501 Concrete

501.1 Description

(1) This section describes concrete requirements including component materials, proportioning, mixing, placing, and protecting concrete mixtures.

501.2 Materials

501.2.1 (Vacant)

501.2.2 Definitions

(1) Use the definitions in 301.2, and interpret these terms used in 501 as follows:

Ancillary concrete	A general term used throughout the standard specs in reference to all concrete items that are not class I concrete.
Coarse aggregates	Aggregate predominantly retained on the No. 4 sieve
Concrete class	The department categorizes concrete as class I, II, or III defined by the sampling, testing, and reporting requirements specified in 715 and 716.
Concrete grade	The department categorizes concrete as grade A, B, C, or E defined by cementitious material content.
Fine aggregates	Aggregate that entirely passes the 3/8-inch sieve, almost entirely passes the No. 4 sieve, and is predominantly retained on the No. 200 sieve.

501.2.3 Sampling and Testing

(1) Sample and test aggregates for concrete according to the following:

Aggregate Sampling	WTM R90
Lightweight pieces	WTM T113
Material finer than No. 200 sieve	WTM T11
Aggregate unit weight	AASHTO T19
Organic impurities for Concrete	AASHTO T21
Aggregate Gradation	WTM T27
Effect of organic impurities in fine aggregate	AASHTO T71
LA Wear	WTM T96
Alkali silica reactivity (ASR) - aggregates	ASTM C1260
ASR - combinations of cementitious materials and aggregates	ASTM C1567
Freeze-thaw	WTM T103
Sodium soundness	WTM T104
Fine aggregate specific gravity	WTM T84
Coarse aggregate specific gravity	WTM T85
Flat and elongated	WTM D4791

(2) Test cementitious materials and admixtures in a department-recognized laboratory, defined as any state department of transportation or other cement and concrete laboratory regularly inspected by the Cement and Concrete Reference Laboratory.

(3) Test for soft or non-durable particles conforming to department laboratory methods. The department will field evaluate or laboratory test to determine aggregate acceptability relative to excessive clay lump quantities.

501.2.4 Cementitious Material

501.2.4.1 Portland Cement

(1) Use cement conforming to ASTM specifications as follows:

- Type I portland cement; ASTM C150.
- Type II portland cement; ASTM C150.
- Type III portland cement; ASTM C150, for high early strength.
- Type IP portland-pozzolan cement; ASTM C595, except maximum loss on ignition of pozzolan component is 2.0 percent and maximum pozzolan content is 30 percent.
- Type IS portland blast-furnace slag cement; ASTM C595, except maximum slag content is 30 percent.
- Type IL portland-limestone cement; ASTM C595.
- Type IT ternary blended cement; ASTM C595, except maximum supplementary cementitious material content is 30 percent.

(2) Obtain portland cement from manufacturers on the APL. The engineer may accept cement not on the APL under the department's cement acceptance program in CMM 870.

(3) For blended cements, provide a manufacturer's written certification stating the source, quantity, and composition of essential constituents and the composition of the final cement provided under the contract. Ensure constituents conform to requirements specified in 501.2.4.2 and 501.2.4.3.

(4) Store cement of different types, brands, and sources separately. Keep batches of concrete made from different types, brands, and sources from becoming intermixed in the work, unless the engineer approves otherwise.

(5) The engineer will reject cement that is partially set or that contains lumps.

(6) The engineer may reject cement if, the temperature at the time of delivery to the mixer exceeds 165 F. To avoid this, store it until it cools to at least 165 F before incorporating into the batch.

501.2.4.2 Supplementary Cementitious Material (SCM)

501.2.4.2.1 General

(1) When the contract requires or allows, use fly ash, slag, silica fume, or alternate SCMs as a direct replacement by weight for cement in concrete mixes. The department will sample and test SCMs during concrete production to verify material conformance.

501.2.4.2.2 Fly Ash

501.2.4.2.2.1 General

(1) Test the fly ash using the test methods prescribed in ASTM C311, starting at least 30 calendar days before its proposed use and continuing at ASTM-required frequencies as the work progresses.

(2) Obtain, from the fly ash manufacturer, a copy of the certified report of test or analysis made by a qualified independent laboratory, showing compliance with ASTM C618 for the appropriate fly ash class, except limit the loss on ignition to 2 percent. Submit the report to the engineer with the mix design, at least 7 business days before use.

(3) Retain test records for at least 5 years after completing the work and provide these records upon request.

(4) For contracts with 100 tons or more of fly ash, obtain under the engineer's observation, one 4-pound sample for every 2000 tons of fly ash used, or fraction thereof. The engineer will take possession of the sample and submit to the BTS laboratory for department verification testing.

501.2.4.2.2.2 Class C Ash

(1) Conform to ASTM C618 class C.

501.2.4.2.2.3 Class F Ash

(1) Furnish a class F fly ash from a source listed on the APL and conforming to ASTM C618 class F.

(2) For class F sources not on the APL, limit the content to a maximum 15 percent.

501.2.4.2.3 Slag

(1) At least 7 business days before use, submit a certified report of test or analysis showing the ground granulated blast furnace slag conforms to ASTM C989, grade 100 or 120.

(2) For contracts with 100 tons or more of slag, obtain, under the engineer's observation, one 4-pound sample for every 2000 tons of slag used, or fraction thereof. The engineer will take possession of the sample and submit to the BTS laboratory for department verification testing.

501.2.4.2.4 Silica Fume

(1) Furnish silica fume conforming to ASTM C1240.

(2) Use a high range water reducer, superplasticizer, conforming to 501.2.5.3.3 in mixtures containing 3 percent or more silica fume.

(3) Submit a mix design, including material sources and quantities, to the department at least 14 calendar days before use. The engineer will coordinate with the BTS laboratory for review and approval analysis.

501.2.4.2.5 Blended SCMs

(1) Furnish blended SCMs conforming to ASTM C1697.

(2) Submit a mix design, including material sources and quantities, to the department at least 14 calendar days before use. The engineer will coordinate with the BTS laboratory for review and approval analysis.

(3) Conform to sampling/testing requirements specified by the engineer.

501.2.4.3 Alternative Supplementary Cementitious Material (ASCM)

(1) Test ASCMs according to ASTM C1709. Submit a mix design, including material sources and quantities, to the department at least 14 calendar days before use. Include a certified report of test or analysis showing the chemical composition, physical properties, and performance test results of the ASCM. The engineer will coordinate with the BTS laboratory for review and approval analysis.

(2) Conform to sampling/testing requirements specified by the engineer.

501.2.5 Chemical Admixtures

501.2.5.1 General

(1) Conform to the manufacturer's recommendations for use of admixtures. The contractor is responsible for ensuring that admixtures used in the same batches of concrete are compatible and produce the required properties in concrete.

501.2.5.2 Air-Entraining Admixtures

(1) Furnish an air-entraining admixture on the APL, or provide a certified report of test or analysis showing the air-entrainer conforms to AASHTO M154 for 7-day and 28-day compressive and flexural strengths and resistance to freezing and thawing. The engineer will not require tests for bleeding and setting time.

(2) If the contractor offers to use an admixture that is essentially the same as one on the APL, with only minor differences in concentration, the department will require certification stating it is essentially the same as the department-approved admixture, and that it contains no other admixture or chemical agent.

