SECTION 501

CONCRETE

501.1 Description. Concrete shall consist of a mixture of cement, fine aggregate, coarse aggregate and water, combined in the proportions specified for the various classes. Admixtures may be added as specifically required or permitted.

501.2 Material. All material shall be in accordance with Division 1000, Material Details, and specifically as follows:

Item	Section
Coarse Aggregate[a]	1005.2
Fine Aggregate[a]	1005.3
Ground Granulated Blast Furnace Slag	1017
Fly Ash	1018
Cement	1019
Concrete Admixture	1054
Concrete Tinting Material	1056
Water	1070

[a]Regardless of the gradation of the coarse and fine aggregate used in concrete for pavement or base, the aggregate shall meet the quality requirements of coarse and fine aggregate for concrete pavement.

501.2.1 Aggregate Acceptance. Aggregate for Portland cement concrete masonry will be sampled and tested by the engineer in accordance with the following table at the last possible point of incorporation into the project.

Item	Property	Minimum Number of Tests
Portland Cement Concrete Masonry	Gradation of Coarse Aggregate - AASHTO T 27 and T 11	One per 500 cubic yards per fraction per project. None if less than 100 cubic yards.
	Gradation of Fine Aggregate - AASHTO T 27 and T 11	
	Deleterious Content - MoDOT Test Method TM 71	
	Absorption of Coarse Aggregate - AASHTO T 85	
	Thin or Elongated Pieces - ASTM D 4791 (+3/4 in., 5:1)	One per project.

501.2.2 Retained Samples. The engineer shall retain the portion of the sample not tested after reducing the original sample to testing size. Approximately twenty percent of the retained samples will be sent to the Central Laboratory for comparison purposes.

501.3 Mix Design. The proportions of cement, fine aggregate and coarse aggregate for concrete shall be approved by the engineer within the applicable limits of the specifications for the class of concrete specified in the contract. The contractor shall submit a mixture designed by absolute volume methods or an optimized mix design method such as Shilstone method or other recognized optimization method. Optimized will refer to aggregate gradations that produce lower water demands, as well as improved workability and finishing characteristics. The target and allowable gradation range of each fraction shall be included. The contractor

may be required to submit representative samples of each ingredient to Construction and Materials for laboratory testing.

501.3.1 Required Information. The concrete mix design shall contain the following information:

(a) Source, type and specific gravity of Portland cement

(b) Source, type (class, grade, etc.) and specific gravity of supplementary materials, if used

(c) Source, name, type and amount of admixtures

(d) Source, type (formation, etc.), ledge number if applicable, and gradation of the aggregate

(e) Specific gravity and absorption of each fraction in accordance with AASHTO T 85 for coarse aggregate and AASHTO T 84 for fine aggregate, including raw data

(f) Unit Weight of each fraction in accordance with AASHTO T 19

(g) The percent of each aggregate component used for optimized concrete mixes

(h) The design air content and slump

(i) Batch weights of Portland Cement and supplemental cementious materials

(j) Batch weights of coarse, intermediate and fine aggregates

(k) Batch weight of water

501.3.2 Paving Concrete. For PCCP mixes, the gradation requirements of Sec 1005 will not apply. For all fractions, 100 percent of each fraction shall pass the 2-inch (50 mm) sieve. When Grade F is required, 100 percent of each fraction shall pass the 3/4-inch (19.0 mm) sieve.

501.3.3 Optimized Masonry Concrete. For optimized PCCM mixes, the gradation requirements of Sec 1005.2 and Sec 1005.3 will not apply. For coarse aggregate, 100 percent of each fraction shall pass the one-inch (25 mm) sieve and no more that 2.5 percent shall pass the No. 200 (75 μm) sieve. For fine aggregate, no more than 2.0 percent shall pass the No. 200 (75 μm) sieve for natural sand, and no more than 4.0 percent shall pass the No. 200 (75 μm) sieve for manufactured sand.

501.3.4 Non-Optimized Masonry Concrete. When optimized aggregate gradations are not selected by the contractor, all provisions, including gradations requirements of Sec 105 shall apply

501.3.5 Fine Aggregate Classes. Fine aggregates are grouped into four classes and a minimum cement factor has been established for each class.

