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 and specifically as follows:

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

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 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 shall apply.

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

501.3.4 Optimized Mix Designs. The contractor may submit an optimized mix design which has a maximum 50 pounds per cubic yard 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.

501.3.4.1 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 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. Manufactured sand produced from limestone or dolomite shall not be used in Portland cement concrete for driving surfaces such as bridge decks, pavements and full depth shoulders

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 unless otherwise specified in the contract documents or approved by the engineer.

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.

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 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. High range water-reducing admixtures may be used when specified or as approved by the engineer. The dosage rate of water-reducing admixture shall be within the ranges recommended by the manufacturer and approved by the engineer. Water-reducing admixtures shall be added in accordance with Sec 501.5.11 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.

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. All other 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.

501.3.14.3.3 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. 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. 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 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.

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:

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. The contractor shall furnish the necessary equipment and personnel to assist the engineer in obtaining a representative QA sample.

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.

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 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 requirements of the QC results.

501.9 QC/QA Frequency Table.

<table>
<tr><th rowspan="2">Tested Property</th><th colspan="2">QC Frequency</th><th colspan="2">QA Frequency</th><th rowspan="2">QC Small Quantity Frequency</th></tr>
<tr><th>Masonry Concrete</th><th>Paving Concrete</th><th>Independent Samples</th><th>Split Samples</th></tr>
<tr><td>Optimized Gradation</td><td rowspan="6">1 per 500 Cubic Yards</td><td>1 per 2000 Cubic Yards</td><td rowspan="6">1 per Project</td><td rowspan="8">1 per 5 QC Samples</td><td rowspan="8">-</td></tr>
<tr><td>Coarse Agg. Gradation</td><td>-</td></tr>
<tr><td>Coarse Agg. Deleterious</td><td rowspan="2">1 per 2000 Cubic Yards</td></tr>
<tr><td>Coarse Agg. Absorption</td></tr>
<tr><td>Fine Agg. Gradation</td><td rowspan="2">-</td></tr>
<tr><td>Fine Agg. Deleterious</td></tr>
<tr><td>Top Size</td><td>-</td><td>1 per Week</td><td>-</td></tr>
<tr><td>Coarse Agg. Thin or Elongated</td><td>1 per Year</td><td>1 per 10000 Cubic Yards</td><td>1 per Year</td></tr>
<tr><td>Concrete Consistency</td><td>1 per 100 Cubic Yards</td><td>1 per 500 Cubic Yards</td><td>1 per Day</td><td rowspan="2">-</td><td>1 per Day</td></tr>
<tr><td>Mix Design Verification</td><td>1 per 500 Cubic Yards</td><td>-</td><td>1 per Mix Design</td><td>-</td></tr>
<tr><td>Compressive Strength</td><td colspan="5">See Relevant Work Item Specification for Frequency</td></tr>
<tr><td>Air Loss</td><td colspan="2">2 per Day</td><td>1 per Project</td><td rowspan="5">-</td><td>1 per Day</td></tr>
<tr><td>Temperature of Ambient Air and/or Subgrade</td><td colspan="2" rowspan="2">As Needed</td><td rowspan="4">-</td><td rowspan="2">As Needed</td></tr>
<tr><td>Frozen Concrete</td></tr>
<tr><td>Metakaolin Certification</td><td colspan="2" rowspan="2">1 per Project</td><td rowspan="2">1 per Project</td></tr>
<tr><td>Silica Fume Certification</td></tr>
</table>

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.

SECTION 502
PORTLAND CEMENT CONCRETE BASE AND PAVEMENT

502.1 Description. This work shall consist of constructing a Portland cement concrete base or pavement, with or without reinforcement as specified, shown on the plans or directed by the engineer.

502.2 Material. All material, proportioning, air-entrainment, mixing, slump and transporting for Portland cement concrete shall be in accordance with Sec 501. All material shall be in accordance with Division 1000 and specifically as follows:

Item	Section
Emulsified Asphalt (SS-1, SS-1H, CSS-1 or CSS-1H)	1015
Steel Reinforcement for Concrete	1036
Concrete Curing Material	1055
Material for Joints	1057

502.3 Concrete Mix Design. Prior to placing any concrete on the project, the contractor shall submit a mix design in accordance with Sec 501 for approval to Construction and Materials. The plant shall be operated such that no intentional deviations from the mix design are made except as follows.

