PART IX -- PORTLAND CEMENT CONCRETE

Section No. **Page No.**

Section 901
Portland Cement Concrete

901.01 GENERAL. This section specifies requirements for portland cement concrete, including methods and equipment for handling and storing materials, and mixing and transporting concrete to the site.

Structural concrete is designated by class and pavement concrete by type.

No concrete shall be mixed, placed or finished when natural light is insufficient, unless an approved artificial lighting system is provided. No concrete shall be placed on a frozen subgrade nor shall frozen aggregates be used in concrete.

Portland cement concrete shall conform to the requirements of Table 901-3, Master Proportion Table for Portland Cement Concrete. It shall be a mixture of portland cement**,** portland-pozzolan cement, or portland blast-furnace slag cement, fine aggregate, coarse aggregate, water and, when specified or allowed, approved admixtures. Fly ash or ground granulated blast furnace slag will be permitted as a partial replacement for portland cement in accordance with Subsection 901.08.

Portland cement concrete shall require a Department approved mix design, be produced from a Department certified plant and be transported in Department certified trucks. The design, control and transportation of concrete mixtures in accordance with these specifications shall be the responsibility of the contractor.

Sufficient plant capacity and transporting apparatus to ensure delivery at the required rate shall be provided. Rate of concrete delivery during concreting operations shall provide for proper handling, placing and finishing of concrete and maintaining a workable surface.

Methods of delivery and handling concrete shall facilitate placing with a minimum of rehandling and without damage to the structure or concrete.

Approved laboratory facilities and testing equipment necessary to sample, test, and control concrete mixtures shall be provided by the contractor. These facilities will not be required for plants producing only minor structure concrete complying with Table 901-3. A laboratory conforming to Section 722 shall be located at an approved location at the plant site. The laboratory shall be for quality assurance purposes.

Quality assurance requirements shall be as specified in the latest edition of the Department's publication entitled "Application of Quality Assurance

Specifications for Portland Cement Concrete Pavement and Structures" or "Application of Quality Assurance Specifications for Precast-Prestressed Concrete Plants."

901.02 MATERIALS. Materials shall comply with the following Subsections:

Portland Cement	1001.01
Portland-Pozzolan Cement	1001.02
Masonry Cement	1001.03
Aggregates	1003.01 & 1003.02
Admixtures	1011.02
Water	1018.01
Fly Ash	1018.15
Portland Blast-Furnace Slag Cement	1001.04
Ground Granulated Blast Furnace Slag	1018.27
Microsilica (Silica Fumes)	1018.28

Cement, fly ash**,** ground granulated blast furnace slag and microsilica shall be certified by the manufacturer in accordance with the Department's current procedures.

The contractor shall keep accurate records of cement, fly ash, ground granulated blast furnace slag, and microsilica deliveries and their use in the work. Copies of these records shall be furnished to the engineer in such form as required.

901.03 TRANSPORTATION AND STORAGE OF CEMENTITIOUS MATERIALS AND MICROSILICA. Cement, fly ash, ground granulated blast furnace slag, and microsilica shall be transported in watertight conveyances and stored in separate approved facilities so that cement, fly ash, ground granulated blast furnace slag, and microsilica will be protected from dampness or water intrusion. Material that is contaminated, is partially set, or contains lumps of caked material will be rejected. When the use of bagged cement, fly ash, ground granulated blast furnace slag or microsilica is permitted, the handling and storage will be as directed.

Different brands or types or the same brand or type from different mills, shall not be mixed or used alternately unless authorized by the DOTD Materials Engineer Administrator. This requirement may be waived in case of plant breakdown during production to allow concrete conforming to the requirements of Subsection 901.01 to be furnished from another plant to finish the placement in progress.

901.04 HANDLING AND STORAGE OF AGGREGATES. Equipment and methods for stockpiling aggregates shall be such that no detrimental degradation or segregation of aggregate will result; no appreciable amount of foreign material will be incorporated into aggregate; and there will be no intermingling of stockpiled materials. Stockpiles of aggregates shall be well drained and shall have uniform moisture content. Material shall not be added to working faces of the stockpiles during continuous operations.

When specified, coarse aggregate shall be separated into two or more sizes to ensure greater uniformity of the concrete mixture. Different grades and types of aggregates shall be stored in separate stockpiles separated by bulkheads or sufficiently separated from each other to prevent material at edges of piles from intermingling. When segregation occurs in the processing and handling of Grade D coarse aggregate, the aggregate shall be separated at the 1-inch (25 mm) sieve into two stockpiles. The stockpiled material shall be reproportioned to meet the gradation requirements of Grade D. Activity that results in contamination or intermingling of aggregates, including overhead handling for the loading of bins or building of stockpiles, will not be permitted.

