**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](https://calibre-internal.invalid/OEBPS/Text/Div1000.xhtml#toc_marker-1) and specifically as follows:

|  |  |
| --- | --- |
| **Item** | **Section** |
| Coarse Aggregate | [1005.2](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005_2) |
| Fine Aggregate | [1005.3](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005_3) |
| Ground Granulated Blast Furnace Slag | [1017](https://calibre-internal.invalid/OEBPS/Text/Sec1017.xhtml#S1017) |
| Fly Ash | [1018](https://calibre-internal.invalid/OEBPS/Text/Sec1018.xhtml#S1018) |
| Cement | [1019](https://calibre-internal.invalid/OEBPS/Text/Sec1019.xhtml#S1019) |
| Concrete Admixture | [1054](https://calibre-internal.invalid/OEBPS/Text/Sec1054.xhtml#S1054) |
| Concrete Tinting Material | [1056](https://calibre-internal.invalid/OEBPS/Text/Sec1056.xhtml#S1056) |
| Water | [1070](https://calibre-internal.invalid/OEBPS/Text/Sec1070.xhtml#S1070) |

**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 cementitious materials

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

(d) Source, formation, ledge number, 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 cementitious materials

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

(k) Batch weight of water

(l) For optimized mixes, the allowable gradation range

**501.3.2 Paving Concrete.** For PCCP mixes, the coarse aggregate gradation requirements of [Sec 1005](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005) will not apply. For all fractions, 100 percent of each fraction shall pass the 2-inch sieve. When Grade F is required, 100 percent of each fraction shall pass the 3/4-inch sieve.

**501.3.3 Masonry Concrete.**  All provisions, including gradations requirements of [Sec 1005](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005) shall apply.

**501.3.3.1** **Modified B-2 Concrete.**

**501.3.4 Optimized Mix Designs.**

**501.3.4.1 Optimized Masonry Concrete.** For optimized PCCM mixes, the gradation requirements of [Sec 1005.2](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005_2) and [Sec 1005.3](https://calibre-internal.invalid/OEBPS/Text/Sec1005.xhtml#S1005_3) will not apply. For coarse aggregate, 100 percent of each fraction shall pass the one-inch sieve and no more that 2.5 percent shall pass the No. 200 sieve. This value may be increased to 3.0 percent passing, provided there is no more than 1.0 percent of the material passing the No. 200 sieve in the fine aggregate. For fine aggregate, no more than 2.0 percent shall pass the No. 200 sieve for natural sand, and no more than 4.0 percent shall pass the No. 200 sieve for manufactured sand.

**501.3.5 Fine Aggregate Classes.** Fine aggregates are grouped into four classes of sand as defined by Sec 1005 and a minimum cement factor has been established for each class in Sec 501.3.6.

**501.3.5.1** **Manufactured Sand.**

**501.3.6 Cement Factors.** The minimum cement requirements in pounds per cubic yard of concrete for the various classes of sand shall be as follows:

|  |  |
| --- | --- |
| **Class of Sand** | **Cement Requirements** |
| **Class A-1** | **Class B** | **Class B-1** | **Class B-2** | **Class MB-2** | **Pavement** | **Seal** |
| A | 600 | 525 | 610 | 705 | 600 | 560 | 660 |
| B | 640 | 565 | 640 | 735 | 620 | 560 | 695 |
| C | -- | 585 | 660 | 750 | 640 | 560 | 715 |
| D | -- | 620 | 695 | 790 | 660 | 560 | 735 |

**501.3.6.1 Modified Cements.** When used, Type IP, I(PM), IS or I(SM) cement shall be substituted on a pound for pound 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.