502.3.1 Field Adjustment. When test results indicate the concrete produced does not meet the specification requirements or is not performing satisfactory, the contractor may adjust the mix design in the field as noted herein. Field adjustments may consist of changing the constituents listed on the approved mix design by no more than 5.0 percent or changing the water cement ratio by no more than 0.02 from the approved mix design. The engineer shall be notified immediately when any change is made to the mix design. Additional fractions of material or new material will not be permitted as a field adjustment. The field adjusted mix shall meet the requirements specified in Sec 501.

502.3.2 Field Redesign. When the constituents listed on the approved mix design are adjusted by more than 5.0 percent or the water cement ratio is changed by more than 0.02, the contractor shall submit a new mix design meeting the requirements specified in Sec 501. The mix design shall be submitted immediately to the District for approval. The contractor will be allowed to continue production while the mix design is reviewed.

502.4 Field Laboratory. The contractor shall provide a Type 1 field laboratory in accordance with Sec 601. A field laboratory shall not be required for small quantity work.

502.5 Acceptance and Payment for Work Types. Acceptance of concrete pavement and base will be by the QC/QA process as designated within. The applicable pay adjustments shall be based on the type of work performed.

502.5.1 Normal Thickness. QC/QA of concrete pavement and base eight inches or thicker shall include a lot and sublot system with a quality level analysis. The concrete adjustment and smoothness adjustment shall apply.

502.5.2 Thin Sections. Concrete pavement and base less than eight inches thick shall not include a lot and sublot system or be eligible for the concrete pay adjustment. For concrete paving less than eight inches in depth the smoothness adjustment shall apply.

502.5.3 Shoulders. Depending on their thickness, shoulders shall be subject to quality control requirements and adjustments of either normal thickness or thin sections. The smoothness adjustment shall not apply to shoulders. When placed integrally to the same thickness, shoulders shall be included with the pavement in lot and sublot system.

502.5.4 Small Quantity. When less than 7500 square yards of concrete paving or base is called for, the paving or base shall be considered a small quantity. This designation applies to individual projects, individual projects in combination contracts, or projects with short discontinuous sections. QA frequency for small quantities will be determined by the engineer. No concrete adjustment or smoothness adjustment shall apply to small quantity work.

502.6 Construction Requirements.

502.6.1 Weather Limitations. Concrete shall not be placed upon frozen subgrade. All concrete shall be effectively protected from freezing until a minimum compressive strength of 3,500 psi has been attained. Regardless of precautions taken, the contractor shall assume all risks, and all frozen concrete shall be replaced at the contractor's expense.

502.6.2 Protection Against Rain. To protect against rain, the contractor shall have on location at all times material for the protection of the edges and surface of the unhardened concrete. The contractor shall protect the concrete from damage due to rain. Failure to properly protect unhardened concrete may constitute cause for the removal and replacement of defective concrete at the contractor's expense.

502.6.3 Equipment. Equipment and tools necessary for handling material and performing all parts of the work shall be satisfactory to the engineer as to design, capacity and mechanical condition. The equipment shall be at the job site sufficiently ahead of the start of construction operations to be examined thoroughly by the engineer and shall be in accordance with the following:

502.6.3.1 Batching Plant, Mixer and Hauling Equipment. The batching plant, mixer, water measuring equipment, weighing and hauling equipment shall be in accordance with Sec 501.

502.6.3.2 Slip-Form Construction. Concrete base or pavement may be constructed by the use of sliding form methods. Slip-form construction shall be in accordance with these specifications.

502.6.3.2.1 Consolidating and Finishing Equipment. The concrete shall be consolidated and finished by a slip-form paver designed to spread, consolidate and shape the concrete in one complete pass of the machine in such a manner to provide a smooth, dense and homogeneous pavement in conformance with the plans and specifications. No apparent slumping of the concrete shall occur within 6 inches of the pavement edge. If necessary to stop the forward movement of the paver, the vibratory and tamping elements shall be stopped immediately.

502.6.3.3 Vibrators. Vibrators used for full width vibration of the concrete shall be of the internal type. Vibrating equipment shall be operated in accordance with the manufacturer's recommendation at a frequency to provide satisfactory results, but shall be no less than 4500 impulses per minute. Hand vibrators shall have a frequency of no less than 4500 impulses per minute.