501.2.5.3 Retarding, Water-Reducing, and Non-Chloride Accelerating Admixtures

501.2.5.3.1 Water-Reducing Admixtures

(1) Furnish a water-reducer on the APL or submit a certified report of test or analysis showing conformance to AASHTO M194, type A, except if it is also a set retarder, then conform to type D.

501.2.5.3.2 Retarding Admixtures

(1) If furnishing an admixture to retard concrete setting, submit a certified report of test or analysis showing conformance to AASHTO M194 type B, except if it is also a water-reducer, furnish one from the APL, conforming to type D.

501.2.5.3.3 High Range Water-Reducing Admixtures

(1) If furnishing a high-range water-reducing admixture, superplasticizer submit a certified report of test or analysis showing conformance to AASHTO M194, type F, except if it is also a set retarder, then conform to type G.

(2) Submit a mix design, including material source and quantity, to the engineer 14 calendar days before use. BTS approval is required before use.

501.2.5.3.4 Non-Chloride Accelerating Admixture

(1) If furnishing a non-chloride accelerating admixture, provide a certified report of test or analysis showing conformance to AASHTO M194, type C, except if it is also a water-reducer, then conform to or type E.

501.2.5.3.5 Hydration Controlling Admixtures

(1) When furnishing hydration stabilizers conform to AASHTO M194, type B or type D.

(2) Submit a mix design, including material source and quantity, to the engineer 14 calendar days before use. BTS approval is required before use.

(3) Conduct preliminary trials on-site to determine the required dosage rate.

501.2.6 Mixing Water

501.2.6.1 General

(1) Furnish water for use with cement in concrete, mortar, neat cement paste, and in other cement mixing operations.

501.2.6.2 Requirements

(1) The contractor may furnish drinking water from municipal water supplies for concrete; the engineer may test this water for compliance with the requirements specified below.

(2) Water from other sources must comply with the following:

Acidity, maximum of 0.1N NaOH to neutralize 200 mL of water; WTP C-001 ..... 2 mL

Alkalinity, maximum of 0.1N HCL to neutralize 200 mL of water; WTP C-001 ..... 15 mL

Maximum sulphate (S04); WTP C-001 ..... 0.05 percent

Maximum chloride; WTP C-001 ..... 0.10 percent

Maximum total solids; WTP C-001

Organic ..... 0.04 percent

Inorganic ..... 0.15 percent

(3) Furnish water that is not brackish and is clean and free of injurious quantities of sugar, oil, or other deleterious substances.

(4) Furnish water that causes no indication of unsoundness, no significant change in the set time, and does not affect the compressive strength of standard 1:3 mortar briquettes by more than 10 percent compared to strengths from mixtures containing distilled water and the same cement and sand.

(5) Do not use water from shallow, muddy, or marshy sources. The contractor shall not use water from suspected sources until the engineer tests and approves it. If supply sources are relatively shallow, enclose the suction pipe intake to keep out silt, mud, grass, and other foreign materials. Position the suction pipe to provide at least 2 feet of water beneath the pipe intake.

501.2.6.3 Sampling and Testing

(1) Under the engineer's observation, obtain at least 2 quarts of water in clean plastic or glass containers, from each source to be tested. Carefully pack and label the samples. The engineer will take possession of the samples for department testing conforming to CMM 870.

501.2.7 Aggregates

501.2.7.1 General

(1) Furnish material conforming to the individual component requirements of 501.2.7.2 for fine aggregates, 501.2.7.3 for coarse aggregates, and 501.2.7.4 for size requirements.

(2) The engineer may prohibit using, or may require additional testing of, aggregates from any source, plant, pit, quarry, or deposit if the character of the material is questionable or the method of operation makes it unlikely that the aggregates produced will conform to specified requirements; or from deposits or formations known to produce unsound materials.

(3) Furnish samples of materials from previously untested sources and from previously tested sources if the engineer requires; obtain department approval before use.

(4) If procuring aggregates from pits or quarries, conform to 104.9 for final cleanup.

501.2.7.2 Fine Aggregates

501.2.7.2.1 General

(1) Fine aggregate consists of a combination of sand with fine gravel, crushed gravel, or crushed stone.

(2) Furnish hard, strong, and durable fine aggregate from an approved source. Use an approved source listed on the APL or follow the source approval process specified in 106.3.4.2.

501.2.7.2.2 Deleterious Substances

(1) Provide fine aggregate free of frozen material and foreign matter. Do not exceed the following deleterious substance limits:

TABLE 501-1 DELETERIOUS SUBSTANCE LIMITS

SUBSTANCE	PERCENT BY WEIGHT[1]
Material passing No. 200 sieve	3.5[2]
Coal	1.0
Clay lumps	1.0
Shale	1.0
Other local deleterious substances	1.0

[1] The total amount of coal, clay lumps, shale, and other deleterious substances must not exceed 3.0 percent by weight.

[2] Reduce to 2.3 percent if used in grade E concrete.

501.2.7.2.3 Organic Impurities

(1) Fine aggregate must not contain harmful quantities of organic impurities. The engineer will reject aggregates that produce a color darker than the standard color, organic plate no. 3, when subjected to the AASHTO T21 colorimetric test for organic impurities, unless they pass the AASHTO T71 mortar strength test by producing a relative strength at 7 days of not less than 95 percent.

501.2.7.3 Coarse Aggregates

501.2.7.3.1 General

(1) Provide coarse aggregates from a department-approved source. Use an approved source listed on the APL or follow the source approval process specified in 106.3.4.2.

(2) Use clean, hard, durable gravel, crushed gravel, crushed stone, or crushed concrete; do not use crushed concrete as coarse aggregates in concrete for bridges, culverts, or retaining walls.

501.2.7.3.2 Physical Properties

(1) Furnish coarse aggregates approved for use in concrete and conforming to table 501-2.

TABLE 501-2 PHYSICAL PROPERTIES

AGGREGATE QUALITY TEST	MAXIMUM PERCENT (by weight)
LA wear	50
Sodium soundness	12
Freeze-thaw	18

(2) The department may prohibit using crushed stone from limestone/dolomite deposits having thinly bedded strata, or strata of a shale nature.

(3) If all coarse aggregates used are produced from the same deposit or source, ensure that testing for wear, sodium sulfate soundness, and soundness by freezing and thawing uses a composite sample. This sample will contain equal percentages of each component coarse aggregate used. If the component coarse aggregates are produced from more than one deposit or source, ensure that testing for wear, sodium sulfate soundness, and soundness by freezing and thawing uses one sample from each deposit or source.

501.2.7.3.3 Deleterious Substances

(1) Ensure aggregates are free of excess flat & elongated particles, lightweight pieces, frozen lumps, vegetation, deleterious substances, or adherent coatings considered injurious. Do not exceed the maximum limits of deleterious substances specified in table 501-3.

TABLE 501-3 DELETERIOUS SUBSTANCES

SUBSTANCE	PERCENT (by weight)
Flat and elongated	15
Lightweight pieces[2] in concrete not for prestressed concrete members	5.0[3]
Lightweight pieces[2] in concrete for prestressed concrete members	2.0
Shale	1.0
Coal	1.0
Clay lumps	0.3
Soft fragments	5.0
Any combination of shale, coal, clay lumps, and soft fragments	5.0
Material passing No. 200 sieve	1.5

[1] As modified in CMM 860.

