on the actual alkali limit of the cement used, therefore, where silica fume is used as the sole method of prevention, the maximum assumed alkali limit of the cement must be indicated on the mix design.
(11) Additional options for prevention Level Z are specified in Section 704.1(g)2.c.1 and Table H
(12) The use of high levels of SCMs in concrete may increase the risk of problems due to deicer salt scaling if the concrete is not properly proportioned, finished, and cured.

**2.c.1** The minimum replacement levels in Table G are appropriate for use with portland cements of moderate to high alkali contents (0.70 to 1.25 percent Na2Oe). Table H provides an alternative approach for utilizing SCMs if the alkali content of the Portland cement is less than or equal to 0.70%.

**Table H**
**Adjusting the Minimum Level of SCM if using low alkali Portland cement**

| Cement Alkalis (% Na2Oe) | Level of SCM |
|---|---|
| ≤ 0.70 | Reduce the minimum amount of SCM given in Table G by one prevention level.(1) |
| (1) The replacement levels should not be below those given in Table G for prevention Level W regardless of the alkali content of the Portland cement. | |

**2.c.2 Requirements for Prevention Level Z.** Where prevention Level Z is required, use the minimum level of SCM shown in Table G or use the minimum level of SCM and the maximum concrete alkali content indicated in Table I.

**Table I**
**Using SCM and Limiting the Alkali Content of the Concrete**

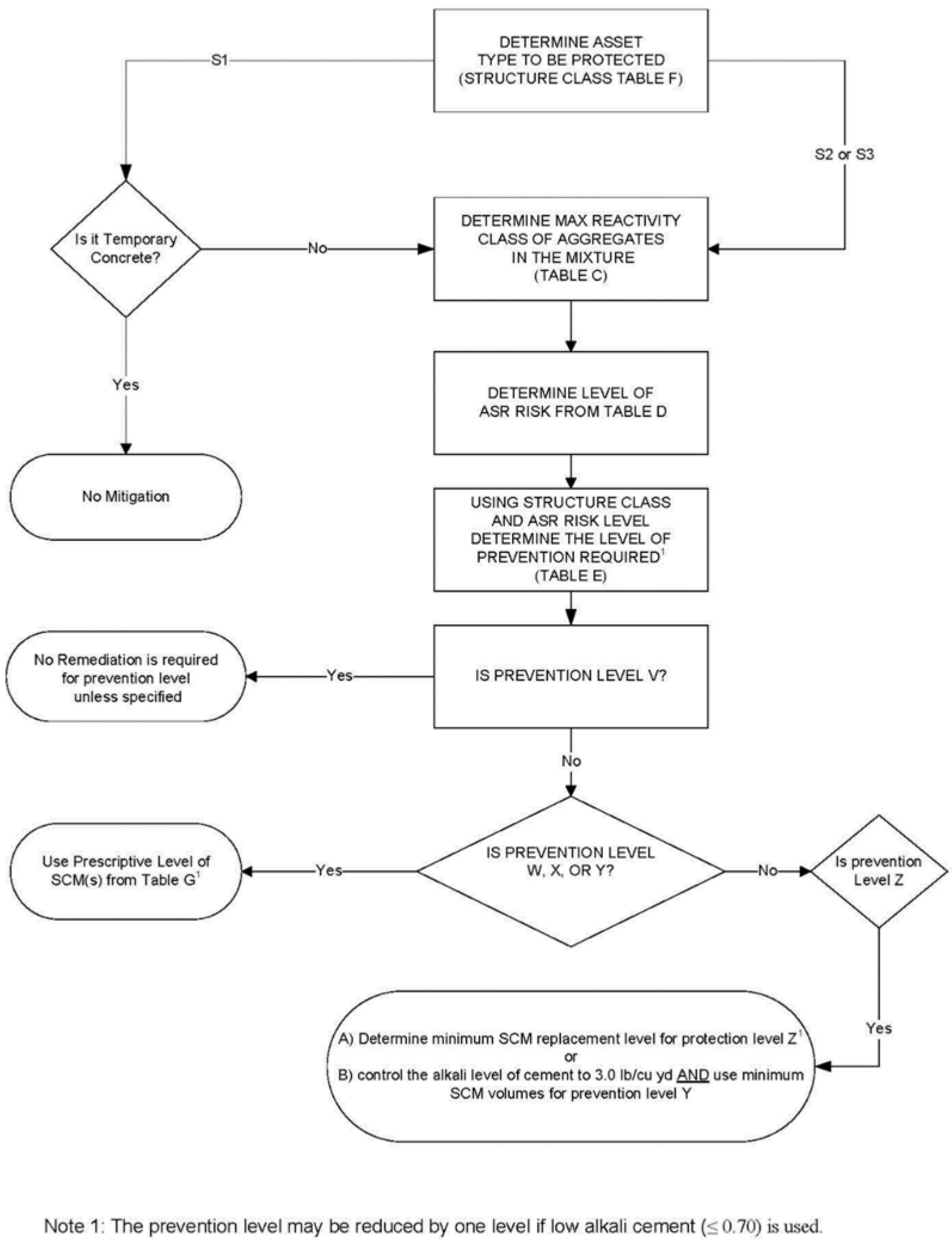
| Prevention Level | SCM as sole prevention | Maximum Alkali Content, (lbs./cy) and Minimum SCM Level |
|---|---|---|
| Z | Level Z from Table G | Maximum Alkali Level Content: 3.0 AND minimum SCM Level Y from Table G |