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**501.3.7 Unit Weight.** The weight per cubic foot shall be the dry rodded weight per cubic foot 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

|  |
| --- |
| **Minimum Design Compressive Strength** |
| **Class A-1** | **Class B** | **Class B-1** | **Class B-2** | **Class MB-2** | **Pavement** | **Seal** |
| 6,000 | 3,000 | 4,000 | 4,000 | 4,000 | 4,000 | 3,000 |

**501.3.9 Absorptions.**Aggregate absorption shall be in accordance with [Sec 1005](https://calibre-internal.invalid/OEBPS/Text/Sec502.xhtml#S502_11_3_3).

**501.3.10 Air-Entrained Concrete.** . 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 course.

(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.

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

**501.3.10.2 Air Content Limitations.** When air-entrained concrete is used, the mix design target range for quantity of air content by volume shall not be less than 4.5 percent or greater than 7.5 percent.

**501.3.11 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 501.5.11](https://calibre-internal.invalid/OEBPS/Text/Sec501.xhtml#S501_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.

**501.3.12 Water-Reducing Admixtures.** Type A water-reducing admixtures may be used in any concrete. Water-reducing admixtures shall be added in accordance with [Sec 501.5.11](https://calibre-internal.invalid/OEBPS/Text/Sec501.xhtml%22%20%5Cl%20%22S501_10_3) by means of a dispenser conforming to the requirements of that section.

**501.3.12.1** 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 will be permitted. Any cementitious material substitution permitted by specification shall be based on the reduced cement content.

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

**501.3.12.2 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.

**501.3.12.3 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.

**501.3.13 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](https://calibre-internal.invalid/OEBPS/Text/Sec613.xhtml#S613).

**501.3.14 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.

**501.3.14.1 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 basis in all concrete.

**501.3.14.2 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 basis in all concrete.

**501.3.14.3 Silica Fume.** Approved silica fume in accordance with ASTM C 1240, except as noted herein may be used to replace a percent of the Portland cement on a pound for pound 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 | - |

**501.3.14.3.1 Silica Fume Approval.** Silica fume shall be approved for use during the mix design submittal process. The manufacturer shall provide representative results of recent tests conducted on samples of the silica fume indicating conformance with Tables 1 and 3 of ASTM C 1240 and this specification. 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.

**501.3.14.3.2 Silica Fume Compatibility.** 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. other

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

**501.3.14.4 Metakaolin.** Approved metakaolin in accordance with AASHTO M 321 may be used to replace a maximum of 15 percent of the Portland cement on a pound for pound basis in all concrete.

**501.3.14.4.1 Metakaolin Approval.**  Metakaolin shall be approved for use during the mix design submittal process. The manufacturer shall provide representative results of recent tests conducted on samples of the metakaolin indicating conformance with AASHTO M321 and this specification. The supplier shall further certify that the material being furnished is in accordance with this specification.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.

**501.3.14.5 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.

**501.3.15 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.

**501.4 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 of each aggregate proposed as pounds per cubic yard of concrete.

(d) Quantity of water proposed, as pounds or gallons per cubic yard of concrete.

(e) Quantity of cement proposed as pounds per cubic yard of concrete.

**501.4.1 Minimum Cement Content.** The concrete shall contain no less than 517 pounds of cement per cubic yard. The use of fly ash, GGBFS, silica fume or metakaolin shall be in accordance with [Sec 501.3.14](https://calibre-internal.invalid/OEBPS/Text/Sec501.xhtml%22%20%5Cl%20%22S501_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.

**501.4.2 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.

**501.5 Plant and Production.**

**501.5.1 Measurement of Material.** The cement and aggregate for concrete shall be measured by weight. The weights 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.

**501.5.2 Weighing Tolerances.** The weighing and batching equipment shall be designed and maintained in such a condition that the material for each batch can be quickly and accurately weighed 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.

**501.5.3 Water Meter Tolerances.** Mixing water shall be measured by volume or by weight. If measured by weight, scales shall be in accordance with [Sec 501.5.2](https://calibre-internal.invalid/OEBPS/Text/Sec501.xhtml#S501_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 or one percent, whichever is greater.