Aggregates shall be handled from stockpiles or other sources to the batch plant so as to secure uniform grading of material. Aggregates that have become segregated or contaminated shall not be used. Aggregates processed or handled by hydraulic methods, and washed aggregates, shall be stockpiled or placed in bins for adequate drainage. Transport containers will be accepted as an adequate bin when adequate drainage is provided. Drainage of aggregates shall meet the approval of the engineer prior to batching. The engineer may require water sprinkling of coarse aggregates in stockpiles that have dried to the extent that the aggregates absorb mixing water. Such sprinkling shall continue until aggregates are saturated.

901.05 SAMPLING AND TESTING. Sampling and testing will be done in accordance with the Department's Materials Sampling Manual and the Department's Testing Procedures Manuals. The contractor shall furnish necessary materials for testing at no direct pay.

901.06 QUALITY CONTROL OF CONCRETE. The contractor shall be responsible for quality control of materials during handling, proportioning, mixing, and placement operations; for initial determination and necessary subsequent adjustments in proportioning of materials used to produce the specified concrete; and for providing suitable equipment for

determination of aggregate gradation, moisture, air content, slump, unit weight (mass), temperature, and trial mixes as necessary. Testing and analysis of the mix for quality control purposes, the setting of dials, gages, scales or meters, adjusting batch weights, and accurate batching shall be the responsibility of the contractor.

The contractor shall have a Certified Concrete Technician present at the plant or job site to make adjustments in batch weights for moisture content, perform necessary adjustments in proportioning materials to produce the specified concrete, and perform tests necessary for control of the concrete mix within specifications requirements. Daily plant operations shall not begin unless the Certified Concrete Technician is at the plant to determine that gradations, moisture contents, and adjusted batch weights are within specifications limits. If a Certified Concrete Technician is not available at the job site, an Authorized Concrete Field Tester is allowed to perform the job site control tests for slump, air content, and mix temperature and report the results to the Certified Concrete Technician. The use of an Authorized Concrete Field Tester at the job site will not relieve the Certified Concrete Technician from performing the remaining duties as outlined in these specifications.

The contractor's Certified Concrete Technician and Authorized Concrete Field Tester shall be certified or authorized upon satisfactory completion of the Department's requirements.

(a) Mix Design: Mixtures shall produce concrete of suitable workability. Slumps shall be within the ranges shown in Table 901-3 or as specified when tested in accordance with DOTD TR 207. The engineer may authorize an increase in maximum slump, by use of water reducers, for concrete used in the construction of walls and diaphragms less than 8 inches (200 mm) thick, and where the engineer considers necessary provided the water-cement ratio is not exceeded and conventional forms are used.

Concrete mixes shall be formulated to produce concrete which, when molded and cured in accordance with DOTD TR 226 and tested in accordance with DOTD TR 230, shall show an average compressive strength not less than as shown in Table 901-3. Class P, Class P(M) and Class P(X) concrete cylinders for compressive strength tests shall be cured by the same methods used in curing the members they represent.

The contractor's Certified Concrete Technician shall submit a proposed concrete mix design on a form provided by the Department giving the intended sources of materials and the mix design for concrete to be furnished. No work shall be started until the portland cement concrete mix

design has been reviewed and accepted. Review and acceptance of this mix design does not release the contractor from the responsibility of producing concrete that meets the minimum requirements of the specifications.

Proportioning for volume of coarse aggregates in concrete mixes, excluding concrete pipe, Types B and D pavement, and minor structure concrete shall be in accordance with Table 901-1 below. An example of proportioning of coarse aggregate is shown in the Department's publication entitled "Application of Quality Assurance Specifications for Portland Cement Concrete Pavement and Structures".

Table 901-1
Volume of Coarse Aggregate Per Unit of Volume of Concrete

Maximum Size of Aggregate, Inches (mm)	Volume of Dry-Rodded Coarse Aggregate Per Unit Volume of Concrete for Different Fineness Moduli of Fine Aggregate[1]				
	2.20	2.40	2.60	2.80	3.00
3/8 (9.50)	0.52	0.50	0.48	0.46	0.44
1/2 (12.5)	0.61	0.59	0.57	0.55	0.53
3/4 (19.0)	0.68	0.66	0.64	0.62	0.60
1 (25.0)	0.73	0.71	0.69	0.67	0.65
1 1/2 (37.5)	0.77	0.75	0.73	0.71	0.69
2 (50.0)	0.80	0.78	0.76	0.74	0.72
3 (75.0)	0.84	0.82	0.80	0.78	0.76

[1]Volumes are based on aggregates in dry-rodded condition as described in AASHTO T19, Unit Weight of Aggregate. These volumes are selected from empirical relationships to produce concrete with a degree of workability suitable for usual reinforced concrete construction. For less workable concrete such as required for concrete pavement construction, they may be increased up to 10 %. For more workable concrete, as may be required for pumping, they may be reduced up to 10%.

In developing mix designs for portland cement concrete pavement Types B and D, the proportions of the aggregate sizes to be used shall meet the requirements of Subsection 1003.02(c).