**3. Cement/Cement-SCM Requirements.** For use with aggregate deemed potentially reactive as specified in Section 704.1(g), provide Portland cement, blended hydraulic cement, or Portland cement-SCM combinations as specified in Section 704.1(b) and the following:

**3.a Portland Cement.** Conforming to the optional chemical requirement in AASHTO M 85 for a maximum alkali content of 1.25% Na2Oe if used for ASR prevention.

**3.b Blended Hydraulic Cement.** Type IS or IP, AASHTO M 240 (ASTM C595). From a manufacturer listed in Bulletin 15.

**3.c. ASR Mitigation Flowchart.**




4. **Admixture Requirements.** Furnish chemical admixtures as specified in Section 711.3.

5. **Exceptions.** If a service record of nonreactivity can be documented, the Department may exempt aggregates

classified through testing as potentially reactive, as specified in Section 704.1(g)2, from the cement/cement-SCM requirements as specified in Section 704.1(g)3.c. The service record must include a minimum of 10 structures, each over 10 years of age and preferably over 15 years of age.

Include the following documentation in the service record:

- A report on the visual examination of each structure for cracking including expansion at joints where applicable.
- Structure type and age.
- Concrete class or mix design proportions if available.
- Cement and alkali content of the cement used during construction.
- Use and type of all SCMs used in the mixture/structure.
- Presence and type of symptoms of distress if found.

Take cores from a representative number of structures and perform petrographic analysis of cores according to ASTM C856 to determine the presence or absence of alkali-silica gel formations and associated microcracking.

Determination of the aggregate classification according to ASTM C295. This analysis must confirm the aggregates from the structures are similar in mineralogical composition to that of the aggregate currently being considered for use.

If field performance history and subsequent testing indicates an aggregate source has begun to form ASR expansion, no exception for use other than the prescriptive methods provided will be accepted.

**(h) Extra Cement Concrete.** If 25% extra cement is allowed rather than the standard use of an anti-washout admixture (AWA) as specified in Section 1001.3(k)3.a, the extra cement may be replaced with other cementitious material in the same proportions as established in the mix design or as specified in Section 704.1(c). Up to 50% of the water dose for the extra cementitious material, based on the water cement ratio of the mix being utilized, may be added. Add additional admixtures, other than an AWA, as required for performance or to meet other mixture criteria as specified.

## 704.2 PLANT AND TRUCK MIXED CEMENT CONCRETE—

**(a) Batching Plant.** Proportion cement, aggregates, water, and admixtures in a plant conforming to AASHTO M 157 for batching plants.

Install a moisture meter to accurately and continuously indicate the variability of the fine aggregate moisture content. If approved, automatic moisture compensating probes for fine and coarse aggregate may be used to control the amount of batched water. Calibrate moisture probes according to the reviewed QC Plan.

Provide scales with graduation increments no greater than 1/1000 of the total scale capacity to measure the weight of aggregates or cement. Increments of less than 5 pounds are not required. Provide scales with capacities approximately equal to the hopper capacity or the central mixer capacity under normal proportioning conditions.