502.6.3.4 Concrete Saw. If sawed joints are required, equipment shall be capable of providing a groove of the specified dimensions in the concrete. Equipment shall be a wet-cut saw, referred to as a "conventional concrete saw" or a lighter weight dry-cut saw, referred to as an "early-entry concrete saw," used to establish joints sooner than the conventional saw.

502.6.3.5 Equipment for Sealing Joints. An approved double boiler-type heating kettle equipped with a mechanical agitator and a satisfactory temperature indicating device shall be required. The equipment shall be capable of heating the joint sealing material uniformly without damage.

502.6.3.6 Auxiliary Equipment. Auxiliary equipment shall be available at all times as follows:

(a) A minimum of one footbridge designed to be readily transportable and having no contact with the concrete base or pavement.

(b) Metal dyes with beveled face numerals 3 inches to 5 inches high and thick enough to make an indentation of 1/4 inch. A satisfactory dye shall be used for marking the location of the station number.

502.6.4 Setting Forms. Forms shall be sufficiently supported to avoid displacement during paving operations. Both straight and curved forms shall be supported in such position that the face of the form shall be vertical on tangents and perpendicular to the superelevated section on curves. The top of the form shall not vary more than 1/8 inch from

the true grade line during placing, compacting and finishing operations. The form alignment shall not vary more than 1/4 inch from the true alignment.

502.6.5 Conditioning of Subgrade. When forms have been securely set to grade, the subgrade shall be brought to proper cross-section in accordance with Sec 209. Low areas of treated bases shall be filled only with concrete integral with the pavement. No direct payment will be made for the concrete used to fill these low areas.

502.6.6 Proportioning and Mixing Concrete. Concrete shall be proportioned and mixed by truck or central mixers in accordance with Sec 501. This shall consist of batching all aggregate, cement and water by means of automatic weighing or metering, with all additives dispensed automatically and interlocked with the automatic weighing or metering controls. For central mixed concrete, the mixing cycle shall be timed and interlocked with the weight batch cycle. The weight setting controls shall be equipped such that the controls may be locked when directed by the engineer. The automatic batching equipment shall be capable of conversion to manual operation if necessary. Manual operation shall not be permitted beyond 24 hours after breakdown in the automatic equipment, except by written approval of the engineer. When a project includes paving that cannot be performed in a normal sequence, the contractor will be permitted to place a maximum of 7000 square yards using manual batching methods. For all contracts having a total of no more than 20,000 square yards of concrete base coarse and concrete pavement combined, manual batching methods will be permitted.

502.6.7 Placing Concrete. The concrete shall be deposited over the entire width of the subgrade in such a manner as to prevent segregation and to minimize handling. Mixers, including truck mixers and trucks used for transporting concrete, will be permitted to discharge concrete by chute or by dumping directly on the subgrade or prepared base provided the underlying material is not damaged or distorted. Honeycomb in the concrete base or pavement edge may be cause for rejection of the concrete.

502.6.8 Tie Bar Placement. Tie bars shall be supported in the proper position by chairs driven into the subgrade, or may be placed by approved mechanical methods prior to the consolidation of the concrete after the concrete has been struck off. Tie bars shall be free from dirt, oil, paint and grease. Tie bars required at longitudinal construction joints shall be positioned before concrete base or pavement consolidation.

502.6.9 Final Strike-off, Consolidation and Finishing. Machine finishing by extrusion methods or by vibrating and screeding processes shall be required for all concrete except as permitted in accordance with Sec 502.6.7. After the final coarse of the concrete has been placed, the concrete shall be struck-off and thoroughly vibrated until concrete of a uniform and satisfactory density is attained. The surface of the pavement shall be of uniform texture and to the proper grade and typical section.

502.6.9.1 Consolidation. Vibrating tubes shall extend into the concrete the distance necessary to provide adequate consolidation. Vibrators shall be operated only when the machine to which the vibrators are attached is moving. Care shall be taken that the vibrator does not penetrate the subgrade or dislodge or move the joints. Vibrators shall not come in contact with the reinforcement, load transfer devices, subgrade or side forms.

502.6.9.2 Added Finishing Water. Moisture in any form shall not be applied to the surface of the concrete except for emergency conditions. When emergency conditions exist and it becomes necessary to apply additional moisture to the surface of the concrete in order to complete the final finishing operation, water may only be applied in the form of a fine pressure spray. Under such conditions, placement of additional concrete on the subgrade shall be discontinued until the emergency conditions cease.