[2] Material having a saturated surface-dry bulk specific gravity of less than 2.45, tested according to WTM T113. Determine the percentage of lightweight pieces by dividing the weight of lightweight pieces in the sample retained on a 3/8-inch sieve by the weight of the total sample.

[3] The engineer may accept aggregates exceeding this value if aggregates from the same deposit or from one of similar geological origin demonstrated a satisfactory service record, or tests the engineer select indicate no inferior behavior.

(2) If using 2 sizes of coarse aggregates, the engineer will determine the percentages of harmful substances based on a sample consisting of 50 percent of sizes No. 1 and No. 2 for source approval; or, based on a sample consisting of the actual mix design percentages of sizes No. 1 and No. 2 used in the work.

(3) The engineer will field evaluate or laboratory test to determine aggregate acceptability relative to excessive clay lump quantities.

501.2.7.3.4 Alkali Silica Reactivity Testing and Mitigation Requirements

(1) If using coarse aggregate from sources containing significant amounts of fine-grained granitic rocks including felsic-volcanics, felsic-metavolcanics, rhyolite, diorite, gneiss, or quartzite; test coarse aggregate according to ASTM C1260 for alkali silica reactivity. Gravel aggregates are exempt from this requirement.

(2) If ASTM C1260 tests indicate a 14-day expansion of 0.15 percent or greater, perform additional testing according to ASTM C1567. Test mortar bars made with coarse aggregate and the blend of cementitious materials proposed for concrete placed under the contract. The department will reject the aggregate if ASTM C1567 tests confirm mortar bar expansion of 0.15 percent or greater at 14 days.

501.2.7.4 Size Requirements

501.2.7.4.1 General

(1) Except as provided below, furnish aggregates in separate sizes and store each size separately to prevent mixture until proportioned into each batch. The engineer will allow the contractor to combine aggregate fractions to produce a gradation within the limits specified in table 501-4, provided they are proportioned separately by weight into the batch in proportions provided in the contractor's mix design.

(2) The contractor may provide coarse aggregate with 100 percent passing the 1-inch sieve in concrete mixes used for the following:

- Curb and gutter, sidewalk, and steps.
- Prestressed concrete members.
- Foundations for soldier pile walls and noise walls.
- Structure repairs or deck overlays.
- Ancillary structure foundations.
- Concrete masonary seals.
- Other engineer-approved applications.

501.2.7.4.2 Aggregate Gradations

(1) Use well graded fine and coarse aggregate conforming to the blended aggregate gradation limits specified in table 501-4.

(2) The department will accept aggregates based on the blended aggregate gradations as batched. Calculate blended values using the actual batch percentages for the component aggregates.

TABLE 501-4 AGGREGATE MASTER GRADATION LIMITS

SIEVE	COMBINED AGGREGATE GRADATION		OPTIMIZED AGGREGATE GRADATION (OAG)
	STANDARD	100 % PASSING 1-inch sieve	TARANTULA CURVE GRADATION BAND
	(% passing by weight)		(volumetric % retained)
2-inch	100	100	0
1 1/2-inch	96 - 100	100	<= 5
1-inch	70 - 99	100	<= 16
3/4-inch	55 - 96	95 - 100	<= 20
1/2-inch	48 - 86	75 - 91	4-20
3/8-inch	38 - 77	56 - 80	4-20
No. 4	30 - 60	42 - 60	4-20
No. 8	25 - 53	36 - 55	<= 12
No. 16	20 - 44	27 - 45	<= 12
No. 30	10 - 32	15 - 32	4-20
No. 50	2 - 14	3 - 14	4-20
No. 100	0 - 6	0 - 6	<= 10
No. 200	0 - 2.3	0 - 2.3	<= 5
ADDITIONAL REQUIREMENTS - OPTIMIZED AGGREGATE GRADATION			
Percent by weight passing the 200 sieve <= 2.3			

OAG sum of volumetric percentages retained on No. 8, No. 16, and No. 30	>= 15
OAG sum of volumetric percentages retained on No. 30, No. 50, No. 100, and No. 200	24-34[1]

[1] Increase to 40 percent if the concrete will be placed by a pump or by hand.

501.2.7.4.2.1 Optimized Aggregate Gradation

(1) Ensure the blended aggregate gradations conform to the volumetric percent retained limits of the tarantula curve for the individual sieves specified in table 501-4. Also conform to the required OAG sums of percentages retained for the sieves specified in table 501-4.

(2) For concrete pavements with a combined contract quantity over 50,000 square yards, the contractor must use optimized aggregate gradations. The contractor has the option to use optimized aggregate gradations for all other concrete items.

(3) When using optimized aggregate gradations, the contractor may use an optimized mix design as allowed in 501.3.2.3.

501.2.7.4.2.2 Combined Aggregate Gradation

(1) For standard mixes and mixes with 100 percent passing the 1-inch sieve, as allowed under 501.2.7.4.1(2), conform to the combined aggregate gradation limits specified in table 501-4.

501.2.8 Concrete Curing Materials

(1) Furnish liquid curing compound conforming to ASTM C309, type 2, class A from the APL. Curing compound not on the APL, including carry-over material from a previous year that is removed from the APL, must be tested by the BTS laboratory if the quantity exceeds 220 gallons.

- Submit a 1-quart sample for each 2000 gallons used, or fraction thereof. Obtain samples under the engineer's observation.
- Submit a certified report of test or analysis that includes the lot/batch number of the sampled material.
- Carry-over curing compound from the previous year must be re-tested and placed on the current year APL before use.

(2) Furnish sheeting conforming to ASTM C171 for white opaque polyethylene film, except that the contractor may use clear or black polyethylene for cold weather protection.

(3) Furnish burlap conforming to AASHTO M182, class 3 or 4. The contractor may use 2 layers of class 1 or class 2 instead of one layer of class 3 or class 4.

(4) Furnish polyethylene-coated burlap conforming to ASTM C171 for white burlap-polyethylene sheets.

501.3 Construction

501.3.1 Concrete Grades

(1) The department's standard concrete grades are defined in table 501-5.

501.3.2 Concrete Composition

501.3.2.1 General

(1) Unless the contract specifies otherwise, for all concrete grades:

- Provide air-entrainment.
- Use a water-reducing admixture.

501.3.2.2 Concrete Proportions

501.3.2.2.1 General

(1) Unless the contract specifies otherwise or if using an engineer-approved optimized mix design, conform to the cementitious material and the water-to-cement ratio master limits for grades of concrete as specified in table 501-5.

TABLE 501-5 CONCRETE GRADES

GRADE	MINIMUM CEMENTITIOUS CONTENT FOR A NOMINAL CUBIC YARD (lb/cy)	MAXIMUM W/CM
A	565	0.45
B	400	0.65
C	660	0.45
E	823	0.36

501.3.2.2.2 Supplementary Cementitious Materials

(1) Replace 15 to 30 percent by weight of the total cementitious material content with approved SCMs for class I concrete as specified in 715.

(2) Replace a maximum of 30 percent by weight of the total cementitious material content with approved SCMs for class II and class III concrete as specified in 716.

(3) Limit Class F fly ash sources not on the APL to maximum 15 percent.