**501.5.4 Calibration Frequency.** Plant scales and water metering devices shall be calibrated and certified annually and after every plant move by an approved commercial scale service. Admixture metering devices shall be calibrated by a commercial scale company, the admixture company or the concrete plant company. Plant scales that have not been moved shall be verified six months after their calibration. A copy of the calibration and verification shall be provided to the engineer.

**501.5.5 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. Fly ash or GGBFS may be weighed separately on the same scale as cement, provided the scale increments are such that the specified weighing accuracy can be maintained. If the fly ash or GGBFS is weighed together with the cement, the cement shall be weighed first and the accuracy shall apply to the combined weight.

**501.5.6 Measuring Silica Fume and Metakaolin.** Silica fume or metakolin shall be measured by weight or volume within a tolerance of plus or minus 2 percent.

**501.5.7 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.

**501.5.8 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 and percent solids of the silica fume admixture being used.

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

**501.5.10 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.

**501.5.11 Air Entrainment 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.

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

**501.5.12.1 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.

**501.5.12.2 Uniformity Testing.** A uniformity test in accordance with ASTM C 94 Annex A1, shall be performed during the annual calibration at a central mix drum plant and at the beginning of production for a project at a mobile paving plant.

(a) A uniformity test shall be performed for the largest and smallest proposed batch size.

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

(c) 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.

(d) The use of a one-quarter cubic foot measure will be permitted in determination of weight per cubic foot.

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

(f) 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.

**501.5.12.2.1 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.

**501.5.12.2.2 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.

**501.5.12.3 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.

**501.5.12.4 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.

**501.5.12.5 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. 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.

**501.5.12.6 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.

**501.5.12.7 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.

**501.5.12.8 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.

**501.5.12.9 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.

**501.5.12.10 Testing Facilities.** The contractor shall provide a Type 1 laboratory in accordance with [Sec 601](https://calibre-internal.invalid/OEBPS/Text/Sec601.xhtml#Sec601) at a paving plant for the engineer to inspect ingredients and processes used in the manufacture and delivery of the concrete. The ready mix producer shall notify the designated MoDOT representative every day that concrete is being supplied for a MoDOT project. A daily log of plant production shall be available for the engineer to review.

**501.5.12.11 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) MoDOT mix identification number assigned to the mix.

(g) Specific class of concrete.

(h) Quantity of concrete in cubic yards.

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

(j) Number of revolutions, when truck mixed.

**501.5.12.12 Concrete Plant Documentation.**The contractor shall complete the required concrete plant documentation once per working day at the central ready mix or paving plant.  The documentation shall be made available to the engineer within 24 hours after concrete is batched.

**501.5.13 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.

**501.5.13.1 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.

**501.5.13.2 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.

**501.5.13.3 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 each component. Calibration of the admixture and water proportioning devices shall be accomplished by weight or volume. Tolerances in proportioning the individual components will be as follows:

|  |  |
| --- | --- |
| **Item** | **Tolerance** |
| Cement, Weight percent | 0 to +4 |
| Fine Aggregate, Weight percent | ± 2 |
| Coarse Aggregate, Weight percent | ± 2 |
| Admixtures, Weight or Volume percent | ± 3 |
| Water, Weight or Volume Percent | ± 1 |

**501.5.13.4 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 container measuring 36 x 36 x 9 inches. 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. A tolerance of ± 1/8 inch 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.

**501.5.13.5 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.

**501.5.13.6 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.

**501.5.13.7 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.

**501.5.13.7.1 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 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.

**501.5.13.7.2 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.

**501.5.13.7.3 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.

**501.5.13.7.4 Scalping Screen.** The continuous mixer shall have a one-inch 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.

**501.5.13.7.5 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.

**501.5.13.8 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. All admixtures shall be stored in temperature controlled environment as designated by the manufacturer to prevent degradation.