501.3.6. Cement Factors. The minimum cement requirements in pounds per cubic yard (kg/m^3) of concrete for the various classes of sand shall be as follows:

Cement Requirements[a,b]							
Class of Sand	**Class A-1 Concrete**	**Class B Concrete**	**Class B-1 Concrete**	**Class B-2 Concrete**	**Class MB-2 Concrete[g,h]**	**Pavement Concrete**	**Seal Concrete**
A[c]	600(360)	525(310)	610(360)	705(420)	600(360)	560(330)	660(390)
B[d]	640(380)	565(330)	640(380)	735(430)	620(370)	560(330)	695(410)
C[e]	--	585(350)	660(390)	750(450)	640(380)	560(330)	715(420)
D[f]	--	620(370)	695(410)	790(470)	660(390)	560(330)	735(430)

[a]When used, Type IP, I(PM), IS or I(SM) cement shall be substituted on a pound for pound (kg for kg) basis for Type I or Type II cement and adjustments in design mix proportions will be required to correct the volume yield of the mixture.

[b]The contractor may submit an optimized mix design which has a maximum 50 pounds per cubic yard (30 kg/m^3) reduction in cement from that shown in the tables. If the contractor chooses this option, the mixture will be subject to review, laboratory testing and approval by the engineer. All other requirements for the cement factor will apply.

[c]Class A sand will include all sand, except manufactured sand, weighing 109 pounds per cubic foot (having a mass of 1740 kg/m^3) or more.

[d]Class B sand will include all chert, river and Crowley Ridge sand weighing from 106 to 108 pounds, inclusive, per cubic foot (having a mass of 1610 - 1730 kg/m^3 inclusive) or glacial sand weighing 108 pounds or less per cubic foot (having a mass of 1730 kg/m^3 or less).

[e]Class C sand will include all chert, river and Crowley Ridge sand weighing from 101 to 105 pounds, inclusive, per cubic foot (having a mass of 1610 - 1680 kg/m^3, inclusive).

[f]Class D sand will include all sand weighing 100 pounds or less per cubic foot (having a mass of 1600 kg/m^3 or less) and any manufactured sand that is produced by the process of grinding and pulverizing large particles of aggregate or which contains more than 50 percent of material produced by the reduction of coarser particles. Manufactured sand produced from limestone or dolomite shall not be used in Portland cement concrete for driving surfaces such as bridge decks, pavements and shoulders.

[g]Modified B-2 (MB-2) concrete may be used in-place of Class B-2 Concrete.

[h]Modified B-2 (MB-2) concrete shall use at least one supplementary cementitious material in accordance with this specification. In no case shall MB-2 concrete use less than 15 percent fly ash or GGBFS when used as the individual supplementary cementitious material. In no case shall MB-2 concrete use less than 6 percent metakaolin when used as the individual supplementary cementitious material.

501.3.7 Unit Weight. The weight per cubic foot (mass/m^3) shall be the dry rodded weight per cubic foot (mass/m^3) of the aggregate, determined in accordance with AASHTO T 19.

501.3.8 Compressive Strength Requirements. Concrete classes shall meet the following compressive strength requirements in pounds per square inch (MPa):

Minimum Design Compressive Strength[1]						
Class A-1 Concrete	**Class B Concrete**	**Class B-1 Concrete**	**Class B-2 Concrete**	**Class MB-2 Concrete**	**Pavement Concrete**	**Seal Concrete**
6,000 (42)	3,000 (21)	4,000 (28)	4,000 (28)	4,000 (28)	4,000 (28)	3,000 (21)

[1]Minimum compressive strength required unless otherwise specified in the contract documents or approved by the engineer.

501.4 Sampling. Sampling of fresh concrete shall be in accordance with AASHTO T 141, except that for central or truck mixed concrete, the entire sample for slump and air tests and for molding compressive strength specimens may be taken at one time after approximately one

cubic yard (m^3) of concrete has been discharged, instead of at three or more regular intervals during the discharge of the entire batch. Acceptability of the concrete for slump and air content and, if applicable, for strength requirements, will be determined by tests on these samples.