502.6.9.3 Surface Texture. After surface irregularities have been removed, the concrete surface shall be given a uniformly roughened finish with a minimum texture depth of 1.00 mm.
502.6.9.3.1 Minimum Diamond Grinding Length. Diamond grinding, except for bump correction, shall be across the entire width of the traveled way and shall be continuous for a minimum of 0.1 mile.

502.6.9.3.2 Wave Texture. The concrete may be tined either longitudinally or transversely.

502.6.9.3.2.1 Wire Comb. A wire comb shall be no less than 10 feet long with a single line of wires exposed to a length of approximately 4 inches. The wire shall be blue-tempered and polished spring steel with nominal

dimensions of 0.028 inch thick and 0.100 to 0.125 inch wide. The wires shall be spaced to provide 1/2-inch clear space between wires and securely mounted in a rigid head. Except for concrete finished by hand methods, the wire comb shall be mechanically operated and capable of covering the full width of slab in a single pass, at a uniform speed and at a uniform depth. Final approval of the wire comb will be based on satisfactory performance during actual use

502.6.9.3.2.2 Texturing with Wire Comb. Successive passes of the comb shall be overlapped the minimum necessary to attain a continuously textured surface. The surface texture produced shall have an average texture depth of approximately 0.125 inch. Small or irregular areas, or areas not suitable for machine texturing when adjacent surrounding concrete is ready for texturing, may be textured with a hand operated device producing a textured surface equivalent to that required for machine combing.

502.6.9.4 Edging at Forms and Joints. After the final finish, but before the concrete initial set, the edges of the concrete along each form line, and on each side of transverse expansion joints and construction joints shall be worked with an edging tool having a radius of approximately 3/8 inch. A well-defined and continuous radius having a smooth, dense finish shall be produced. The surface of the concrete shall not be unduly disturbed by tilting of the tool during use. Tool marks on the pavement shall be eliminated by brooming or dragging the surface. In doing this, the rounding of the corner of the pavement shall not be disturbed. All concrete on top of the joint filler shall be completely removed. All joints shall be tested with a straightedge before the concrete has set, and corrections made if one side of the joint is higher than the other.

502.6.9.5 Station Numbers. The contractor shall indent station numbers into all pavement immediately following the final finishing operations and before the concrete's final set. The numbers shall be placed at alternating full stations as ascertained by measurements determined by the engineer. Equations in stationing shall also be marked in the pavement. On undivided pavement, the station numbers shall be on the left side of the pavement with respect to the ascending stationing and shall be on the pavement edge unless an integral curb is involved, in which case the numbers shall be placed on the face of the curb. On divided pavement, station numbers shall be placed on the median side of each pavement. The numbers shall be placed facing the centerline of the pavement, or the centerline of each pavement in the case of divided pavements. The numbers shall be placed on a troweled area of the finished surface. No direct payment will be made for marking station numbers.

502.6.9.6 Hand Finishing. Compacting, vibrating and finishing concrete by hand methods will be permitted:

(a) For all curves having a form line radius of less than 200 feet or where wood forms are used.

(b) For all irregularly shaped areas.

(c) For pavement lanes less than 200 feet long.

(d) For pavement lanes less than 10 feet wide.

(e) For bridge approaches and pavement to first expansion joint.

(f) When a breakdown of the mechanical compacting and finishing equipment occurs or in the event of some other emergency. After a breakdown, only material which has already been proportioned and which may be rendered unsatisfactory for use may be finished by hand.

(g) For all Portland cement concrete base.

502.6.10 Joints. Joints shall be of the specified type and dimensions, and constructed at the locations shown on the plans or as approved by the engineer. Where joints are preformed, the form or joint shall be set and securely fastened to ensure the joint being in the required position when the concrete is finished. The final position of dowels and tie bars shall be parallel to the subgrade and perpendicular to the line of the joint. Dowel supporting assemblies shall conform to one of the types shown on the plans. The concrete shall be placed to avoid displacement or disarrangement of the joint installations.