Trial mixes are required to demonstrate the mix performance and the compatibility of mix components for the following:

(1) Fly Ash
(2) Ground Granulated Blast Furnace Slag
(3) Microsilica
(4) Heavyweight Concrete
(5) Flexural Strength (when required)
(6) Unusual Materials and Applications

For the above trial mixes the contractor shall submit test results for slump, unit weight (mass), air content, set times, and compressive strength (flexural strength for pavements) at 3, 7, and 28 days. The contractor shall furnish materials to the Department for verification of trial mixes.

When requested by the contractor, the Department will determine gradation, unit weight (mass), specific gravity and absorption factor of the aggregates.

Trial mixes may be waived in writing by the District Laboratory Engineer for previously accepted mix designs.

The minimum cement factors may be waived in writing by the District Laboratory Engineer provided the contractor's mix design meets the average compressive strengths in Table 901-3 plus the over-design compressive strengths in Table 901-4.

(b) Quality Control Tests: The contractor shall be responsible for determining gradation and moisture content of fine and coarse aggregates used in the concrete mixture and for testing the mixture at the job site for slump, unit weight (mass), temperature, and air content (when used). The contractor shall conduct operations to produce a mix complying with the reviewed and accepted mix design, except that variations will be permitted within specified control limits for individual samples. Test results for gradation, slump, unit weight (mass), and air content shall be plotted on control charts for individual samples. These control charts shall be submitted to the engineer.

Times at which to obtain control test samples shall be set by the contractor using random number tables in accordance with DOTD S 605 or by random selection. Gradation control limits of aggregates shall be as shown in Subsection 1003.02. When required, additional test samples shall be taken as directed for slump, concrete temperature, and air content.

The minimum number of quality control tests to be performed by the contractor for structural and pavement concrete shall be in accordance with the Materials Sampling Manual. For minor structure concrete only, the contractor will not be required to have a Certified Concrete Technician or Authorized Concrete Field Tester, but shall implement a quality control testing program to ensure that the concrete meets the requirements of these specifications.

When producing concrete for Types B and D pavements, gradations shall be determined daily on each stockpile of aggregate to be used. All gradation calculations shall be based on percent of dry weight (mass). Upon determination of the gradation of each stockpile, the percent of the total aggregates retained shall be determined mathematically based on the

proportions of the combined aggregate blend, and checked for conformance with Table 1003-1A.

(c) Mix Adjustments: With prior notification given to the engineer, the contractor may adjust the ratio of fine to coarse aggregate as reviewed and accepted, by no more than 5 percent. In no case shall it be adjusted so as to materially affect the volume of concrete. If the proportions of the aggregate sizes used do not satisfy the gradation requirements of Subsection 1003.02(c) due to changes in the gradation of one or more stockpiles, the proportions shall be adjusted to bring the combined aggregates back within specification limits. These minor adjustments for gradation will not require a new mix design. The mix produced shall be uniform, workable and within the specification limits of Table 901-3. When plant operations do not produce a uniform and workable mix, plant operations shall cease and corrective action shall be taken prior to restart.

When tendency of individual slump, air content, concrete temperature, or gradation measurements, as plotted on control charts, indicates that the mix is not uniform and may fall outside tolerance limits, the contractor shall immediately make adjustments to keep the mix within specified limits. If the contractor fails to make proper adjustments and the mix deviates from specification requirements or if the mix is obviously defective, the mix will be rejected.

For workability properties only, changes in mix proportions will be permitted provided the water-cement ratio is not exceeded, minimum cement factor is maintained, proper batch adjustments are made, and prior notification is given to the engineer.

No changes in source of materials or percentage of cement, fly ash, ground granulated blast furnace slag, or microsilica shall be made until a new Mix Design form showing the new material or adjusted proportions has been submitted by the contractor and approved.

(d) Acceptance and Verification for Types B and D Pavements: Sampling and testing for acceptance and verification for concrete for Types B and D pavements shall be in accordance with the provisions of the Materials Sampling Manual, except as follows:

(1) Gradation testing for acceptance will not be required.

(2) Verification tests will be performed by the District Laboratory to assure conformance to the gradation of the total combined aggregates shown in Table 1003-1A at the frequency of one sample per aggregate size per lot, with a maximum of one sample per aggregate size per day. Samples are to be obtained from the aggregate feed (conveyor) belt as

described in the Materials Sampling Manual, DOTD Designation S101, Aggregates and Aggregate Mixtures.

(3) Upon determination of the gradation of each aggregate size sampled, the percent retained based on the dry weight (mass) of the total combined aggregates will be determined mathematically based on the proportions of the combined aggregate blend, and checked for conformance with Table 1003-1A.