501.5 Consistency. The slump of the concrete shall be within the limits for the respective classes of concrete. The concrete shall be uniform in consistency and shall contain the minimum quantity of water required to produce the designated slump. The slump of concrete mixes will be determined in accordance with AASHTO T 119. The quantity of mixing water in the concrete shall be considered the net quantity after proper allowance has been made for absorption by the aggregate. The slump and mixing water content of the concrete, when placed in the work, shall not exceed the following limits:

Slump and Maximum Water/Cementitious Materials Ratio			
Class of Concrete	**Max. Slump, In. (mm)**	**Max. Pounds of Mixing Water Per Pound of Cementitious Materials** (Max. Kilograms of Mixing Water Per Kilogram of Cement)	
		Air-Entrained	**Non-Air-Entrained**
A-1	3 1/2 (90)	0.46	0.51
B	4 (100)	0.51	0.55
B-1	4 (100)	0.44	0.53
B-2	3 (75)	0.40	----
MB-2	6 (150)	0.42	----
Pavement	----	0.50	0.53
Seal	8 (200)	----	0.53

501.6 Measurement of Material. The cement and aggregate for concrete shall be measured by weight (mass). The weights (masses) of coarse and fine aggregates to be used will be calculated from the proportions approved by the engineer. Batches that do not contain the proper quantities of material shall be wasted at the contractor's expense.

501.6.1 Weighing Tolerances. The weighing (mass determination) and batching equipment shall be designed and maintained in such a condition that the material for each batch can be quickly and accurately weighed (determined) and shall be operated within a tolerance of plus or minus 0.5 percent for cement and plus or minus 1.0 percent for aggregate. The equipment used for delivery of material to the weigh hoppers shall not permit intermingling of material. Weighing hoppers shall discharge completely and there shall be no accumulation of tare material. Scales shall be accurate to within 0.4 percent of the net load applied. The change in load required to change the position of rest of the indicating element or elements of indicating scales an observable amount shall not be greater than 0.1 percent of the nominal scale capacity. If beam-type scales are used, a separate beam shall be provided for each type of material to be used and means shall be provided for adjustment of tare on a scale separate from those used for other material.

501.6.2 Water Meter Tolerances. Mixing water shall be measured by volume or by weight (mass). If measured by weight (mass), scales shall be in accordance with Sec 501.6.1. The device for the measurement shall be readily adjustable and under all operating conditions shall measure the required quantity within a tolerance of one quart (one liter) or one percent, whichever is greater.

501.6.3 Calibration Frequency. Plant scales and water metering devices shall be calibrated and certified by an approved commercial scale service. A copy of the certification and calibration shall be provided to the engineer upon request. Plants shall be calibrated and certified annually, and whenever plants are moved or found to be out of tolerance during

verification. Scales and water metering devices shall be verified by the contractor in the presence of the engineer every 30 working days.

501.7 Mixing. The mixer shall produce concrete uniform in color, appearance and distribution of the material throughout the mixture. The cement, aggregate and no less than 60 percent of the water shall be mixed a minimum of one minute. The remaining water shall be added within 15 seconds after all other material for the batch is in the mixer. If mixers having multiple compartment drums are used, the time required to transfer material between compartments will be considered mixing time. The speed at which the drum rotates shall be as designated by the manufacturer. If such mixing does not result in uniform and smooth texture concrete, a sufficient number of additional revolutions at the same speed shall be performed until a thorough mixing of each batch of concrete is secured. The mixing time shall be measured from the time all cement, aggregate and 60 percent of the water are in the drum. The volume of concrete mixed in each batch shall not exceed the manufacturer's rated capacity. The mixer shall be equipped to automatically time the mixing of each batch of concrete. If the automatic timing device becomes inoperable, a manual timing device shall be provided to complete the day's operation.

501.8 Central and Truck Mixed Concrete. The following additional requirements will apply to central and truck mixed concrete.

501.8.1 Mixer Inspection. All central mixers, truck mixers and agitators shall be in accordance with of these specifications prior to use, and inspection of the equipment shall be made periodically during the work. Only equipment found acceptable in every respect and capable of producing uniform results will be permitted.

501.8.2 Uniformity Testing. Central mixed concrete shall be mixed in a stationary mixer. Except as otherwise permitted in accordance with Sec 501.8.9, the concrete shall be transported to the point of delivery in a truck mixer operating at agitating speed or in an agitator truck. The mixing time shall be in accordance with Sec 501.7, and as necessary to produce concrete that meets the uniformity criteria when tested in accordance with Section 10.3 of ASTM C 94, with the following additions and exceptions:

(a) the two samples shall be obtained within an elapsed time of no more than 15 minutes.

(b) The air content, slump and mix proportions of the concrete tested shall be in accordance with these specifications for that class of concrete or the uniformity tests shall be invalid.