502.6.10.1 Expansion Joints. Expansion joints shall extend for the full cross-section of the concrete pavement. Filler placed prior to the placement of the concrete shall be installed with a removable cap or edging bar as a guide for edging the joint and protection of the filler during the concrete's placing and finishing. Joints constructed after the placement of concrete shall be sawed full depth, and the exposed edges shall be ground to a chamfer of 3/8 inch. The filler shall rest snugly on the subgrade from form to form. The joints shall be sealed in accordance with Sec 502.5.4. Upon removal of the forms, any struts or fins of concrete extending across the joint shall be removed to the full width of the joint and the full thickness of the concrete base or pavement.

502.6.10.2 Construction Joints. Construction joints shall be made at the close of each day's work or when the work is stopped or interrupted for more than 30 minutes. Transverse construction joint shall be located 15 feet from the last contraction joint Construction joints shall be constructed perpendicular to the top surface and the centerline of the concrete base or pavement. Construction joints may be formed with a timber header or may be sawed full depth. The final joint shall conform to the cross-section of the pavement. Before paving operations are resumed, all surplus concrete and other refuse shall be removed from the subgrade.

502.6.10.3 Sawing Joints. Unless otherwise provided, all transverse contraction joints and all Type L longitudinal joints shall be sawed in a single cutting operation with all joint cuts to the dimensions shown on the plans. For intersections and irregular pavement, joints shall be sawed at locations as approved by the engineer. Sawing of the joints shall begin as soon as the concrete has hardened sufficiently to permit sawing without excessive raveling. All joints shall be established before uncontrolled shrinkage cracking takes place. The sawing of any joint shall be omitted if a crack occurs at or near the joint location prior to the time of sawing. Sawing shall be discontinued when a crack develops ahead of the saw. The engineer reserves the right to have the contractor install preformed type joints on multiple width construction when the use of sawed joints fails to prevent random cracking. Any pavement with random cracking not controlled by dowels or tie bars shall be either removed and replaced using dowels or tie bars as appropriate to the nearest controlled joint or repaired with some other method approved by the engineer at the contractor's expense.

502.6.10.3.1 Forming Longitudinal Joint. A joint forming device may be used to establish the longitudinal joint between the two driving lanes or between the driving lane and shoulder 6 foot wide or greater. The pavement shall have a plan thickness of 8 inches or greater.

502.6.10.3.1.2 Joint Forming Device. The joint forming device shall consist of a pair of straight blades mounted under the paver. The first blade shall be placed under the front of the primary pan extending forward between the vibrators, if mechanically possible. The second blade shall be placed on the finishing pan in identical alignment to the first blade. Blade depth shall be equal to one-third of the slab thickness.

502.6.10.3.1.3 Depth Verification. The engineer shall have access behind the paver to randomly check joint formation by inserting a thin metal strip equal to one-third of the slab thickness into the formed joint.

502.6.10.3.1.4 Joint Continuity. The contractor shall ensure longitudinal joint continuity between consecutive day's paving.

502.6.10.3.1.5 Unacceptable Results. If the test results or the quality of the joint forming process are not satisfactory to the engineer, the contractor shall saw the longitudinal joint for the length affected.

502.6.10.4 Sealing Joints. All sawed contraction joints shall be unsealed, unless otherwise specified. Sawed or formed expansion joints shall be sealed with joint sealing material before the pavement is opened to any traffic, including construction traffic. Immediately prior to sealing, the joints shall be thoroughly cleaned and dried. The sealing material shall be heated to the pouring temperature recommended by the manufacturer. Any material which has been heated above the maximum safe heating temperature will be rejected. Any excess material shall be removed from the pavement surface.

502.6.10.5 Joint Filler at Railroad Crossings. Bituminous filler for use between railroad crossing approach slabs and the crossing shall be an approved commercial bituminous mixture in accordance with Sec 401. The mixture shall be tamped into a firm and compacted state.

502.6.11 Curing. Immediately after the finishing operations have been completed and as soon as marring of the concrete will not occur, the entire surface and exposed edges of the newly placed concrete shall be covered and cured in accordance with one of the following methods. The concrete shall not be left exposed for more than 30 minutes between stages of curing or during the curing period.