**501.6 Re-Dosing.** When the measured air content is below the minimum specified limit, the contractor will be allowed one attempt per mixer truckload to re-dose the concrete in the field. The contractor shall obtain approval of the a Re-Dosing Plan from the engineer prior to the start of work. 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

**501.7 Quality Control.** The contractor shall control and monitor the quality of the work. Mixture suppliers shall have either a standard quality control plan on file with the Construction & Materials Division for the applicable plant or be included in the contractor’s quality control plan. The contractor's test results will be used when applicable to determine the PWL, provided the contractor's QC tests and the engineer's QA tests compare favorably, and provided the engineer's inspection and monitoring activities indicate the contractor is following the approved QC Plan.

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**501.7.1 Retained Samples.**  All aggregate samples taken by the contractor shall be retained for the engineer for a minimum of seven days after the contractor’s tests are complete and accepted unless otherwise instructed. These samples shall be maintained in clean covered containers, without contamination, readily accessible to the engineer. The retained sample's identification shall consist of, but is not limited to:

 (a) Time and date sampled.

 (b) Product specification number.

 (c) Type of sample, i.e. belt, bin, stockpile.

 (d) Lot and sublot designation, if applicable.

 (e) Sampler/Tester.

 (f) Project Job Number.

**501.7.2 Sampling.** Sampling of fresh concrete shall be in accordance with AASHTO R 60, 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 of concrete has been discharged, instead of at three or more regular intervals during the discharge of the entire batch. Aggregates shall be randomly sampled from the discharge gate of storage bins or from the conveyor belt.

**501.7.3 Optimized Gradation.** The gradation of each optimized mix shall be determined using AASHTO T 27 and AASHTO T 11. Acceptable results will be obtained when the gradation is within the tolerances listed on the mix design.

**501.7.4 Coarse Aggregate Gradation.** The gradation of each coarse aggregate fraction used shall be determined using AASHTO T 27 and AASHTO T 11. Acceptable results will be obtained when the gradation is within the sec 1005 specifications. This requirement is waived for optimized mix designs.

**501.7.5 Coarse Aggregate Deleterious.** The deleterious content of each coarse aggregate fraction used shall be determined using MoDOT Test Method TM 71. Acceptable results will be obtained when the deleterious content is within the sec 1005 specifications.

**501.7.6 Coarse Aggregate Absorption.** The absorption of each coarse aggregate fraction used shall be determined using AASHTO T 85. Acceptable results will be obtained when the absorption is within ± 0.3% of the mix design value. Absorption within ± 0.6% of the mix design value may be accepted after successful correction action is taken. Results greater than ± 0.6% of the mix design value are cause for rejection.

**501.7.7 Fine Aggregate Gradation.** The gradation of each fine aggregate fraction used shall be determined using AASHTO T 27 and AASHTO T 11. Acceptable results will be obtained when the gradation is within the sec 1005 specifications.

**501.7.8 Fine Aggregate Deleterious.** The absorption of each fine aggregate fraction used shall be determined using MoDOT Test Method TM 71. Acceptable results will be obtained when the deleterious is within the Sec. 1005 specifications.

**501.7.9 Top Size.** For paving concrete, the top size of coarse aggregate used shall be checked using AASHTO T 27 and AASHTO T 11. For optimized paving mixes, the top size check may be performed as part of the optimized graduation. Acceptable material shall have 100% passing the same smallest sieve specified to have 100% passing for the class of concrete and aggregate used.

**501.7.10 Coarse Aggregate Thin or Elongated.** The thin or elongated particles of each coarse aggregate fraction used shall be determined using ASTM D4791. This test shall be performed on the plus ¾ inch material for a 5:1 ratio. Acceptable results will be obtained when the thin or elongated particles are within the Sec. 1005 specifications.