(c) The use of a one-quarter cubic foot (0.007 m^3) measure will be permitted in determination of weight per cubic foot (mass/m^3).

(d) Cylinders may be cured in damp sand after the first 48 hours.

(e) The contractor may designate the mixing time for which uniformity tests are to be performed. The mixing time shall be a minimum of 60 seconds. The maximum mixing time shall not exceed the mixing time established by uniformity tests by more than 60 seconds for air-entrained concrete. The mixed concrete shall meet the uniformity requirements specified above before any concrete may be used for pavement or structures. The engineer may allow the use of the test concrete for appropriate incidental construction. Tests shall be performed by the contractor, in the presence of the engineer. No direct payment will be made for labor, equipment, material or testing. After operational procedures of batching and mixing are thus established, no changes in procedure will be permitted without re-establishing procedures by uniformity tests.

501.8.2.1 Measuring Mixing Time. Measurement of mixing time shall start at the time all the solid material is in the drum and shall end at the beginning of the next sequential operation.

501.8.2.2 Verification of Mixer. Mixer performance tests shall be repeated whenever the appearance of the concrete or the coarse aggregate content of samples selected in accordance with ASTM C 94, as modified above, indicates that adequate mixing is not being accomplished.

501.8.3 Truck Mixed Concrete. Truck mixed concrete shall be mixed at the proportioning plant and the mixer shall operate at agitating speed while in transit. Truck mixed concrete may be mixed at the point of delivery, provided the cement or cement and mixing water, are added at that point. Mixing of truck mixed concrete shall begin immediately after the introduction of the mixing water and cement to the aggregate or the introduction of the cement to the aggregate.

501.8.4 Truck Mixer Requirements. A truck mixer shall consist of a watertight revolving drum suitably mounted, fitted with adequate blades, and equipped with a device for determining the number of mixing revolutions. Truck mixers shall produce a thoroughly mixed and uniform mass of concrete and shall discharge the concrete without segregation. A truck agitator shall consist of a watertight revolving drum or a watertight container suitably mounted and fitted with adequate revolving blades. Truck agitators shall transport and discharge the concrete without segregation. Mixers and agitators shall be cleaned of accumulation of hardened concrete or mortar.

501.8.5 Rating Plate. Except as hereinafter permitted, each truck mixer shall have permanently attached to the truck a metal rating plate issued by and in accordance with the capacity requirements of the Truck Mixer Manufacturers Bureau (TMMB), as approved by NRMCA, on which is stated the maximum capacity in terms of volume of mixed concrete for the various uses to which the equipment is applicable. The truck shall also have attached a manufacturer's data plate that shall state the actual capacity as an agitator, and the maximum and minimum mixing and agitating speeds. If truck mixers are used for mixing or agitating, the volume of concrete in each batch shall not exceed the maximum capacity shown on the metal rating plate issued by the TMMB, as approved by NRMCA, except that if a lower capacity for agitating is shown on the manufacturer's data plate, that lower capacity shall govern. The minimum batch size for truck mixers shall be one cubic yard (m^3). The engineer may reduce the batch size or reject use of any truck mixer that does not produce concrete uniform in color, appearance and distribution of material throughout the mass. A quantity of concrete that results in axle and gross loads in excess of statutory limits will not be permitted.

501.8.6 Truck Mixing Requirements. Truck mixers and agitators shall be operated at the speed of rotation designated by the manufacturer of the equipment. Truck mixed concrete shall initially be mixed no less than 70 or more than 100 revolutions of the drum at mixing speed after all ingredients, including water, are in the mixer, except that when the batch volume does not exceed 57.5 percent of the gross volume of the drum or 91 percent of the rated maximum capacity, the number of revolutions required for mixing shall be no less than 50 or more than 100. When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed, agitation of the concrete shall continue during transportation at the speed designated by the manufacturer of the equipment as agitating speed. Water may be added to the mixture no more than two times after initial mixing is completed. Each time water is added, the drum shall be turned an additional 30 revolutions, or more if necessary, at mixing speed, until uniform mixing is accomplished. All water added will be included in determining the effective water in the mixture.

501.8.7 Water Adjustments at Job Site. Each increment of water added at the job site shall be measured within a tolerance of one percent of the total effective water required for the batch. Water used to wash the drum of the mixer shall not be used as mixing water.