502.6.11.1 White Pigmented Membrane. After the free water has left the pavement surface, the entire surface shall be sealed by spraying with a uniform application of white pigmented membrane curing material. The contractor shall provide satisfactory equipment to ensure uniform mixture and coverage of curing material, without loss, on the pavement at the rate of not less than one gallon for each 200 square feet. If rain falls on the newly coated pavement before the film has dried sufficiently to resist damage, or if the film is damaged in any other way, the contractor shall apply additional curing material to the affected portions. All areas cut by finishing tools subsequent to the application of the curing material shall immediately be given new applications at the rate specified above. If hairline cracking develops before the membrane can be applied, the concrete shall be initially cured with wet burlap in accordance with Sec 502.6.2 before the membrane is placed. Membrane curing shall not be used on Portland cement concrete base. Emulsified asphalt may be used to cure the concrete base if the surface coarse is to be a bituminous type.

502.6.11.2 Burlap. The top surface of the concrete shall be temporarily covered with thoroughly damp burlap after the concrete has set sufficiently to prevent marring of the surface. Burlap shall be handled in such a manner that contact with earth or other deleterious substances is avoided. All burlap, except burlap previously used for curing concrete, shall be thoroughly washed. The burlap shall be kept thoroughly wet until removed for application of the final curing material. Neither the top nor the edge of the concrete shall be left unprotected for more than 30 minutes. When the burlap is removed, white pigmented membrane curing material shall be continued by one of the approved methods.

502.6.12 Removing Forms. Forms shall be removed carefully to avoid damage to the concrete base or pavement. Honeycombed areas not rejected shall be immediately repaired. If the forms are removed less than 72 hours after placing concrete, the sides of the concrete shall be cured by one of the methods specified above. Any trench excavated for the forms shall be entirely backfilled so water will not stand next to the concrete base or pavement.

502.6.13 Opening to Traffic. The concrete base and pavement shall not be opened to any traffic until the concrete has attained a minimum compressive strength shown below. Prior to opening to public traffic, pavement shall be cleaned and all sawed joints that have opened more than ¼ inch sealed.

Traffic Type	Compressive Strength
Light Construction	2500 PSI
Low Volume Public	
All Types	3000 PSI

502.7 Contractor Quality Control.

502.7.1 Quality Control The contractor shall control and monitor the quality of the work. 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.

502.7.2 Control Charts. If control charts are utilized by the contractor, the QC Plan shall state the location where control charts will be posted.

502.7.3 Lot/Sublots. A lot shall be the surface area placed in a single day. For high daily production rates exceeding 7,500 square yards per day, the contractor may choose to divide the day's production into two equal lots. Each lot shall be divided into no less than four or more than six sublots of equal surface area. The contractor shall notify the engineer of the size of the sublot or of the decision to divide a day's production into two equal lots prior to taking any core samples. When a day's production involves less than 600 square yards, combine the following day's or days' production to reach 600 square yards and treat as a single lot, except while completing a particular mix design or project, in which case combine with the previous day's production and treat as a single lot. The QC Plan shall identify the number of sublots each lot will utilize and describe how lots and sublots will be designated.

502.7.4 Random Numbers. .Sampling location will be determined by the engineer using random sampling procedures in accordance with ASTM D 3665

502.7.5 Coring. Cores shall not be taken until after all smoothness correction has been completed. Cores shall be taken in accordance with AASHTO T 24 in the diameter listed below. Cores shall not be taken until a minimum compressive strength of 3,000 psi has been attained. Cores shall be neatly cut with a core drill. The contractor shall fill the core holes with an approved non-shrink grout within one day after sampling. The contractor shall furnish all tools, labor and material for cutting samples and filling the cored hole. The QC Plan shall identify the method for determining when concrete cores can be extracted.

Concrete Base or Pavement Thickness	Core Diameter
< 12 inches	4 inch
≥ 12 inches	6 inch

502.7.6 28 Day Cylinder Compressive Strength. See Sec 501 for requirements on sampling and testing of compressive strength cylinders. 28 Day cylinders for less than eight inch pavements shall meet the design strength shown on the plans or 3500 psi if omitted.

502.7.7 Pavement Thickness. The pavement thickness shall be taken by direct physical measurement of the freshly placed concrete. Acceptable thickness for any measurement occurs if the thickness is less than 10 percent deficient from the plan thickness.

502.7.8 Core Thickness. Pavements eight inches or greater shall be cored and the core thickness determined by the average caliper measurement in accordance with AASHTO T 148. Acceptable thickness for any measurement occurs if the thickness is less than 10 percent deficient from the plan thickness. For small quantities, pavement thickness may be used in lieu of core thickness

502.7.9 28 Day Core Compressive Strength. After the core thickness is determined, the cores shall be sawed to an L/D ratio of 2.0 and tested in accordance with AASHTO T 22. The contractor shall determine the compressive strength by approved methods. Cores shall be tested for compressive strength 28 days after placement. For small quantities, 28 day cylinder compressive strength may be used in lieu of core compressive strength.