Provide a minimum of ten 50-pound weights at the plant for checking the scale's accuracy. Store the weights in a manner to maintain their weight-calibration accuracy.

Check the accuracy of the bin scales according to PTM No. 410.

Provide the plant with the following equipment for developing the concrete design and to control the quality of aggregates used and the concrete produced:

| Number of Each | Equipment |
|---|---|
| 1 | Sample splitter for fine aggregate having an even number of equal width chutes that discharge alternately to each side of the splitter. A minimum of 12 total chutes is required. The minimum width of the individual chutes is to be at least 50% larger than the largest particles in the sample and the maximum width of the individual chutes is to be 3/4 inch. Include two receptacles to hold the samples following splitting. Splitter design must allow samples to flow smoothly without restriction or loss of material. |
| 1 | Sample splitter for coarse aggregate having an even number of equal width chutes that discharge alternately to each side of the splitter. A minimum of eight total chutes is required. The minimum width of the individual chutes is to be at least 50% larger than the largest particles in the sample. Include two receptacles to hold the samples following |

| | |
|---|---|
| | splitting. Splitter design must allow samples to flow smoothly without restriction or loss of material. |
| | Or |
| 1 | Adjustable sample splitter for both coarse aggregate and fine aggregate having an even number of equal width chutes that discharge alternately to each side of the splitter. A minimum of 12 total chutes is required. For coarse aggregate, the minimum width of the individual chutes is to be at least 50% larger than the largest particles in the sample. For fine aggregate, the minimum width of the individual chutes is to be at least 50% larger than the largest particles in the sample and the maximum width of the individual chutes is to be 3/4 inch. Include two receptacles to hold the samples following splitting. Splitter design must allow samples to flow smoothly without restriction or loss of material. |
| 1 | Mechanical Sieve Shaker (with timer)—PTM No. 616 |
| 1 Set Each | Standard Sieves for Fine and Coarse Aggregate—ASTM E 11 |
| 1 | Oven capable of maintaining a uniform temperature of 230F ± 9F—PTM No. 616 |
| 1 | Calculating machine |
| 1 | Cylindrical Metal Measure 1 cubic foot— AASHTO T 19 and T 121, ASTM C136 |
| 1 | Air Meter, acceptable type— AASHTO T 196 and T 152 |
| 1 | Slump Cone— AASHTO T 119 |
| 1 | Cylinder Compression Machine—PTM No. 604(1) |
| 1 | Curing Tank—PTM No. 611(2) |
| 1 | Capping Device—PTM No. 604(1) |
| 1 | Balance conforming to the requirements of AASHTO M 231 for the class of general purpose scale required, for the principle sample weight of the sample being tested—PTM No. 616. |
| 1 | Platform scale conforming to the requirements of AASHTO M 231 for the class of general purpose scale required, for the principle sample weight of the sample being tested—PTM No. 616, and AASHTO T 121 and ASTM C136 |
| Sufficient | 6-inch by 12-inch Cylinder Molds—PTM No. 611 |
| | Necessary Incidental Equipment |
| 1 | Maturity Meter—PTM No. 640, if used |
| Sufficient | Temperature Sensors—PTM No. 640 if used |

Note (1)—Equipment requirements may be waived if arrangements for testing have been made at the producer's central facility or at a commercial testing laboratory that participates in the AASHTO Accreditation Program in the area of Concrete Testing. Commercial testing laboratories are to conform to ASTM E329 for Concrete Inspection and Testing except for the equipment listed above.

Note (2)—Equipment requirements may be waived if, after 24 hours (±2 hours), specimens made for checking the strength of trial mixes are properly transported to a central facility or commercial testing laboratory for curing according to PTM No. 611.

Provide the plant with proper laboratory equipment, space, and utilities as specified in Section 609.

**(b) Mixers and Agitators.** AASHTO M 157. If directed, test air content of individual mixed concrete samples taken approximately at the beginning, the midpoint, and the end of the batch. If the air content varies by more than 1.5%, discontinue the use of the mixer or agitator until the condition is corrected.

If mixing in truck mixers at the plant, use inclined-axis, revolving-drum type mixers or horizontal-axis, revolving-drum high-discharge type mixers.

**(c) Mixing and Delivery.** Maintain concrete temperature after mixing between 50F and 90F for general concrete, and between 50F and 80F for bridge deck concrete. Do not ship concrete exceeding these temperature ranges. Maintain adequate two-way communications between the concrete plant and the work site to provide both uniformity and control of the concrete mixture.