501.8.8 Handling and Discharge Requirements. Central or truck mixed concrete shall be delivered to the site of the work and shall meet the following conditions:

(a) The handling and discharge of concrete shall not cause segregation or damage to the concrete and will allow placement with a minimum of handling. All handling and discharge shall occur prior to initial set of the concrete.

(b) Truck mixed concrete shall not exceed 300 revolutions after the beginning of mixing.

501.8.9 Non-Agitating Equipment. The discharge of concrete transported in non-agitating equipment shall not cause segregation or damage to the concrete and will allow placement with a minimum of handling. All handling and discharge shall occur prior to initial set of the concrete. Bodies of non-agitating hauling equipment shall be smooth, mortar-tight metal containers capable of discharging the concrete at a satisfactory, controlled rate without segregation.

501.8.10 Testing Facilities. Proper facilities shall be provided for the engineer to inspect ingredients and processes used in the manufacture and delivery of the concrete. A Type 1 field laboratory in accordance with Sec 601 shall be provided at the proportioning plant. Facilities for obtaining representative samples of each fraction of aggregate, cement and each admixture just prior to incorporation into the mix shall be provided by the producer. Aggregate samples may be taken either by sampling the flowing aggregate stream or by belt sampling. The producer shall furnish the necessary equipment and personnel to assist the engineer in obtaining a representative sample.

501.8.11 Delivery Tickets. The manufacturer of truck mixed concrete and of central mixed concrete for use in structures shall furnish to the engineer with each truck load of concrete before unloading at the site, a delivery ticket on which is shown information concerning the concrete as follows:

(a) Name of concrete plant.

(b) Serial number of the ticket.

(c) Truck number when a truck mixer is utilized.

(d) Name of contractor.

(e) Job Number, route and county designation.

(f) Specific class of concrete.

(g) Quantity of concrete in cubic yards (m^3).

(h) Date and time when batch was loaded or of first mixing of cement and aggregate.

(i) Number of revolutions, when truck mixed.

501.9 Volumetric Batched and Continuous Mixed Concrete. Upon written request by the contractor, the engineer may approve the use of concrete proportioned by volume. If concrete is proportioned by volume, the other requirements of these specifications with the following modifications will apply.

501.9.1 Proportional Devices. Volume proportioning devices, such as counters, calibrated gate openings or flow meters, shall be available for controlling and determining the quantities of the ingredients discharged. In operation, the entire measuring and dispensing mechanism shall produce the specified proportions of each ingredient.

501.9.2 Controls. All indicating devices that affect the accuracy of proportioning and mixing of concrete shall be in full view of and near enough to be read by the operator while concrete is being produced. The operator shall have convenient access to all controls.

501.9.3 Calibration. The proportioning devices shall be calibrated by the contractor in the presence of and subject to approval from the engineer. Calibration of the cement and aggregate proportioning devices shall be accomplished by weighing (determining the mass of) each component. Calibration of the admixture and water proportioning devices shall be accomplished by weight (mass) or volume. Tolerances in proportioning the individual components will be as follows:

Item	Tolerance
Cement, Weight (Mass) percent	0 to +4
Fine Aggregate, Weight (Mass) percent	± 2
Coarse Aggregate, Weight (Mass) percent	± 2
Admixtures, Weight (Mass) or Volume percent	± 3
Water, Weight (Mass) or Volume Percent	± 1

501.9.4 Verification of Yield. Verification of the proportioning devices may be required at any time by the engineer. Verification shall be accomplished as follows. With the cement meter set on zero and all other controls set for the designated mix, the activated mixer shall discharge mixed material into a 1/4 cubic yard (0.25 m^3) container measuring 36 x 36 x 9 inches (1000 x 1000 x 250 mm). When the container is level-struck full, making provisions for settling the material into all corners, the cement meter shall show a discharge equal to the design proportion of cement for 1/4 cubic yard (0.25 m^3). A tolerance of ± 1/8 inch (± 3 mm) from the top of the container will be permitted. If the correct yield is not obtained, the proportioning devices shall be adjusted to obtain the design mix or the proportioning devices shall be recalibrated as directed by the engineer.

501.9.5 Water Control. The rate of water supplied shall be measured by a calibrated flow meter coordinated with the cement and aggregate feeding mechanism and with the mixer. The rate shall be adjustable in order to control slump at the desired level.

501.9.6 Liquid Admixture. Liquid admixtures shall be dispensed through a controlled flow meter. A positive means to observe the continuous flow of material shall be provided. If an admixture requires diluting, the admixture shall be diluted and thoroughly mixed prior to introducing the admixture into the dispenser. When admixtures are diluted, the ratio of dilution and the mixing shall be approved by and performed in the presence of the engineer.