502.7.10 Weak Longidudinal Joint. The contractor shall indicate in the Quality Control Plan if the longitudinal joint forming device is going to be utilized on the project. To ensure the joint forming device is producing weakness in the finished concrete joint, the contractor shall take 4-inch diameter cores of the longitudinal joint. Cores shall be taken at random locations determined by the engineer and tested the following day after paving. The cores shall be centered within ± ½ inch around the joint forming trail. The first one-third of the slab thickness and the second one-third of the slab thickness of each core shall be sawed off from the top and tested in the vertical position for split tensile strength. The average strength ratio of the first and second cores shall be 1/3 or less.

502.7.10.1 Testing Frequency. On the first day of paving the rate shall be doubled to four cores per day. If satisfactory results are consistently achieved, the engineer may reduce the frequency table rate of cores taken.

502.7.11 General Concrete Requirements. Sec 501 quality control requirements shall apply as modified below.

502.7.11.1 Entrained Air Content. The as placed air content shall be calculated using the as delivered air content measurement and air loss when applicable and used for all requirements. The as placed air content shall be 5.0 percent or greater. The contractor shall halt production and make appropriate adjustments whenever the as-placed air content is between 4.5 and 5.0 percent. Whenever the as delivered air content minus the air loss indicates the as placed air content would be less than 4.5 percent re-dosing shall be required or the entire truck rejected.

502.7.11.2 Aggregate Gradation or Deleterious. When any one gradation or deleterious test is outside the allowable range, the contractor shall take immediate steps to correct the gradation or deleterious content.

502.7.12 Surface Smoothness. See Sec 610 for additional details. Smoothness testing is waived for concrete base.

502.7.13 Surface Texture. The surface texture shall be tested in accordance with ASTM E 965, except as modified herein, to ensure the texture is adequate for desired friction characteristics. The test locations will be the same locations as identified for strength and thickness determination. Testing will be waived if the contractor elects to diamond grind or tine the concrete with a wire comb. Surface texture testing is waived for concrete base.

502.7.13.1 Sample Container. Plastic sample containers for ASTM E 965 testing shall be of a rigid material that will crack or break if the container is deformed. Damaged or deformed containers shall not be used.

502.7.13.2 Required Texture Depth. The results of ASTM E 965 shall show a texture depth of any sublot to have a minimum value of 1.00 mm. Any sublot showing a texture depth of less than 1.00 mm shall require diamond grinding of the pavement represented by this sublot to attain the necessary texture. All testing of the surface texture shall be completed no later than the day following pavement placement.

502.7.14 Opening to Traffic. For early opening traffic prior to 28 days after placement, a single early break cylinder meeting the requirements is acceptable.

502.7.15 Vibration Rate. The contractor shall have a tachometer available at all times for checking the vibration frequency of vibratory equipment. Acceptable vibration rates are a minimum of 4500 impulses per minute.

502.8 Quality Assurance. The engineer or designated representative will be responsible for monitoring the work and quality control efforts of the contractor.

502.8.1 Independent QA Samples. 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. For 28 day cylinder or core compressive strength and thickness results a favorable comparison will be obtained when the engineer's QA test results are within two standard deviations from the mean of the QC's results for that particular lot. For all other independent QA samples, a favorable comparison will be obtained when QA samples meet the same specification criteria as QC.

502.8.2 Split Samples. There are no QA split samples for Sec 502 other than those general concrete requirements of Sec 501.

502.8.3 Material Rendered Unfit. The engineer may at any time reject and require the contractor to dispose of any batch of concrete mixture which is rendered unfit for use due to contamination, segregation, improper slump or improper entrained air content. Such rejection may be based on only visual inspection. In the event of such rejection, the contractor may while in the presence of the engineer, take a representative sample of the rejected material and test it to determine acceptability.