(4) If the results of the verification sample indicate that the combination of aggregates being used does not meet the requirements of Subsection 1003.02(c), the aggregates shall be re-sampled and tested again. If the results of the second verification sample indicate that the combination of aggregates being used does not meet the requirements of Subsection 1003.02(c), the contractor will be notified and required to make adjustments to his operations to produce a mix meeting these specifications. No concrete from this plant shall be placed on DOTD projects until the adjustments are made and approved by the District Laboratory Engineer. An additional verification sample may be required prior to resuming operations.

901.07 SUBSTITUTIONS. Mixtures may be substituted with approval in accordance with Table 901-2.

Table 901-2
Portland Cement Concrete Mixture Substitutions

Structural Class[1]	Substitute
AA (M)	No Substitutions
AA	AA(M)
A(M)	AA(M), AA
A	AA(M), AA, A(M)
D	No Substitutions
F	No Substitutions
P(X)	No Substitutions
P(M)	No Substitutions
P	P(M)
S	No Substitutions
Minor Structure Class[1]	
M	AA(M), AA, A(M), A, B
R	AA(M), AA, A(M), A, B, M
Y	No Substitutions
Pavement Type[1, 2]	
B	D
D	B
E	No Substitutions

[1]The mixture being substituted shall meet the requirements of Table 901-3 and the mix design for its class or type. The compressive strength of the substituted mix shall meet the strength requirements of the original mixture specified.

[2]When justified in writing and approved by the engineer, small irregular areas of paving projects using Types B or D concrete may be substituted with Class A concrete.

901.08 COMPOSITION OF CONCRETE. Type of cement and composition of concrete shall be in accordance with the requirements of this subsection and Table 901-3.

(a) Cement: Allowable types of cement are as follows:

Use	Allowable Cement Types
General Construction (Structural Class Concrete and Minor Structure Class Concrete)	Type I or II portland cement; Type IP portland-pozzolan cement; Type IS portland blast-furnace slag cement
Concrete Pavement	Type I or II portland cement; Type IP portland-pozzolan cement; Type IS portland blast-furnace slag cement
Prestressed or Precast Concrete	Type I, II or III portland cement; Type IP portland-pozzolan cement; Type IS portland blast-furnace slag cement

For concrete placements having a least dimension of 48 inches (1200 mm) or greater or if designated on the plans or the project specifications as being mass concrete, the allowable cement type shall be Type II portland cement, Type IP portland-pozzolan cement, or Type IS portland blast-furnace slag cement. The cement, or combination of cement and fly ash or ground granulated blast furnace slag, shall be certified to generate a heat of hydration of not more than 70 calories/gram (290 kJ/kg) at 7 days.

Due to the gradation of aggregate or other conditions, additional cement may be required to achieve minimum compressive strength.

When using only Types I or II portland cement in concrete mixes, fly ash conforming to Subsection 1018.15 or grades 100 or 120 ground granulated blast-furnace slag conforming to Subsection 1018.27 may be partially substituted for portland cement on a pound (kilogram) for pound (kilogram) basis. The contractor may use a maximum of 25 percent fly ash by weight (mass) of cement for concrete pipe, up to 20 percent fly ash by weight (mass) of cement for other minor structures and concrete pavement, and up to 15 percent fly ash by weight (mass) of cement for structural concrete. In lieu of fly ash, the contractor may use grade 100 or grade 120 ground granulated blast-furnace slag up to 50 percent by weight (mass) of cement. The combination of slag and fly ash will not be allowed as a partial substitution for cement.

(b) Chemical Admixtures: An air-entraining admixture will be required in paving concrete when placed by slip-form methods or when a central mixing plant or non-agitating haul trucks are used.

Air-entraining and water-reducing admixtures will be required in Class AA, F or AA(M) concrete. When an air-entraining admixture is used, the total air content of the concrete mix shall be tested in accordance with DOTD TR 202, and shall be as specified in Table 901-3.

A water-reducing admixture will be required for mass concrete.

When the ambient air temperature is 70°F (20°C) or below, the water-reducing admixture shall be the normal-set type. When the ambient air temperature is above 70°F (20°C) and below 85°F (30°C), the water-reducing admixture may be either the normal-set type or the set-retarding type. When the ambient air temperature is 85°F (30°C) or above, the water-reducing admixture shall be the set-retarding type, except for concrete containing fly ash or ground granulated blast furnace slag where this choice is optional. Set-retarding admixtures shall be used in an amount sufficient to produce the necessary retardation; however, the amount used shall not be less than is necessary to comply with Subsection 1011.02.

The contractor shall consider the influence of different materials and job conditions, including local weather on setting characteristics. With approval of the mix design, the contractor may use approved admixtures other than as stated above in order to control setting characteristics.

Admixtures shall comply with Subsection 1011.02 and be listed on QPL 58.

Water contents for superplasticized concrete mixes shall not be reduced to levels that will restrict cement hydration. The amount of water in the superplasticizer shall be included as a part of required mixing water. The dosage of superplasticizer may be adjusted depending on the consistency of the mix.