501.9.7 Concrete Mixer. The concrete mixer shall be approved by the engineer and shall be an auger-type continuous mixer used in conjunction with volumetric proportioning. The mixer shall produce concrete, uniform in color and appearance, with homogeneous distribution of the material throughout the mixture. Mixing time necessary to produce uniform concrete shall be established by the contractor and shall comply with other requirements of

these specifications. Only equipment found acceptable in every respect and capable of producing uniform results will be permitted.

501.9.7.1 Material Storage Capacity. The continuous mixer shall be capable of carrying sufficient unmixed dry bulk cement, fine aggregate, coarse aggregate, admixtures and water, in separate compartments to produce no less than 6 cubic yards (4.5 m^3) of concrete at the job site. Each batching or mixing unit or both, shall carry in a prominent place a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed concrete, discharge speed and the weight-calibrated constant of the machine in terms of a revolution counter or other output indicator.

501.9.7.2 Measurement of Cement. The continuous mixer shall be capable of positive measurement of cement being introduced into the mix. A recording meter visible to the operator and equipped with a ticket printout shall indicate the quantity.

501.9.7.3 Measurement of Water. The continuous mixer shall provide positive control of the flow of water and admixtures into the mixing chamber. Water flow shall be indicated by a flow meter and be readily adjustable to provide for minor variations in aggregate moisture. The mixer shall be capable of continuously circulating or mechanically agitating the admixtures.

501.9.7.4 Scalping Screen. The continuous mixer shall have a one-inch (25 mm) maximum size scalping screen over the fine aggregate bin to screen out mud balls, conglomerate lumps or any other contaminant material that could interrupt the flow of fine aggregate during proportioning.

501.9.7.5 Batching Operations. The continuous mixer shall be capable of being calibrated to automatically proportion and blend all components on a continuous or intermittent basis as required, and shall discharge mixed material through a conventional chute.

501.9.8 Handling Materials. Storage facilities for all material shall be designed to permit the engineer to make necessary inspections prior to the batching operations. The facilities shall also permit identification of approved material at all times, and shall be designed to avoid mixing with or contaminating by, unapproved material. Coarse and fine aggregate shall be furnished and handled so variations in the moisture content affecting the uniform consistency of the concrete will be avoided.

501.10 Air-Entrained Concrete .Air content for all classifications of concrete shall be determined in accordance with AASHTO T 152. Air-entrained concrete shall be used for the construction of the following items:

(a) All retaining walls and bridge units, except culvert-type structures and seal courses.

(b) Concrete median barriers.

(c) All piles (not required for cast-in-place concrete piles).

(d) Concrete pavements.

(e) Approach slabs and paved approaches.

(f) Concrete medians and median strips.

(g) Sidewalks, curb ramps and steps.

(h) Curbs, gutters, curb and gutter and surface drain basins and drains.

(i) Concrete pedestals for signs, signals and lighting.

501.10.1 Other Concrete. All other concrete, except seal concrete, may be air-entrained but only in accordance with the requirements of these specifications.

501.10.2 Required Air Content. If air-entrained concrete is used, the designated quantity of air by volume shall be a minimum of 5.0 percent. For concrete pavement, the specified air content will apply to the measurements taken behind the paver or to measurements taken in front of the paver minus the established air loss through the paver.

501.10.3 Incorporation Procedures. Air-entraining admixtures shall be added to the concrete during the mixing process. The admixture shall be of such volume and strength that the admixture can be accurately measured and dispensed in accordance with the manufacturer's recommendations. The dispenser shall consistently deliver the required quantity of admixture within a tolerance of ± 3 percent.

501.10.4 Redosing. When the measured air content is below the minimum specified value, the contractor will be allowed to re-dose the concrete in the field one time. The contractor shall submit a Re-dosing Plan to the engineer for approval. The Re-dosing Plan shall address the following:

(a) Field measurement of the air entrainment admixture
(b) Brand of air entrainment admixture being used
(c) Incorporation and mixing of the air entrainment admixture
(d) The use of additional water

501.10.4.1 Allowed. The Re-dosing Plan shall be approved prior to use.

501.10.4.2 Other Requirements. All other requirements of this specification shall still apply.

501.10.4.3 Unacceptable Results. Concrete with a measured air content below 4.0 percent is unacceptable.

501.11 Concrete Admixtures for Retarding Set. If specified in the contract, an approved retarding admixture shall be provided and incorporated into the concrete. If not specified in the contract, the use of an approved retarding admixture will be permitted upon written notification from the contractor. Any retarding admixture shall be added in accordance with Sec 501.10.3 by means of a dispenser conforming to the requirements of that section. No direct payment will be made for furnishing the retarding admixture or for incorporating the admixture into the mixture.