502.8.4 Contractor Responsibility for QA Cores. QA strength and thickness cores that are not in possession of the engineer for the entire time from extraction till testing shall be sealed in tamper proof bags after extraction.**502.9 QC/QA Frequency Table**

<table>
<tr><th colspan="2" rowspan="2">Tested Property</th><th rowspan="2">QC Frequency</th><th colspan="2">QA Frequency</th><th rowspan="2">QC Small Quantity Frequency</th></tr>
<tr><th>Independent Samples</th><th>Split Samples</th></tr>
<tr><td rowspan="2">< 8 Inches</td><td>28 Day Cylinder Compressive Strength</td><td rowspan="2">1 per 7500 Square Yards</td><td rowspan="2">1 per 30000 Square Yards</td><td rowspan="5">-</td><td>1 per Day</td></tr>
<tr><td>Pavement Thickness</td><td>1 per Location</td></tr>
<tr><td rowspan="2">≥ 8 Inches</td><td>Core Thickness</td><td rowspan="2">1 per Sublot</td><td rowspan="2">1 per Lot</td><td>1 per Day</td></tr>
<tr><td>28 Day Core Compressive Strength</td><td>1 per Location</td></tr>
<tr><td colspan="2">Weak Longitudinal Joint</td><td>2 per Day</td><td>1 per Week</td><td>1 per Project</td></tr>
<tr><td colspan="2">General Concrete Requirements</td><td colspan="4">Per Section 501</td></tr>
</table>

Surface Smoothness	Per Section 610			
Surface Texture	1 per Sublot	-	-	1 per Project
Opening to Traffic	1 per Location	1 per Day		1 per Location
Vibration Rate	2 per Day	-		-

502.10 Method of Measurement. Final measurement of the completed pavement will not be made except for authorized changes during construction, or where appreciable errors are found in the contract quantity. Where required, measurement of the Portland cement concrete base and pavement complete in place, will be made to the nearest 1/10 square yard. The revision or correction will be computed and added to or deducted from the contract quantity.

502.11 Basis of Payment.

502.11.1 Compensation. The contract unit price for Portland cement concrete base and pavement will be considered as full compensation for all material, including reinforcement, dowels, dowel supports, tie bars and any other items entering into the construction of the traveled way pavement or Portland cement concrete shoulders, and for the cost of QC testing. No additional compensation will be allowed for any excess thickness.

502.11.2 Payment. The accepted quantities of concrete base will be paid for at the contract unit price with proper allowance made for any deductions for deficiency in thickness and compressive strength. The accepted quantities of Portland cement concrete pavement will be paid for at the contract unit price with proper allowance made for any deductions for deficiency in thickness, compressive strength, smoothness or marred surface.

502.11.3 Width. When paving widths are greater than the travel lane widths, payment for profiling will apply to the traffic lane design driving width only, normally 12 feet. Random lane coring for thickness or required lane replacement will include the full paved lane width to the longitudinal joints or edge of shoulder, whichever is first.

502.11.4 Concrete Adjustment. Each lot of material shall have its contract unit price adjusted based off the pay factor total.

502.11.4.1 Pay Factor Total. The total pay factor (PF_{TOTAL}) for each lot is equal to the weighted sum of the pay factors (PF) for each pay factor item for each lot, and is determined as follows:

$$PF_{TOTAL} = + (0.5) PF_{THICKNESS} + (0.5) PF_{COMPRESSIVE\ STRENGTH}$$

The PF for each pay factor item for each lot is based on the PWL_{TOTAL} of each pay factor item of each lot and is determined as follows:

When $PWL_{LOWER} \geq 70$: $PF = (0.5) PWL_{TOTAL} + 55$
When $PWL_{LOWER} < 70$: $PF = (2.0) PWL_{TOTAL} - 50$

502.11.4.2 Quality Level Analysis. Compressive strength and thickness shall be evaluated for acceptance on a lot-by-lot basis using a Quality Level Analysis (QLA) as defined in Sec 106 and herein. For thickness and compressive strength in this specification, PWL_{UPPER} shall be 100.

502.11.4.3 Lower Specification Limits. The lower specification limit (LSL) for compressive strength and thickness shall be 4,000 psi for compressive strength and plan thickness minus ½ inch for thickness.

502.11.5 Smoothness Adjustment. The contract unit price for concrete pavements will be adjusted in accordance with Sec 601.5. The contract unit prices for concrete pavement will be considered full compensation for the costs of the smoothness testing and correction.

502.11.6 Payment for Material Rendered Unfit. Any material rrendered unfit per Sec 502.8.3 and subsequently proved acceptable by the contractor shall be paid for at the contract unit price.