Final slump of superplasticized concrete shall be appropriate for its application. It shall not exhibit excessive bleeding or segregation of aggregates as determined by the project engineer.

The method of adding and mixing the superplasticizer to the mix shall be as recommended by the manufacturer.

When multiple admixtures are used, the admixtures shall be manufactured by the same company and shall be compatible.

The use of admixtures in other classes or types of concrete will be optional with the contractor with written approval.

(c) Water: The total amount of water in the mixture, including admixtures and free water, shall not exceed the maximum water-cement ratio specified in Table 901-3. Free water shall include all water entering the mix with the aggregates, except water absorbed by the aggregate.

Because of the absorptive nature of lightweight aggregate and the inability to obtain a true saturated surface dry condition for determining free moisture, a maximum amount of water cannot be specified for Class Y concrete. The slump requirement of Table 901-3 or as specified will be the governing factor in determining maximum allowable water.

(d) Aggregate: All aggregates for use in portland cement concrete shall meet the requirements of Subsection 1003.01.

(1) Coarse Aggregate: Coarse aggregate, except for gradations for Types B and D pavements, shall be the grade specified in Table 901-3 and shall comply with the requirements of Subsection 1003.02(b).

(2) Fine Aggregate: Fine aggregate, except for gradations for Types B and D pavements, shall comply with the requirements of Subsection 1003.02(a).

(3) Aggregates for Types B and D Pavements: Aggregates shall comply with the requirements of Subsection 1003.02(c).

901.09 EQUIPMENT.

(a) General: Sufficient plant capacity and transporting equipment to ensure delivery at the required rate shall be provided. Rate of concrete delivery during concreting operations shall provide for proper handling, placing and finishing of concrete and maintain a workable surface. Methods of delivering and handling concrete shall facilitate placing with a minimum of rehandling and without damage to the structure or concrete.

(b) Plant Equipment: Batch plants shall include approved storage, weigh hoppers, and measuring devices. Equipment shall be properly sealed and vented to minimize dusting and loss of material.

Materials shall be incorporated into the mix by methods that will ensure uniform distribution. The amount of each material used in the mix shall be recorded and certified by the contractor's authorized representative.

The plant shall be equipped with adequate water storage and a device for automatically controlling the amount of water used in each batch.

For plants using direct-fill elevating weigh hoppers, computer controlled indicator lights may be used as an indication of aggregate weights but shall not be the sole means of control for aggregate proportioning. Means of control shall be provided so that, as the quantity desired in the weigh hopper is approached, material may be added slowly and shut off with precision. Weigh hoppers shall be constructed as to eliminate accumulation of materials and to discharge completely. Suitable provisions shall be made for removal of overload from the hopper by the operator. Approved radio communication shall be provided between the concrete batcher and front-end loader operator. Actual weights of material batched each time shall be entered on the Batch Certification Form. The plant shall demonstrate satisfactory performance by producing consistent concrete with adequate compressive strengths.

(1) Storage Bins and Silos: For plants with overhead storage bins, which feed directly into the weigh hopper, or storage bins with belt feed to the weigh hopper, the bins shall have adequate separate compartments for fine aggregate and each size of coarse aggregate. Each compartment shall be designed to discharge efficiently and freely into the weigh hopper. Means of control shall be provided so that, as the quantity desired in the weigh hopper is approached, material shall be added slowly and shut off with precision.

Silos shall be weatherproof, sealed, free of holes, and shall prevent contamination. Silos shall be designed to freely discharge and shall be equipped with vibrators to maintain flow of material and prevent accumulation. Silos shall be designed with sufficient capacity for the

operation. Silos shall be provided with a positive means of shut off without leaking into the weigh hopper. A separate silo shall be used for each dry bulk material added to the mix. If a silo is divided into compartments for cement, fly ash, ground granulated blast furnace slag and microsilica, a positive means of separation shall be provided.

(2) Measuring Devices: Materials shall be measured by weighing except where other methods are authorized.

Batch plants may be equipped to proportion materials by approved automatic weighing devices. Moisture probes can be used to determine the moisture content of aggregates for batch adjustment provided the accuracy is confirmed by the engineer to be within 0.5 percent of the results obtained by the Certified Concrete Technician in accordance with DOTD TR 106.

Fine aggregate and each size of coarse aggregate from separate bins shall be weighed either separately or cumulatively on scales in the weigh hopper. The allowable quantities of bulk fly ash, bulk ground granulated blast furnace slag, or bulk microsilica may be weighed cumulatively in the same hopper with the cement, provided the cement is weighed first and the scale system is separate from that used for the aggregates.

Weigh hoppers shall be constructed to eliminate accumulation of materials and to discharge completely. Suitable provisions shall be made for removal of an overload from the hopper by the operator.