501.12 Water-Reducing Admixtures. Type A water-reducing admixtures may be used in any concrete. When Type A water-reducing admixture is added to pavement concrete for paving purposes, a reduction of cement up to 25 lbs per cubic yard (15 kg/m^3) will be permitted. The dosage rate of Type A water-reducing admixture shall be within the ranges recommended by the manufacturer and approved by the engineer. Any cementitious material substitution permitted by specification shall be based on the reduced cement content. Water-reducing admixtures shall be added in accordance with Sec 501.10.3 by means of a dispenser conforming to the requirements of that section. High range water-reducing admixtures may be used when specified or as approved by the engineer.

501.12.1 Modified B-2 Utilized. Modified B-2 concrete shall use a Type A or Type D water-reducer admixture.

501.12.2 Silica Fume and Metakoalin Utilized. Concrete utilizing silica fume or metakaolin shall use a water-reducer admixture that may be added by hand methods. The amount of water contained by the water-reducer admixture shall be included in the overall water content of the concrete.

501.12.3 Consistency Requirement. When a water-reducer admixture is used the maximum allowed slump may be increased to 6 inches for all concrete classes. The concrete shall be homogeneous with no aggregate segregation.

501.13 Accelerating Admixtures. The use of calcium chloride or other approved accelerating admixtures in concrete mixtures will not be permitted, except in concrete used for pavement repair in accordance with Sec 613.

501.14 Supplementary Cementitious Materials in Concrete . The contractor may use fly ash, GGBFS, silica fume or metakaolin in the production of concrete in accordance with these specifications. Ternary mixes will be allowed for all concrete classes. Ternary mixes are mixes that contain a combination of Portland cement and two supplementary cementitious materials. Supplementary cementitious materials may be used to replace a maximum of 40 percent of the Portland cement. The amount of each supplementary cementitious materials used in a ternary mix shall not exceed the limits specified herein.

501.14.1 Fly Ash. Approved Class C or Class F fly ash may be used to replace a maximum of 25 percent of the Portland cement on a pound for pound (kg for kg) basis in all concrete.

501.14.2 Ground Granulated Blast Furnace Slag. Approved GGBFS may be used to replace a maximum of 30 percent of the Portland cement on a pound for pound (kg for kg) basis in all concrete.

501.14.3 Silica Fume. Approved silica fume may be used to replace a percent of the Portland cement on a pound for pound (kg for kg) basis. The following limits shall apply when silica fume is used:

Silica Fume Replacement Limits, %		
Class of Concrete	**Minimum**	**Maximum**
MB-2	6	8
A-1, B, B-1, B-2, PCCP, Seal	----	8

501.14.3.1 Silica Fume Requirements. Silica fume shall be approved prior to use and be in accordance with ASTM C 1240, except as noted herein. If dry compacted form, the admixture shall be 100 percent silica fume with no admixtures. Silica fume slurries may contain other approved admixtures, such as water reducers or retarders, if the admixtures are included by the manufacturer of the silica fume admixture.

501.14.3.2 Manufacturer Certification. The contractor shall furnish to the engineer a manufacturer's certification along with the brand name, batch identification, quantity represented, percent solids and the type, name and quantity of any admixtures, that are provided in the silica fume admixture.

501.14.3.3 Silica Fume Test Results. The manufacturer's certification shall contain results of recent tests conducted on samples of the silica fume material taken during production or transfer and indicating conformance with Tables 1 and 3 of ASTM C 1240 and this

specification. The supplier shall further certify that the material being furnished is in accordance with this specification.

501.14.3.4 Silica Fume Approval. For approval prior to use, the supplier shall furnish the same information to: Construction and Materials, P.O. Box 270, Jefferson City, MO 65102, along with any requested samples for testing.