For each truck, furnish a plant delivery slip signed at the plant by the technician or other designated person. Include the following information on the delivery slip:

- Contract number, complete state project number or purchase order number.

- The concrete plant supplier code.
- Method of concrete mixing (i.e., central or truck).
- Class of concrete, JMF number, and trial mix number (i.e., trial #1, 2, etc.).
- Number of cubic yards.
- Time of completion of mixing.
- Truck number.
- Number of mixing revolutions, if applicable.
- Total amount of batch water used in each truck (pounds).
- The total weight in pounds of the total cementitious materials.
- The types of additives used in each truck (i.e., water reducer, AEA, retarder, etc.).

Submit the plant delivery slip and batcher-mixer slip (according to AASHTO M 157) to the Inspector-in-Charge. Do not use any concrete until it is approved for use by the Inspector-in-Charge.

Conform to AASHTO M 157, except as follows:

- If mixing in a plant, mix for not less than 50 seconds or more than 90 seconds for normal strength concrete, and not less than 70 seconds for HES concrete.
- If mixing in the truck drum at the plant, mix for not less than 70 or more than 125 truck-drum revolutions, at a mixing speed of not less than 6 truck-drum revolutions per minute (rpm) nor more than 18 truck-drum rpm. Upon completion of the designated number of mixing revolutions, reduce the truck-drum speed to not less than 2 rpm or more than 6 rpm. Do not exceed a total of 300 truck-drum revolutions.

Deliver the mixed concrete to the work site and discharge within 11/2 hours after completion of mixing. As an alternative, use a set retarding admixture or a workability retention admixture or both, listed in Bulletin 15 and according to manufacturer's dosage recommendations, to extend the initial set time and time for discharge to 2 hours after the completion of mixing. Agitate, but do not mix the concrete en-route to the work site.

- In hot weather, under conditions contributing to quick concrete stiffening, or if the concrete temperature is 80F or above, do not allow the time between completion of mixing and discharge to exceed 1 hour. As an alternative to maintaining the concrete temperature below 80F, use an approved, set retarding admixture to extend the initial set time and enable the mix to remain workable for the full 11/2 hours of allowable mixing time.
- If using mixer or agitator trucks, agitate concrete for at least 20 revolutions immediately before placement. Do not use concrete that has exceeded 45 minutes without agitation.
- If wash water is used to clean the truck drum, completely discharge this wash water before the introduction of the succeeding batch.
- Do not allow concrete to come in contact with aluminum unless the aluminum is coated with an acceptable coating (delivery of concrete in an aluminum truck bed is allowed).

**(d) Clean Out Areas**. Concrete clean out areas, either contractor designed, or detailed within the contract documents, are incidental.

## 704.3 VOLUMETRIC MIXED CEMENT CONCRETE

**(a) General.** Use a plant inspected and listed in Bulletin 42. Make trial mixtures with a calibrated mixing plant. Provide plant equipment, facilities, and a concrete technician(s) as specified in Section 704.1. Do not begin production until the mixing plant and all equipment and facilities necessary for performing the work have been inspected and accepted. Mixing plants may be truck mounted.

**(b) Usage.** Volumetric mixing plants may be used to produce concrete for endwalls, inlets, manholes, end anchors, sign posts, and similar miscellaneous structures requiring small quantities of concrete. If allowed by the District Executive in writing, volumetric mixing plants may also be used for pavement patching and structures. Approved plants may produce concrete for precast items.

**(c) Equipment.** Prominently attach a permanent metal plate(s) to the plant plainly marking the gross volume in terms of mixed concrete, the operating speed, the plant auger mixing angle, and the plant weight-calibrated cement constant in terms of a revolution counter or other output indicator, all as rated by the manufacturer.

**1. Compartments.** Provide separate compartments to carry the ingredients. Cover the aggregate bins and prevent contamination and intermixing of the fine and coarse aggregates during loading and transporting. Keep the cement bins free of moisture and contamination. Provide suitable means to carry water and additives and to incorporate the additives with the mixing water in the mix

**2. Feed System.** Provide a feeder system mounted under the compartment bins to deliver the ingredients to the mixing unit. Equip each bin with an accurately controlled individual gate to form an orifice for volumetrically measuring the material drawn from the bin compartment. Do not charge aggregate bins more than 4 hours before mixing.