Scales shall be accurate to 0.5 percent throughout the range of use. Maximum graduation on scales shall be 0.1 percent of the rated scale capacity. When beam type scales are used, poises shall be designed to be locked in any position to prevent accidental change of position, and the weigh beam and a telltale device shall be in view of the operator. Plant and laboratory measuring devices shall be subject to approval and shall be tested, inspected, and certified by a qualified independent scale service or the Weights and Measures Division of the Louisiana Department of Agriculture and Forestry at no cost to the Department every 90 calendar days, and more often when the engineer deems it necessary to assure their accuracy.

Individual aggregates shall be batched within 2 percent, and the total weight (mass) of aggregate shall be within 1 percent of the required weight (mass).

Cement, fly ash, ground granulated blast furnace slag, and microsilica shall be within 1 percent of the required weight (mass). Cement in standard bags need not be weighed; however, when used, they shall be used in full bag increments and the quantities of other materials shall be

adjusted accordingly. Bagged fly ash and bagged ground granulated blast furnace slag will not be allowed.

Mixing water shall be measured by volume or weight (mass). Water measuring devices shall be accurate to 1 percent at 1/2 the maximum allowable water per batch and the maximum graduation shall be 1 gallon (4 L).

Approved methods and equipment for adding air-entraining admixtures or other admixtures into the batch shall be used. The quantity of admixtures shall be measured into the mixer with an accuracy of 3 percent. Admixtures shall be mechanically dispensed in a liquid state with the mixing water. A separate dispensing device shall be provided for each admixture.

(3) Ticket Printer System: Certified concrete plants may be equipped with an approved automatic ticket printer system for recording required batching information. When an automatic ticket printer system is not used, quantities and batching information shall be determined by visual observation, recorded, and certified correct by the contractor's authorized representative.

The approved ticket printer system shall be tamper-proof and shall print time of batching, amount of water, batch weights, moisture content of aggregates, and quantities of admixtures. The Certified Concrete Technician may add moisture content of aggregates or quantities of admixtures to the printed ticket when the automatic system does not have these capabilities. During a breakdown, quantities shall be determined by visual observation and certified as stated above.

All records of batches shall show batch number, day, month, year, and time of day to the nearest minute for each batch. The maximum quantity of water that can be added at the jobsite shall be shown on the batch ticket. The engineer shall be provided with a legible copy of all batch records identified with lot number and mix design number.

(c) Hauling Equipment: Hauling equipment shall be watertight and shall be capable of discharging concrete at a satisfactorily controlled rate without segregation.

(1) Truck Mixer: Truck mixers shall be the revolving drum type, equipped with pressurized, calibrated tanks for carrying a portion of the mixing water.

Pick-up and throw-over blades in the mixing drum shall be replaced when worn beyond the limit recommended by the manufacturer. The contractor shall have available a copy of the manufacturer's design,

showing dimensions and arrangements of blades in reference to original height and depth.

Only the prescribed and verifiable amount of water is permitted in the tank unless the tank is equipped with a device by which the quantity of water added can be readily verified.

Truck mixers shall be equipped with electrically or mechanically actuated revolution counters, which display the number of revolutions. Counters shall be located to provide safe and convenient inspection.

Each truck mixer shall have attached thereto in a prominent place a metal plate on which is plainly marked the uses for which the equipment is designed, the maximum rated capacity of the drum in terms of concrete volume and rotation speed for both agitating and mixing speeds.

Truck mixers shall be equipped with means for accurately measuring the amount of water used in each batch.

(2) Agitator Hauling Equipment: Agitators shall be supplied with adequate mixing blades or paddles to agitate the mix and prevent segregation. Covers shall be provided when directed.

Each agitator shall have attached thereto in a prominent place a metal plate on which is plainly marked the uses for which the equipment is designed, the maximum rated capacity in terms of concrete volume, and agitation speed.

(3) Non-Agitator Hauling Equipment: The bodies of nonagitating hauling equipment shall be smooth, metal, and mortar tight containers. Covers shall be provided when directed.

(d) Portable Mixers: Portable mixers shall have a minimum capacity of one cubic yard (cu m) and shall be capable of uniformly mixing and discharging concrete without segregation.

901.10 BATCHING AND MIXING.

(a) General: Concrete shall be thoroughly mixed in a mixer of an approved size and type, which will ensure uniform distribution of materials through the mass.

Pick-up and throw-over blades or mixing paddles in the mixing drum or mixing unit shall be replaced when worn beyond the limit recommended by the manufacturer. The contractor shall have available a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth.