(4) Minimum SCM content may be waived by the engineer.

501.3.2.2.3 Water

(1) Water-to-cementitious material ratio (w/cm) is the weight of total free water divided by the weight of total cementitious materials.

501.3.2.2.4 Aggregates

(1) Proportion fine aggregates and coarse aggregates to meet the blended aggregate gradation limits established in 501.2.7.4.2.1 or 501.2.7.4.2.2.

501.3.2.3 Optimized Concrete Mixtures

(1) The contractor may use an optimized concrete mixture with reduced cementitious material content for concrete items with optimized aggregate gradations as defined in 501.2.7.4.2.1.

(2) Develop an optimized mix design as specified in 710.

- Provide a minimum cementitious material content of 500 pounds per cubic yard of concrete, except for grades C and E conform to table 501-5.
- Provide a minimum Vpaste/Vvoids of 1.25. The paste/void ratio equals the volume of paste divided by the volume of voids.

501.3.2.4 Concrete Admixtures

501.3.2.4.1 General

(1) Dispense admixtures in liquid form only. Incorporate non-liquid admixtures in an aqueous solution according to the manufacturer's instructions before dispensing. Maintain admixtures at uniform concentration. The contractor is responsible for the uniform operation of the admixture and for its compatibility with other mix components and any other admixture used.

501.3.2.4.2 Air Entrainment

(1) Use an admixture conforming to 501.2.5.2 with non-air-entrained cement to produce air-entrained concrete. Ensure that concrete air content conforms to the following:

- Grade E concrete contains 6.0 percent air, +/- 1.0 percent.
- Slip-formed concrete contains 7.0 percent air, +/- 1.5 percent.
- Other concrete contains 6.0 percent air, +/- 1.5 percent.

(2) Test fresh concrete air content according to WTM T152 or WTM T395 at the contract-required frequency and as the engineer directs. Test concrete placed by pumping or belting at the point of discharge from the pump line or belt.

(3) The engineer may verify air content using a method that measures air volume directly. The contractor may request a check test performed according to WTM T152 to validate the engineer's method.

501.3.2.4.3 Set Retarder

501.3.2.4.3.1 General

(1) Use admixtures to retard concrete setting conforming to 501.2.5.3.

501.3.2.4.3.2 Bridge Superstructures

(1) If required, add a retarding admixture conforming to 501.2.5.3 to the concrete mix used for the superstructures of cast in place reinforced concrete slab, concrete floor slabs, sidewalks, and parapets of other types of structures, including the top slab of concrete for box girder bridges according to the following:

(2) Add the department-approved retarding admixture, to the concrete mix, as the engineer directs, if the air temperature when placing the concrete is 70 F or above; or if it is 50 F or above and it is expected to take 4 or more hours to place the concrete in any one span or pour. Add the retarding admixture in the proportions the manufacturer recommends for the anticipated temperature.

501.3.2.4.3.3 Extended Delivery Time

(1) If the contractor elects to use a retarder to extend delivery time for ready-mixed concrete, as specified for delivery in 501.3.5.2, add it to the concrete mix if the concrete temperature when placing the concrete is 60 F or above.

(2) Add the retarding admixture according to the manufacturer's instructions to obtain at least a one-hour delay in the initial set, as defined in AASHTO T197, at the temperature during placement.

501.3.2.4.4 Water Reducer

(1) Use a water-reducing admixture conforming to 501.2.5.3. Determine the specific type and dosage based on the atmospheric conditions, the desired properties of the finished concrete, and the manufacturer's recommended dosage. The actual dosage must at least equal the manufacturer's recommended dosage. Both the type and dosage used require engineer approval before use.

501.3.3 Handling Materials

501.3.3.1 Aggregates

(1) Keep materials required to manufacture concrete clean and free from contamination. The department will not accept aggregates mixed with foreign matter. Keep the fine aggregate and the coarse aggregates separate until measuring and placing in the batch. If mixing or storing aggregates from different supply sources in the same pile, the engineer will reject the entire pile. The engineer may approve use of aggregates from different sources alternately in the same class of construction or mix; this permission is contingent on amending the job mix and batch weights as necessary to protect the concrete quality produced.

(2) If using a composite material from 2 or more sources for any aggregate for a job mix, proportion material from the respective sources separately into the batch by weight in the proportions the engineer approves.

(3) Store aggregates in stockpiles. The aggregates must not go directly from the washing plant to the proportioning bins. After washing, drain fine aggregate in stockpiles for at least 12 hours before weighing for the batch, unless the engineer reduces this waiting period. After washing and before placing in the proportioning plant, allow coarse aggregates to drain for periods that ensure uniformity in the moisture content.

(4) Choose reasonably smooth, firm, and well-drained sites for aggregate stockpiles cleared of vegetable matter and foreign material that might contaminate the aggregates. If necessary, build adequate bulkheads or partitions for keeping the fine and the several sizes of coarse aggregates separated. If the aggregates become intermixed, then do not use them.

(5) Construct coarse aggregate stockpiles in a way that minimizes segregation of the coarse and fine fractions.

(6) Exercise care in removing aggregates near the bottom of stockpiles, to avoid incorporating foreign materials, and use of material removed from near the bottom of drainage stockpiles at production plants and batching plants is prohibited unless tests indicate the material is satisfactory.

501.3.3.2 Cement

(1) Handle bulk cement in a way that precludes contamination and avoids loss.

(2) If using packaged cement, deposit it directly from the containers, as shipped, into the mixer when placing the aggregates into the mixer, or dump it directly on the batch aggregates just before placing the batch aggregates into the mixer, except as required otherwise to conform to 415.3.13 and 502.3.9.2 for mixing concrete under cold weather conditions. Take care to place the container's full contents into the batch.

501.3.3.3 Fly Ash or Slag

(1) Use separate facilities equal to those used for cement for handling, storing, transporting, and conveying the fly ash or slag.

501.3.4 Proportioning

501.3.4.1 Aggregates

(1) Measure the specified quantities of each size of fine and coarse aggregates by weight into each batch, except as specified for volumetric plant and mixer in 501.3.6.4.

501.3.4.2 Cement

(1) Measure the specified quantity of cement accurately into each batch.

(2) The contractor may proportion cement in sacks by volume if the operations allow the engineer to accurately determine the quantity of cement proportioned into each batch. Do not use batches

requiring a fractional part of a sack of cement, unless the contractor elects to weigh the fractional part required for each batch.

(3) Proportion cement in bulk by weight, except as specified for volumetric plant and mixer in 501.3.6.4.

501.3.4.3 Water

(1) Measure water by volume or by weight. Use water-measuring equipment capable of accurately measuring to within one percent of the quantity required for each batch. Ensure that the measurement accuracy is uniform under all construction conditions and that variations in pressure in the water supply line do not affect it.

(2) Use water-measuring equipment with preset controls that enable the operator to automatically cut off the flow after discharging the required quantity of water. Use equipment that has an accurately calibrated and easily read indicator showing the quantity of water used in each batch. Arrange this measuring equipment to facilitate checking the calibration accuracy.

501.3.4.4 Admixtures

501.3.4.4.1 General

(1) The contractor may proportion admixtures by volume or by weight. Follow a department-approved procedure for adding the specified quantity of each admixture. Add admixtures during initial batching of the concrete except as specified in 501.3.4.4.2.