Set the cement bin feeding mechanism to discharge a given volumetric weight equivalent of cement at a continuous and uniform rate during the concrete mixing operation. Coordinate the coarse and fine aggregate feeding mechanisms with the cement feeding mechanisms to deliver the required proportions.

**3. Mixing Unit.** Provide an auger-type mixer incorporated in the plant's discharge chute, or another suitable mixing mechanism that produces concrete of uniform consistency and discharges the mix without segregation. Examine the mixing screw daily and clean as necessary to prevent the build-up of mortar or concrete.

**4. Dials and Measuring Devices.** Equip the plant with accurate revolution-counter indicators that allow the volumetric weight equivalent of cement, fine aggregate, and coarse aggregate discharged to be read during the concrete-mixing operation. Equip the counter with a ticket print-out to record this quantity.

Equip the plant with a water flow meter or gauge to indicate the discharge rate of water (by volume) entering the mix and a water meter to register the total amount of water discharged during the mixing operation. Also, equip the plant with suitable gauges for checking the rate of flow of all additive(s) entering the mix. Coordinate the water and additive flow meters with the cement and aggregate feeding mechanisms. Equip the flow meters with scales appropriate for the type and amount of material being measured. Mount a tachometer indicating the drive shaft speed on the plant.

Place gauges, dials, and other devices that indicate the accuracy of concrete proportioning and mixing in full view so the operator can accurately read or readjust them while concrete is being produced. Provide the operator convenient access to all controls.

**(d) Calibration.** Use a unit constructed to allow convenient calibration of the gate openings and meters. Conduct a calibration once a year in the presence of Department representatives. Make satisfactory arrangements with the Department at least 1 week in advance of calibration. During the yearly calibration, calibrate the cement meter according to the manufacturer's recommendation and check the aggregate gate settings against the calibration data for the plant. Maintain the calibration data in the plant and submit the data to the District.

After performing the yearly calibration and before starting work, provide a mix design for review and acceptance and run a yield test to verify the design. Adjustments to correct for yield may require recalibration or a design change.

Conduct a recalibration if there is a change in the source of fine or coarse aggregate or cement. Conduct additional calibrations if directed. Provide each plant with data on the accepted recalibration.

If hydraulic drive units are used, perform the following additional calibration procedure: At the beginning of the actual batching operation, check the cement meter against the count and time used for the cement during the calibration of the individual materials. If a discrepancy occurs, adjust the belt speed of the unit so the actual cement meter count does not vary from the calibrated meter count by more than two counts per 60 seconds.

**(e) Mixing and Delivery.** Proportion, measure, and batch cement and aggregates by a weight equivalent method. The measuring and batching mechanism is required to produce the specified proportions of each ingredient within the following tolerances:

- Cement, Weight 0 to +4%
- Fine Aggregate, Weight ±2%
- Coarse Aggregate, Weight ±2%
- Admixtures, Weight or Volume ±3%
- Water, Weight or Volume ±2%

The tolerances are based on a volume/weight relationship established during the calibration of the measuring devices.

During mixing, maintain the drive shaft speed, as indicated by the tachometer, within 50 rpm of the operating speed. Set the auger mixer angle in the range determined by the manufacturer. Do not exceed 1/2 hour between the continuous placing of succeeding batches.

**1. Testing.** Conduct slump and air content tests according to PTM No. 601. Conduct the unit weight test, the concrete uniformity test, and the output meter calibration test according to AASHTO T 121, ASTM C136, AASHTO M 157, and PTM No. 626. If there is any doubt in the uniformity of the concrete, perform further testing as directed.

**2. Recording.** Provide a batcher mixer slip with each load of ingredients. Include the following information on the batcher mixer slip:

- Aggregate gradation and moisture information.
- Class of concrete and the corresponding dial setting, as determined in the design.
- Water discharge rate limitations.

Use a separate batcher mixer slip for each class of concrete. Deliver the batcher mixer slip to the Inspector-in-Charge at the work site. Do not use the concrete until the Inspector-in-Charge verifies the data noted on the slip complies with the specifications.

**(f) Clean Out Areas**. Concrete clean out areas, either contractor designed, or detailed within the contract documents, are incidental.