Mixing operations shall begin within 30 minutes after addition of cement to the aggregates. When cement is charged into a mixer drum containing surface-wet aggregate and the ambient temperature is above

90°F (32°C), or when high early strength cement is used, this limit shall be reduced to 15 minutes. When there is an interruption to the mixing operations, the mixer shall be thoroughly cleaned. The entire contents of the mixer shall be removed from the drum before materials for a succeeding batch are placed therein. Materials composing a batch shall be deposited simultaneously in an operating mixer. A portion of mixing water shall enter in advance of cement and aggregates. No mixer having a rated capacity of less than one cubic yard (cu m) shall be used nor shall a mixer be charged in excess of its rated capacity. The minimum size batch shall be one cubic yard (cu m). Mixers with worn blades or excessive build-up will be rejected. Concrete exposed to salt water or a corrosive environment shall be mixed for 2 minutes and the water content of the mixture shall be carefully controlled.

(b) Central Plant and Site Mixing: Concrete shall be mixed for at least 50 seconds. Mixing time shall begin after all materials, including water, are in the mixer. Mixing time ends when the discharge chute opens. The mixer shall be equipped with an approved timing device, which will automatically lock the discharge lever when the drum has been charged and release it at the end of the mixing period. During mixing, the mixer shall be operated at a drum speed for which it has been designed as shown on the manufacturer's name plate on the mixer.

(c) Truck Mixing: Aggregates, cement, fly ash, ground granulated blast furnace slag and microsilica for concrete shall be measured in accordance with Subsection 901.09 and charged into the drum at the proportioning plant.

Size of batch in truck mixers shall not exceed the maximum rated mixing capacity of the mixer as stated by the manufacturer and stamped on a metal plate on the mixer. When a truck mixer is used for complete mixing, each batch shall be mixed for not less than 70 nor more than 130 revolutions of the mixer drum at the rate of rotation designated as the mixing speed by the equipment manufacturer on the metal plate on the mixer. Any additional mixing shall be at the speed designated by the equipment manufacturer as the agitating speed. All materials, including mixing water, shall be in the mixer drum before actuating the revolution counter or taking an initial reading.

When the prescribed amount of water is added at the batch plant and slump is on the low side at the jobsite it will be permissible to add a minimum of 75 percent of the mixing water at the time cement and aggregates are added at the batch plant and the remaining mixing water at the job site prior to discharging concrete into forms. Water added at the

job site may be added in 1 or 2 increments with additional mixing within the range of 20 to 30 revolutions at designated mixer speed for each increment; however, the total of 130 revolutions shall not be exceeded. Water added at the jobsite shall not cause the maximum allowable water-cement ratio or slump of the batch to be exceeded.

If water or superplasticizer is allowed to be added to a partial load, only a proportional amount will be added. The method of adding and mixing superplasticizer to the mix shall be in accordance with the manufacturer's recommendation. When the slump is more than the maximum specification limit, the batch will be rejected; additional mixing or agitation to reduce the slump will not be allowed even though the maximum time limit or number of revolutions have not been exceeded.

Slump tests, unit weight (mass), acceptance cylinders, and temperature measurements will not be made until all mixing water has been added to the batch.

(d) Partial Mixing at Central Plant: When partial mixing is allowed at a central plant, the mixing time at the central plant may be reduced to 30 seconds. Additional required mixing shall be completed in a truck mixer at mixing speed. Mixing time in the truck mixer shall be a minimum of 10 and a maximum of 70 revolutions.

(e) Time Limitations: The maximum allowable time from the addition of cement to the mix to complete discharge of the concrete shall be 90 minutes or a maximum of 300 revolutions, whichever may occur first. When transport is by non-agitator truck, the maximum allowable time from the addition of cement to the mix to complete discharge of the concrete shall be 45 minutes. In hot weather or any other conditions contributing to rapid loss of plasticity or uniformity of concrete, maximum allowable time may be reduced by the engineer.

(f) Hauling Equipment: Wet batches of concrete may be transported in a truck mixer, agitator or other approved equipment. Non-agitator trucks will not be allowed for structural concrete, but will be permitted for pavement concrete when air-entrainment admixture is used. Maximum volume of mixed concrete transported in an agitator truck at agitation speed shall be in accordance with the manufacturer's specified rating.

(g) Portable Mixing: Portable mixers shall be approved in writing for mixing one cubic yard (cu m) of concrete or less per day for minor structure concrete.

(h) Delivery: Sufficient plant capacity and transporting apparatus to insure delivery at the required rate shall be provided. Rate of concrete

delivery during concreting operations shall be such as to provide for proper handling, placing and finishing of concrete and maintain a workable surface. Methods of delivering and handling concrete shall be such as will facilitate placing with a minimum of handling and without damage to the structure or concrete.

901.11 TEMPERATURE LIMITATIONS.

(a) General: Air temperature and mix temperature shall be determined at the point of placement in the shade away from artificial heat.

(b) Hot Weather Limitations: Hot weather limitations shall apply to concrete for:

(1) Bridge Decks, Approach Slabs, and Mass Concrete: Hot weather concreting practices will be required when the job site temperature in the shade and away from artificial heat is 80°F (27°C) and rising. When internal temperature of plastic concrete reaches 85°F (30°C), the contractor shall prevent the temperature of succeeding batches from going beyond 90°F (32°C) by approved methods. If necessary, forms shall be precooled by approved methods immediately prior to concrete placement.