(2) If using more than one admixture, add each admixture in a way that prevents intermixing the admixtures before incorporating into the mixture. The contractor may introduce the admixture into the water line, directly into the mixer when adding the water, or uniformly dispense it into the fine aggregate just before incorporating into the mix.

501.3.4.4.2 Adding Air-Entraining Admixtures in the Field

(1) The department will allow re-tempering with air-entraining admixtures at the work site for concrete delivered in truck mixers.

(2) If additional air-entraining admixture is needed at the work site to raise the air content of the concrete above the lower spec limit, measure it in a calibrated container and then add to the mixer in a dilute solution with water. Mix the concrete at mixing speed for at least 30 revolutions before discharge.

501.3.4.5 Weighing Equipment for Aggregates

501.3.4.5.1 General

(1) The contractor may use manual, automatic, or semi-automatic batching plants for weighing fine and coarse aggregates.

(2) Ensure each plant has bins for holding each aggregate weighed, and batchers, and scales for weighing the aggregates, and conforms to the requirements specified below.

(3) The contractor may use batching plants that are a complete unit with bins, batchers, and scales mounted on a rigid framework for direct discharge of the aggregate from the bin to the batcher; or plants with the bins mounted separately from the batchers and provided with appropriate means for conveying the aggregate from the bin to the batcher. Ensure the framework supporting bins and batchers is rigidly constructed and mounted on firm foundations.

(4) After erection, test each batching plant before use. Fully load aggregate bins, batchers, and scales with aggregate for not less than 5 hours before testing, in order to allow for settlement and adjustment under working conditions.

(5) Provide each batching plant with at least 10 standard 50-pound weights accurate to within 0.1 percent.

(6) When the engineer is observing the testing, furnish any accessories and assistance required to test the weighing and metering equipment. If difficulties occur in calibrating and testing the weighing or metering equipment, or if discrepancies occur during use, the engineer may require an authorized testing firm or agency test the scales or meters. If testing weighing equipment, ensure the material bins are fully loaded at the time.

(7) The contractor may batch aggregates, both fine and coarse, in separate or accumulative weigh batchers.

501.3.4.5.2 Scales

(1) Use either the beam, digital, or springless dial-type scales suitable for supporting the batcher and of a simple rugged design with a minimum number of adjustments, consistent with the accuracy required. Use scales designed and constructed to prevent displacement of scale parts and that provide a means for readily checking the proper position and alignment of scale levers. Ensure pivots are constructed of

material that satisfactorily resists wear under repeated weighing and are set accurately in substantial mountings to ensure a permanent spacing of the knife edges under all loading and use conditions.

(2) If provided beam scales, they must have a separate beam, or separate beam and fractional beam for each aggregate weighed. Provide each beam with a sliding poise and locking device to firmly hold it in position. Provide a means to display to the scale operator that the required load weight is approaching, for example, a springless dial indicator or tare beam. If using a graduated dial, provide it with a separate movable pointer or marker for each aggregate weighed. Set these pointers or markers to indicate the load of each aggregate as required. Provide a moisture resistant dial face.

(3) If using digital scales, conform to NIST handbook 44.

(4) Design, build, and maintain the scales to an accuracy within 0.4 percent of the net load in the hopper. Arrange the scales or indicating devices so the operator can maintain full view of them.

(5) Use graduated dials, beams, or other indicators to allow readings or settings made to within 0.1 percent of the capacity of the scale.

(6) Ensure accessibility to the scale working parts for inspection and cleaning, and protect working parts against contamination. Provide full and complete instructions for setting up and adjusting the scale.

501.3.4.5.3 Manually Operated Batching Plants

(1) Bins must have: suitable size and shape, no leakage, compartments or separate bins for each size of aggregate, rigid framework that, if mounted on a suitable foundation, holds them in the correct position.

(2) Multiple compartment bins must have partitions that extend above the top of the bins to prevent intermixing of the separate sizes of aggregates if heaped above the top of the bins.

(3) Weigh batchers must: have suitable size and shape, not leak, rest entirely upon the scales, and hang free. Provide clearance between the batcher top and bin discharge gates, or charging facilities, to house a full batch without hand raking, and sufficient clearance to remove any overload of aggregate. Provide a means to tightly close the batcher discharge gate during the batching interval. Ensure the design, construction, and operation of the batcher and its appurtenances does not retain varying tare materials on any of its parts, and completely and quickly discharges without shaking or jarring the scales.

501.3.4.5.4 Automatic and Semi-Automatic Batching Plants

(1) Use automatic and semi-automatic plants with bins, batchers, and scales conforming to the requirements specified above for manually operated batchers.

(2) Provide a means to protect the device for setting the batch weights against tampering by unauthorized personnel.

(3) Provide an audible signal device activated by the discharge of any batch whose weight is outside the specified tolerance. Ensure a loud enough signal to hear throughout the plant area under normal operating conditions.

(4) Provide automatic and semi-automatic batching plants with a device to indicate any underweight or overweight material.

(5) Provide automatic batching equipment with batching devices that if activated by a single starting mechanism, automatically batches or measures any given material, and automatically stops the flow of material after attaining the desired quantity, within the allowable tolerance.

(6) Use an interlocking batcher charging mechanism on automatic plants that guards against opening until the batcher entirely discharges and the scale balances within +/- 0.3 percent of the scale capacity, and against opening if the batcher discharge gate is open. Also, it should interlock to ensure against opening if the batcher charging mechanism is open, and against opening if the batch is either over or underweight by more than 1.5 percent of the specified batch weight in individual batchers or 1.5 percent of the specified intermediate and final accumulative batch weight in accumulative batchers.

(7) Provide semi-automatic batching equipment with suitable batching devices that open or start separately, if actuated by individual starting mechanisms, to allow weighing or measuring the material, and close or stop automatically after attaining the desired quantity, within the allowable tolerance.

(8) Use an interlocking batcher discharge mechanism for semi-automatic plants to ensure against opening if the batch is either over or underweight by more than 1.5 percent of the specified batch weight in individual batchers, or 1.5 percent of the specified intermediate and final accumulative batch weights in accumulative batchers.

(9) Ensure that the batcher discharge mechanisms of automatic or semi-automatic plants interlock against opening until aggregate batchers and the cement batcher are charged with the correct weights.

(10) Equip the batching system with automatic controls to stop the cycle in the underweight check position and the overweight check position for each material to allow tolerance limit checking.

(11) The contractor may use a batching system consisting of a combination of automatic and semi-automatic batchers provided it furnishes the appropriate controls and interlocks.

(12) If the control system of automatic or semi-automatic batching plants breaks down, the contractor may manually operate plants for up to 72 hours while making repairs.

501.3.4.6 Weighing Equipment for Cement, Fly Ash, and Slag

(1) The contractor may use manual, automatic, or semi-automatic batchers for batching cement. If using a combination of bin, batcher, and scales to proportion cement in bulk, conform to 501.3.4.5 for batching plants, with the following additions and exceptions:

(2) Use a separate batcher and scales.

(3) If using a beam scale, provide a tare beam and a weigh beam or beams capable of being lifted out of weighing position to allow checking the batcher's tare weight to determine if it discharges all the cement into the batch, unless there are other positive means to determine if complete discharge took place.