**501.7.11 Concrete Consistency.**  The first truck of the day shall always be tested for concrete consistency. Samples shall be from material discharged from trucks at the point of incorporation in accordance with AASHTO R 60. Determination of percentage of air content and slump shall be from the same sample as follows:

**501.7.11.1 Air Content.** Air content for all classifications of concrete shall be determined in accordance with AASHTO T 152 When field measured air content exceeds 7.5 percent, but is less than or equal to 9.0 percent, the concrete may be placed if allowed by the contractor's quality control plan and at the contractor's risk that all other concrete requirements will be met, including strength. When field measured air content is less than 4.5 percent, the concrete may be re-dosed with air entrainment admixture in accordance with Sec. 501.6. Under no circumstances shall any concrete be incorporated into the work with an air content less than 4.5 percent or greater than 9.0 percent.

**501.7.11.1.1** Unless otherwise stated, all air content specifications requirements are the in-place air content. In-place air content is assumed to be as delivered air content when no pump or paver is used. Whenever a pump and/or paver is used, the in-place air content shall be the as delivered air content minus the air loss as calculated in Sec 501.7.14

**501.7.11.2 Slump.** 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:

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| **Slump and Maximum Water/Cementitious Materials Ratio** |
| **Class of****Concrete** | **Max.****Slump, In.** | **Max. Pounds of Mixing Water Per Pound of****Cementitious Materials** |
| **Air-Entrained** | **Non-Air-Entrained** |
| A-1 | 3 1/2 | 0.46 | 0.51 |
| B | 4 | 0.51 | 0.55 |
| B-1 | 0.44 | 0.53 |
| B-2 | 3 | 0.40 | - |
| MB-2 | 6 | 0.42 |
| Pavement | - | 0.50 | 0.53 |
| Seal | 8 | - |

**501.7.12 Mix Design Verification.** The contractor shall obtain compressive strength samples to verify the mix design consisting of two six inch or three four inch cylinders. This sample shall be prepared using the AASHTO T 23 Standard Cure procedures. An acceptable result shall be considered when the average of the sample set meets the minimum compressive strength as required by the plans and these specifications at 28 days of age.

**501.7.13 Compressive Strength.** At the rate(s) specified for individual work items, the contractor shall obtain a compressive strength samples for the following purposes. All compressive strength samples shall be prepared using the AASHTO T 23 Field Cure procedures. An acceptable result shall be considered when the compressive strength meets the applicable specification requirement for the work item.

(a) “Early Break” cylinder sample shall consist of a single six or four inch cylinder. The contractor shall be responsible for determining the number of samples needed for “Early Break” compressive strength.

(b) “28 Day” cylinders set shall be samples of either two six inch or three four inch cylinders. The results of this testing set shall be averaged to determine the reported value.

**501.7.13.1 Maturity Method.** At the contractor’s option, the maturity method may be used to determine compressive strength. See Sec 507 for additional details.

**501.7.14 Air Loss.** Whenever air entrainment is required, air loss through the paver and/or pumper shall be determined by sampling the concrete both ahead of and behind the paver and/or pumper and subtracting the percent air values obtained. Any calculated air gain through a paver and/or pumper shall be discarded and considered zero air loss, The engineer shall be given notification prior to determining the air loss in order to witness the air loss determination.

**501.7.15 Temperature of Ambient Air and/or Subgrade.** The contractor shall monitor the air temperature and the subgrade temperature to comply with the temperature limitations for the item being constructed. Concrete shall not be placed on frozen subgrade. Temperatures shall be obtained in accordance with MoDOT Test Method TM 20.

**501.7.16 Frozen Concrete.** The contractor shall include a method, meeting the approval from the engineer, of monitoring the concrete that demonstrates that the concrete has been protected from freezing in the Quality Control Plan. This requirement is waived whenever air temperatures are routinely above 40 degrees Fahrenheit.

**501.7.17 Metakaolin Certification.**  The contractor shall furnish to the engineer a manufacturer’s certification along with the brand name, batch identification and quantity represented. 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.

**501.7.18 Silica Fume 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.  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.