501.14.3.5 Silica Fume Slurry. Liquid silica fume admixture shall be protected from freezing at all times.

501.14.3.6 Admixture Compatibility. All admixtures used shall be compatible with the silica fume admixture and shall be recommended or approved in writing by the manufacturer of the silica fume admixture.

501.14.4 Metakaolin. Approved metakaolin may be used to replace a maximum of 15 percent of the Portland cement on a pound for pound basis in all concrete.

501.14.4.1 Metakaolin Requirement. Metakaolin shall be approved prior to use and be in accordance with AASHTO M321.

501.14.4.2 Manufacturer Certification. The contractor shall furnish to the engineer a manufacturer's certification along with the brand name, batch identification and quantity represented.

501.14.4.3 Metakaolin Test Results. The manufacturer's certification shall contain results of recent tests conducted on samples of the metakaolin taken during production or transfer and indicating conformance with AASHTO M321 and this specification. The supplier shall further certify that the material being furnished is in accordance with this specification.

501.14.4.4 Metakaolin Approval. For approval prior to use, the supplier shall furnish the same information to: Construction and Materials, P.O. Box 270, Jefferson City, MO 65102, along with any requested samples for testing.

501.14.5 Source Changes. Changes in class or source of fly ash, grade and source of GGBFS, brand and source of silica fume or brand and source of metakaolin used in concrete structures will be permitted only with written approval from the engineer. Only fly ash, GGBFS, silica fume or metakaolin resulting in concrete of the same color shall be used in any individual unit of the structure.

501.14.6 Mix Proportions. When fly ash, GGBFS, silica fume or metakaolin is used, an adjustment in design mix proportions will be required to correct the volume yield of mixture. Approval shall be obtained from the engineer prior to any change in mix design or proportions.

501.14.7 Mixing Water. Maximum mixing water shall be based on total cementitious material. The quantity of mixing water in the concrete shall be considered the net quantity after proper allowance has been made for absorption by the aggregate.

501.14.8 Measuring Fly Ash and Ground Granulated Blast Furnace Slag. Fly ash or GGBFS shall be measured in the same manner and with the same accuracy as cement. (The mass determination of) Fly ash or GGBFS may be weighed (determined) separately on the same scale as cement, provided the scale increments are such that the specified weighing (mass determination) accuracy can be maintained. If the (mass of) fly ash or GGBFS is weighed (determined) together with the cement, the (mass of) cement shall be weighed (determined) first and the accuracy shall apply to the combined weight (mass).

501.14.9 Measuring Silica Fume and Metakaolin. Silica fume or metakolin shall be measured by weight (mass) or volume within a tolerance of plus or minus 2 percent.

501.14.10 Silica Fume and Metakaolin Batching Sequence. Silica fume or metakaolin shall be added at the plant at the same point in the batch sequence as recommended by the manufacturer of the material . The silica fume or metakaolin may be added by hand methods.

501.14.11 Calculating Silica Fume Solids. For silica fume solutions**,** the quantity of liquid silica fume admixture needed to furnish the required silica fume solids shall be calculated based on the weight per gallon (mass per liter) and percent solids of the silica fume admixture being used.

501.14.12 Measuring Cementitious Materials. Fly ash, GGBFS, silica fume or metakaolin will be considered as cement when measuring mixing time.

501.15 Commercial Mixture. If specified in the contract that an approved commercial mixture of concrete may be used, the contractor shall notify the engineer in writing, setting out for approval the source and proportions of the mixture proposed to be furnished. The statement shall include the following:

(a) The types and sources of aggregate.

(b) Type and source of cement and other cementitious material.

(c) Scale weights (masses) of each aggregate proposed as pounds per cubic yard (kg/m^3) of concrete.

(d) Quantity of water proposed, as pounds or gallons per cubic yard (kg or L per m^3) of concrete.

(e) Quantity of cement proposed as pounds per cubic yard (m^3) of concrete. n.

501.15.1 Minimum Cement Content. The concrete shall contain no less than 517 pounds (305 kg) of cement per cubic yard (m^3). The use of fly ash, GGBFS, silica fume or metakaolin shall be in accordance with Sec 501.14. The plant shall comply with other requirements of these specifications or be as approved by the engineer. The concrete will be subject to acceptance or rejection by visual inspection at the job site.

501.15.2 Certification. The supplier shall furnish certification with the first truck load of each day's production of concrete that the material and mix proportions used are in accordance with the approved mixture. Upon completion of the work, plant certification shall be furnished by the supplier for the total quantity delivered.