(4) Mechanically operate the batcher discharge gate in a way that does not affect the scale balance.

(5) Ensure that the batcher charging mechanism of automatic batchers interlock against opening until the batcher entirely discharges and the scale balances within +/- 0.3 percent of scale capacity, and against opening if the batcher discharge gate is open. Also, it should interlock against opening if the batcher charging mechanism is open; and against opening if the batch is either over or underweight by more than one percent of the specified batch weight.

(6) If using semi-automatic batchers, ensure the batcher discharge mechanism interlocks against opening if the batch is either over or underweight by more than one percent of the specified batch weight.

(7) Ensure that the batcher discharge mechanisms of automatic or semi-automatic plants interlock against opening until charging the cement batcher and aggregate batchers with the correct weight.

(8) The contractor may weigh and batch fly ash or slag along with the cement, but if this occurs, weigh the cement into the batcher first, and then add the fly ash or slag to the top of the batch of cement to the appropriate accumulative weight.

(9) For separate scales, bins, and hoppers used to batch fly ash or slag conform to the requirements specified above for cement-weighing equipment.

501.3.4.7 Dispensing Equipment for Admixtures

(1) Use accurate, volumetric, mechanical measuring dispensers, capable of presetting to deliver a specified quantity of admixture, or engineer-approved scales. Furnish a separate volumetric dispenser or scale for each admixture. Use a dispensing system with a device that either detects and indicates the presence or absence of flow of the admixture, or provides a convenient way to visually observing the admixture during batching or discharging. Ensure that the dispenser piping is free from leaks and properly valved to prevent back flow or siphoning.

(2) Interlock admixture-dispensing systems used in conjunction with semi-automatic plants, automatic plants, or on-site mixers of 21 cubic feet or more with the batching operations. Ensure that the system is capable of dispensing the admixture within +/- 3.0 percent of the required volume or weight of admixture, or the minimum dosage rate per 100 pounds of cement, whichever is greater.

501.3.5 Ready-Mixed Concrete

501.3.5.1 General

(1) The contractor may use ready-mixed concrete instead of site-mixed concrete, except for grade E concrete. Do not use ready-mixed concrete to produce grade E concrete.

(2) Interpret ready-mixed concrete to include central-mixed, transit-mixed, and shrink-mixed concrete, defined as follows:

Central-mixed concrete	Concrete completely mixed in a stationary mixer and transported to the point of delivery with or without mechanical agitation in the transporting vehicle.
Transit-mixed concrete	Concrete completely mixed in a truck mixer.
Shrink-mixed concrete	Concrete mixed partially in a stationary mixer with the mixing completed in a truck mixer.

501.3.5.2 Delivery

(1) Deliver ready-mixed concrete at a rate that ensures reasonably continuous progress in the placing and finishing operations. If the time intervals between successive loads or batches causes a partial drying of previously placed concrete provide additional equipment of the kind necessary to preclude these delays. Failing in this, discontinue use of ready-mixed concrete and use site-mixed concrete.

(2) Provide sufficient facilities for the production and delivery of ready-mixed concrete for concrete pavement to ensure placement at a uniform rate of not less than 80 cubic yards per hour, unless performing single-lane construction.

(3) Deliver and completely discharge the concrete within the following limits, beginning when adding water to the cement, or when adding cement to the aggregates.

Delivered in Agitating Vehicles:

- 60 minutes if the concrete temperature is 60 F or higher at placement, and the contractor does not use a department-approved retarder.
- 90 minutes if the concrete temperature is less than 60 F at placement.
- 90 minutes if the concrete temperature is 60 F or higher at placement, and the contractor uses a department-approved retarder.

Delivered in Non-Agitating Vehicles:

- 30 minutes if the concrete temperature is 85 F or higher at placement, and the contractor does not use a department-approved retarder.
- 45 minutes if the concrete temperature is 60 to less than 85 F at placement, and the contractor does not use a department-approved retarder.
- 60 minutes if the concrete temperature is less than 60 F at placement.
- 60 minutes if the concrete temperature is 60 F or higher at placement, and the contractor uses a department-approved retarder.

(4) The engineer or inspector will consult with BTS if a hydration controlling admixture, as specified in 501.2.5.3.5, is added to the mixture.

(5) The engineer or inspector may reduce these times under conditions contributing to quick stiffening of the mix, or during cold weather when loss of heat occurs to the extent that the concrete temperature is not correct at placement.

(6) Except during the mixing revolutions, operate the drum or agitator of the vehicle at agitating speed until discharging the mix. Ensure the concrete's uniform composition, required consistency, and required air content at time of delivery.

(7) The contractor may deliver central-mixed concrete to the work site by equipment with non-agitating body types. These body types are smooth, mortar-tight, metal containers capable of discharging the concrete at a satisfactorily controlled rate. Do not use aluminum bodies. Provide watertight covers for protection against the weather if necessary. The concrete in these vehicles should show no appreciable water gain at the surface. The concrete should freely and readily discharge from the vehicle, be free of excessive segregation of the fine and coarse aggregates, and have an air content within the required range at the point of discharge. Slump tests made during discharge should not differ by more than 2 inches. Remove foreign material and accumulated concrete before batching concrete into those vehicles.

501.3.5.3 Mixers and Mixing

(1) The contractor may use stationary mixers, or truck mixers of the revolving drum type or, with the engineer's written approval, other types specifically designed for mixing. For agitators, use truck mixers or truck agitators. The manufacturer shall attach in a prominent place, to each stationary mixer, truck mixer, or truck agitator a metal plate plainly marked with the various uses of the equipment, the drum or container capacity in volume of mixed concrete, and the rotation speed of the mixing drum or blades.

(2) If using a stationary mixer to mix concrete, mix at least one minute, provided that plant operating procedures are reasonably stabilized and controlled, and that it achieves visible blending of materials during charging to the engineer's satisfaction. If this mix time does not achieve proper stabilization, control, and blending, the engineer may increase the mixing time to 75 seconds.

(3) Exceptions to the minimum mixing time for stationary mixers specified above are contained in an approved list, BTS maintains, of reduced minimum mixing times for specific makes and models of stationary mixers. If these department-approved reduced minimum mixing times do not produce satisfactory stabilization, control, and blending the engineer may increase the mixing time as needed.

(4) Blending implies a uniform volume of flow of all batch ingredients throughout the charging time interval, except for the brief introduction of water and coarse aggregate. Charge the batch into the mixer so that:

1. Some water enters shortly before the solid material, and all water is in the drum by the time mixing begins.
2. Introduce admixtures uniformly throughout the charging time interval.
3. Introduce some coarse aggregate before other solid materials.
4. For the remaining solid material charging time, introduce the large and small sizes of the coarse aggregate, sand, and cement in an acceptably uniform rate of flow, as determined by visual inspection.
5. Start mixing time after all solid materials are in the mixer.

(5) The maximum mixing time for stationary mixers must not exceed the minimum specified above, by more than 60 seconds.

(6) Consider transfer time in multiple drum mixers as part of the mixing time.

(7) For stationary mixers, compute the total mixed concrete volume based on the nominal cubic yard determined in DT2220 or DT2221.This volume must not exceed the manufacturer's rated maximum mixing capacity, for the type and volume of mixer used, in the concrete plant mixer standards of the Concrete Plant Manufacturer's Bureau.