**501.8 Quality Assurance.**

**501.8.1 Contractor Assistance.**

**501.8.2 Small Quantity QA.** The independent QA aggregate testing may be waived when less than 500 cubic yards of a mixture are used. The independent QA consistency testing may be reduced to once per project when less than 500 cubic yards of a mixture are used.

**501.8.3 Independent QA Samples.**  QA independent aggregate samples will be of sufficient size to retain half for possible disputes. Further testing of QA retained material will be under the direction of the engineer.. The engineer's test results, including all raw data, will be made available to the contractor when completed and no later than the next working day. A favorable comparison will be obtained when QA samples meet the same specification criteria as QC.

**501.8.4 Split QA Samples.** QA will test samples split from QC samples as follows.

**501.8.4.1 Gradation Comparison.** A favorable coarse and fine gradation comparisons shall be obtained when QA is within the below ranges of QCs result.

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| **Sieve Size** | **Range** |
| 3/4 inch and larger | ±5.0% |
| 1/2 inch | ±5.0% |
| 3/8 inch | ±4.0% |
| No. 4 | ±4.0% |
| No. 8 | ±3.0% |
| No. 10 | ±3.0% |
| No. 16 | ±3.0% |
| No. 20 | ±3.0% |
| No. 30 | ±3.0% |
| No. 40 | ±2.0% |
| No. 50 | ±2.0% |
| No. 100 | ±2.0% |
| No. 200 | ±1.0% |

**501.8.4.2 Aggregate Deleterious Comparison.** A favorable comparison for coarse and fine aggregate deleterious content shall be obtained when the QA is within one half the Sec 1005 requirements of the QC results.

**501.8.4.3 Coarse Aggregate Absorption Comparison.**  A favorable comparison of coarse aggregate absorption shall be obtained when the QA is within one half the [Sec 1005.2](../Text/Sec1002.xhtml%22%20%5Cl%20%22S1002_2) requirements of the QC results.

**501.8.4.4 Top Size Comparison.**  A favorable comparison of coarse aggregate top size shall be obtained when the QA is within the specification limits.

**501.8.4.5 Coarse Aggregate Thin or Elongated Comparison.** A favorable comparison of coarse aggregate absorption shall be obtained when the QA is within one half the [Sec 1005.2](../Text/Sec1002.xhtml%22%20%5Cl%20%22S1002_2) requirements of the QC results.

**501.9 QC/QA Frequency Table.**

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| **Tested Property** | **QC Frequency** | **QA Frequency**  | **QC Small Quantity Frequency** |
| **Masonry Concrete** | **Paving Concrete** | **Independent Samples** | **Split** **Samples** |
| Optimized Gradation | 1 per 500 Cubic Yards  | 1 per 2000 Cubic Yards | 1 per Project | 1 per 5 QC Samples | - |
| Coarse Agg. Gradation | - |
| Coarse Agg. Deleterious  | 1 per 2000 Cubic Yards |
| Coarse Agg. Absorption |
| Fine Agg. Gradation | - |
| Fine Agg. Deleterious |
| Top Size | - | 1 per Week | - |
| Coarse Agg. Thin or Elongated | 1 per Year | 1 per 10000 Cubic Yards | 1 per Year |
| Concrete Consistency | 1 per 100 Cubic Yards | 1 per 500 Cubic Yards | 1 per Day | - | 1 per Day |
| Mix Design Verification | 1 per 500 Cubic Yards | - | 1 per Mix Design | - |
| Compressive Strength | See Relevant Work Item Specification for Frequency |
| Air Loss | 2 per Day | 1 per Project | - | 1 per Day |
| Temperature of Ambient Air and/or Subgrade | As Needed | - | As Needed |
| Frozen Concrete |
| Metakaolin Certification | 1 per Project | 1 per Project |
| Silica Fume Certification |

**501.10 Measurement.** See specification section for work item being constructed for measurement information.

**501.11 Payment.** See specification section for work item being constructed for payment information.