(8) Equip stationary mixers with a timing device that automatically locks the discharge mechanism during the full mixing time and releases it at the end of the mixing period.

(9) If mixing concrete in a truck mixer, mix each batch for 70 or more revolutions at the manufacturer-designated mixing speed. Do not exceed 300 total revolutions per batch, the sum of the revolutions at mixing and agitating speeds. Begin mixer revolutions only after all materials, including mixing water are in the mixer.

(10) Add the mixing water at the batching plant, but if obtaining the specified slump requires more water, add it in the field with the engineer’s permission. Do not exceed the maximum specified water to cementitious materials ratio. Calculate the maximum water as the sum of free water added with the aggregates and all added mixing water. If adding more water at the work site, perform an additional 20 revolutions of the truck mixer at mixing speed before discharging any concrete. The process of adding more water and additional mixing must happen within 45 minutes of introducing the mixing water to the cement or the cement to the aggregates. The engineer may extend the time limit for adding water and additional mixing to 75 minutes for those grades of concrete mixed under the conditions described in 501.3.5.2 whose delivery time limit is 1 1/2 hours. If additional mixing revolutions are necessary because of added water at the site, the total revolutions at mixing and agitating speeds must not exceed 300.

(11) If using a truck mixer or agitator to transport concrete completely mixed in a stationary mixer, rotate the drum or agitator at the agitating speed during transportation and until discharge.

(12) Equip truck mixers with an engineer-approved revolution counter. Unless equipped to control and count revolutions at mixing speed, perform mixing at the batching plant or job site with the mixer operated at agitating speed while in transit.

(13) For truck mixers operating from plants erected to supply concrete to highway projects, if the delivery time is short enough that the truck cannot exceed the maximum number of revolutions at mixing speed in transit, then mixer may operate at mixing speed in transit.

(14) If using a stationary mixer for partial mixing of the concrete, the contractor may reduce the mixing time in the stationary mixer to the minimum required to blend the ingredients, about 30 seconds.

(15) If using a truck mixer to finish the partial mixing done in a stationary mixer, mix each batch for 50 or more revolutions at the manufacturer-recommended speed. Do not exceed 300 total revolutions at mixing and agitating speeds.

(16) For truck mixers, compute the total concrete volume mixed per batch based on the nominal cubic yard determined in DT2220 or DT2221 and do not exceed the manufacturer's rated capacity, or the following percentages of the drum’s gross volume:

- For complete mixing, 63 percent.
- For partial mixing, initial (shrink) mixing done in stationary mixer, 70 percent.

(17) The engineer may obtain representative samples from approximately the 1/6 and 5/6 discharge points of the concrete load of any truck mixer or truck agitator. If the slump of the 2 samples differs by more than one inch, or the entrained air content in them differs by more than one percent, correct the condition before using the load.

(18) For central-mixed or shrink-mixed concrete, if using more than one batch to make up a load, properly proportion each batch using all the ingredients, including admixtures, fly ash, or slag.

(19) Do not incorporate water used to clean mixing equipment and accessories into the mix.

(20) Replace the pick-up and throw-over blades of truck mixers or agitators if any part or section is worn one inch or more below their original height. Provide a copy of the manufacturer's design, showing dimensions and blade arrangement, upon the engineer's request.

501.3.5.4 Inspection

(1) Notify the engineer at least 24 hours before the contractor requires delivery of ready-mixed concrete so the engineer can inspect the proposed ready-mix plant and facilities.

(2) With each load of ready-mixed concrete, provide a computer-printed batch ticket which includes load and truck identification, the actual batch weights of all materials in that load, the mixing time for central plant-mixed concrete or the start of the batch life as specified in 501.3.5.2(3) for transit-mixed concrete, and other pertinent data. Give batch tickets to the inspector upon arrival at the work site. The department will only accept loads that arrive in satisfactory condition and have a batch ticket. The engineer will only accept hand written batch tickets in remote locations where no computerized plant is available within deliverable distance of the work site.

(3) Instead of requiring a batch ticket for each load, the engineer may accept central-mixed concrete used in pavement and associated bid items based on daily production records from a computer-controlled plant erected specifically for work under the contract. Submit a complete load-by-load written record that ties the truck IDs to the batch quantities and batch times for each day's production to the engineer at the end of each day's production. During concrete production, operate under a plan acceptable to the engineer that ties the truck ID to the batch quantities and batch time for each load. In that plan describe how that information will be made available to the engineer immediately upon request. The engineer may also require batch tickets to address short-term operational difficulties.

(4) The engineer may accept minor quantities of ready-mixed concrete used in miscellaneous bid items without batch tickets.

501.3.6 Site-Mixed Concrete

501.3.6.1 General

(1) Site-mixed concrete is concrete manufactured in standard batch or volumetric type portable mixers at the work site. Use volumetric mixers only for work that specifically allows volumetric proportioning.

501.3.6.2 Batch Mixer

(1) Use a powered revolving drum type mixer conforming to the following requirements, unless the engineer allows another type.

(2) Maintain the mixer in good working order and operate it in a way that does not combine the mixed batch with the following dry batch, and so that the ingredients of only one batch are intermixed with each charge of the mixer. Keep charging devices, the throat, and drum interior free of accumulated materials. If charged with the batch, revolve the mixer drum at a speed that does not exceed the manufacturer's specified speed for the mixer, provided the drum makes between 14 and 20 revolutions per minute. Replace pick-up and throw-over blades showing a wear in excess of 3/4 inch from their original factory depth. Mixers must have a rated capacity of at least 5 cubic feet of mixed concrete per batch.

(3) Equip mixers with an engineer-approved automatic timing device, in proper working order, designed and constructed so that it starts when the charging skip is raised and dumped. The timing mechanism must have a device that transmits an audible or visible signal when mixing is complete.

(4) Equip mixers, with a rated capacity of 21 cubic feet or more of mixed concrete, with an engineer-approved discharge-locking device, in good working order, and automatically controlled by the timing device.

(5) Keep the box or compartment containing the timing device closed and locked at all times except for adjustment or repairs. Only the contractor or an authorized representative shall make adjustments under the direct supervision of the engineer or inspector.

(6) Compute the total volume of concrete mixed per batch based on the nominal cubic yard determined in DT2220 or DT2221 and do not exceed the mixer's rated capacity by more than 10 percent as established by the Mixer Manufacturer's Bureau of the Associated General Contractors of America. The capacities above are contingent on the mixer drum retaining the batch without segregating, spilling, or leaking during charging, mixing, and discharging; and upon adequate methods of handling, placing and finishing the resultant concrete.

(7) Stop using and repair or replace with a satisfactory mixer, any concrete mixer that is not adequate or suitable for the work, has insufficient power, inefficient mixing action, or has auxiliary units that do not function properly.

501.3.6.3 Batch Mixing Time

(1) Mix each batch for at least 50 seconds but not more than 90 seconds. During this time, the drum revolves at the rate specified above. Start the mixing time after all solid materials are in the drum.

(2) Introduce the mixing water to the drum ahead of the other materials and continue to discharge for a short time after all solid materials are in the drum.

501.3.6.4 Volumetric Plant and Mixer

(1) Use a truck-mounted mobile concrete plant and mixer, designed for automatic volume proportioning of concrete materials, and for mixing concrete for immediate use at the work site, for grade E concrete, and the engineer may allow its use for bid items from other grades. This machine must produce a thoroughly mixed and uniform concrete.

(2) Calibrate the plant on a weight-volume relationship according to the manufacturer's recommended procedures. Recalibrate the plant if changing aggregates and, as the engineer deems necessary.

(3) Volumetric proportioning equipment and procedures are subject to the engineer's approval. Equip the plant with either a water flowmeter or a recording water meter.

501.3.7 Concrete Consistency

(1) Concrete must have a uniform consistency, with all ingredients uniformly distributed throughout the weight, and so that the mortar clings to the coarse aggregate. Concrete must not have a consistency sufficiently wet so it flows and segregates, or a mealy, dry consistency.

(2) Use the minimum quantity of water that achieves the desired workability, as the engineer determines. Obtain the engineer's approval of any changes in this quantity.

501.3.7.1 Slump

(1) Use a 1-inch to 4-inch slump for concrete used in structures or placed in forms, except as follows:

- Do not exceed a slump of 2 inches for grade E concrete.
- Increase slump as specified in 502.3.5.3 for concrete placed underwater.
- The contractor may increase the slump to a maximum of 9 inches for a mixture that contains a high range water reducer conforming to 501.2.5.3.3. Do not exceed the maximum w/cm allowed for the grade of concrete being used when a high range water reducer is in use.

(2) Use the applicable slump specified in 415.2.1 for concrete pavements.

(3) Concrete pavement repair and replacement must conform to the following:

- Use the following slumps for the technique used:

SLIP-FORMED	NOT SLIP-FORMED
2.5 inches or less	4 inches or less

- The contractor may increase the slump to a maximum of 9 inches for a mixture that contains a high range water reducer conforming to 501.2.5.3.3. Do not exceed the maximum w/cm allowed for the grade of concrete being used when a high range water reducer is in use.

(4) Perform the slump tests for concrete according to WTM T119.

501.3.8 Placing

501.3.8.1 General

(1) Except as specified in 501.3.5.2 for ready-mixed concrete, place the concrete within 30 minutes of first adding water to the batch. Use placement techniques that minimize segregation. Batch, mix, place, and finish concrete within a monolithic unit as continuously as practicable.

501.3.8.2 Hot Weather Concreting

501.3.8.2.1 General

(1) The contractor is responsible for the quality of the concrete placed in hot weather. For concrete placed under the bid items enumerated in 501.3.8.2.1(2), submit a written temperature control plan at or before the pre-pour meeting. In that plan, outline the actions the contractor will take to control concrete temperature if the concrete temperature at the point of placement exceeds 80 F. Do not place concrete under these bid items without the engineer's written acceptance of that temperature control plan. Perform the work as outlined in the temperature control plan.

(2) If the concrete temperature at the point of placement exceeds 90 F, do not place concrete under the following structure and concrete barrier bid items:

Concrete Masonry Bridges	Concrete Masonry Retaining Walls
Concrete Masonry Bridges HES	Concrete Masonry Retaining Walls HES
Concrete Masonry Culverts	Concrete Masonry Endwalls
Concrete Masonry Culverts HES	Concrete Masonry Overlay Decks
Concrete Barrier Single-Faced 32-Inch	Concrete Barrier (type)
Concrete Barrier Double-Faced 32-Inch	Concrete Barrier Fixed Object Protection (type)
Concrete Barrier Transition Section 32-Inch	Concrete Barrier Transition (type)

(3) The department will pay $0.75 per pound for the quantity of ice required to reach a target concrete temperature of 80 F if the following conditions are met:

1. The un-iced concrete temperature exceeds 85 F.
2. The contractor has performed the actions outlined in the contractor's accepted temperature control plan.
3. The contractor elects to use ice.

(4) If the engineer directs the contractor to use ice when the un-iced concrete temperature is 85 F or less, the department will pay $0.75 per pound for that ice.

(5) Notify the engineer whenever conditions exist that might cause the temperature at the point of placement to exceed 80 F. If project information is not available, the contractor should obtain information from similar mixes placed for other nearby work.

501.3.8.2.2 Bridge Decks

(1) For concrete placed in bridge decks under the bid items enumerated in 501.3.8.2.2(2), submit a written evaporation control plan at or before the pre-pour meeting. In that plan, outline the actions the contractor will take to maintain concrete surface evaporation at or below 0.2 pounds per square foot per hour. Do not place concrete under these bid items without the engineer's written acceptance of that evaporation control plan. If the engineer accepts an evaporation control plan calling for ice, the department will pay $0.75 per pound for that ice. Perform the work as outlined in the evaporation control plan.

(2) If predicting a concrete surface moisture evaporation rate exceeding 0.2 pounds per square foot per hour, do not place bridge deck concrete under the following bid items:

Concrete Masonry Bridges	Concrete Masonry Overlay Decks
Concrete Masonry Bridges HES	

(3) Provide evaporation rate predictions to the engineer under one or more of the following conditions:

1. Conditions exist that might cause concrete surface evaporation to exceed 0.2 pounds per square foot per hour.
2. The concrete temperature at the point of placement exceeds 80 F.
3. The engineer requests that information.

(4) Compute the evaporation rate from the predicted ambient conditions at the time and place of the pour using the nomograph provided in CMM 525 Figure 1, or using a computerized equivalent. Use weather information from the nearest national weather service station. The engineer will use this information to determine if the pour will proceed as scheduled.

(5) On the day before the pour, the engineer will notify the contractor in writing whether or not to proceed with the pour as scheduled. If the actual computed evaporation rate during the pour exceeds 0.2 pounds per square foot per hour, the engineer may allow the contractor to complete the pour. If the engineer allows placement to continue, the department will pay $0.75 per pound for the quantity of ice required to maintain concrete surface evaporation at or below 0.2 pounds per square foot per hour. If ice is not available the department will pay for any actions, beyond those described in the contractor's evaporation plan, required to complete the pour as the engineer directs.

501.3.9 Mixing and Protecting During Cold Weather

(1) Mix, place, and protect concrete according to the method specified below, applicable to its use.

(2) Mix, place, and protect concrete for pavement, pavement repair and replacement, pavement widening, pavement gaps, driveways, alleys, headers, surface drains, pavement approach slabs, base, base widening or patching, curb, gutter, curb & gutter, ditch checks, sidewalks, steps not a part of a structure, loading zones, safety islands and other concrete of a similar nature as specified in 415.3.13.

(3) Mix, place, and protect concrete for bridges, culverts, retaining walls, end walls, or any other structure consisting, wholly or in part, of concrete, if placed during cold weather, as specified in 502.3.9.

501.4 (Vacant)

501.5 Payment

(1) The department will not pay directly for the concrete specified under this section. Concrete is incidental to the various bid items using it. Payment under those bid items includes providing materials, including aggregates and associated aggregate source testing, cement, fly ash, slag, and admixtures; and for preparing, transporting, storing, protecting and curing concrete.

(2) If required to remove and replace any concrete damaged by lack of proper protection. Perform this work at no expense to the department.

(3) The department will pay for ice used to cool concrete in hot weather as specified in 501.3.8.2 under the Ice Hot Weather Concreting administrative item.