(2) Pavement Concrete: Internal temperature of the plastic concrete shall not exceed 95°F (35°C) at the time of placement.

(c) Cold Weather Limitations: Mixing and concreting operations for concrete mixes not containing ground granulated blast-furnace slag or Type IS cement shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 40°F (5°C), and shall not be resumed until an ascending air temperature in the shade and away from artificial heat reaches 35°F (2°C) provided the high temperature forecasted by the U.S. Weather Service is above 40°F (5°C). For concrete mixes containing ground granulated blast-furnace slag or Type IS cement, operations shall be discontinued at a descending air temperature in the shade and away from artificial heat of 55°F (13°C) and can resume at a temperature of 50°F (10°C) and rising provided the high temperature forecasted by the U.S. Weather Service is above 55°F (13°C). Production shall not begin until the temperature at the point of placement is within the above limitations. Concrete shall not be placed if the U.S. Weather Service forecasts the temperature to be less than 35°F (2°C) within the 24 hour period following placement unless authorized in writing.

When concrete placement at lower air temperatures is authorized in writing, aggregates may be heated by either steam or dry heat prior to being placed in the mixer. The apparatus used shall heat the mass

uniformly and shall be arranged to prevent occurrence of overheated areas. If the air temperature is less than 35°F (2°C) at the time of placing concrete, the engineer may require water or aggregates to be heated to not less than 70°F (20°C) nor more than 150°F (65°C). After placement, the concrete shall be protected by additional covering, insulating materials, or other methods approved by the engineer.

901.12 ACCEPTANCE AND PAYMENT SCHEDULE. Acceptance and payment schedules in Table 901-5 will apply to all cast-in-place structural portland cement concrete. Acceptance and payment schedules in Table 901-6 will apply to all minor structure portland cement concrete. Acceptance and payment schedules for portland cement concrete pavement are shown in Table 601-1 of Section 601. These schedules do not apply to precast concrete.

Table 901-3
Master Proportion Table for Portland Cement Concrete

	Average Compressive Strength, psi (MPa) at 28 days	Grade of Coarse Aggregate	Min. Cement, lb/yd^3 (kg/m^3) of Concrete [9,14]	Maximum Water/Cement ratio, lb/lb (kg/kg) [1,9]	Total Air Content (Percent by volume) [4]	Slump Range [10], inches (mm)		
						Non-Vibrated	Vibrated	Slip Form Paving [2]
Structural Class [11]								
AA(M)	4400 (30.4)	A, P	560 (332)	0.44	5±1	2-5 (50-125)	2-4 (50-100)	N.A.
AA	4200 (29.0)	A, P	560 (332)	0.44	5±1	2-5 (50-125)	2-4 (50-100)	N.A.
A(M)	4400 (30.4)	A, P	510 (302)	0.53	5±2	2-5 (50-125)	2-4 (50-100)	N.A.
A	3800 (26.2)	A, F [8], P	510 (302)	0.53	5±2	2-5 (50-125)	2-4 (50-100)	1-2.5 (25-65)
D	3300 (22.8)	A, B, D, P	420 (249)	0.58	5±2	2-5 (50-125)	1-3 (25-75)	N.A.
F	3400 (23.5)[5]	A,P	460 (273)	0.44	5±1	2-5 (50-125)	2-4 (50-100)	N.A.
P(X)	7500 (51.7)[5]	A, F [8], P	700 (415)	0.40	5±2	N.A.	2-10 (50-250)	N.A.
P(M)	6000 (41.4)[5]	A, F [8], P	600 (356)	0.44	5±2	N.A.	2-6 (50-150)[7]	N.A.
P	5000 (34.5)[5]	A, F [8], P	560 (332)	0.44	5±2	N.A.	2-6 (50-150)[7]	N.A.
S	3800 (26.2)	A,P	650 (385)	0.53	5±2	6-8 (150-200)	N.A.	N.A.
Minor Structure Class [11]								
M	3000 (20.7)	A, B, P	470 (279)	0.56	5±2	2-5 (50-125)	2-4 (50-100)	1-2.5 (25-65)
R	1800 (12.4)	A, B, D, P	370 (219)	0.70	5±2	2-5 (50-125)	2-4 (50-100)	N.A.
Y	3000 (20.7)	Y	560 (332)	-[3]	6-9	N.A.	1-3 (25-75)	N.A.
Pavement Type [11]								
B	4000 (27.6)[6]	N/A[13]	475 (282)	0.53	5±2	N.A.	2-4 (50-100)	1-2.5 (25-65)
D	4000 (27.6)[6]	N/A[13]	450 (267)	0.53	5±2	N.A.	2-4 (50-100)	1-2.5 (25-65)
E	4000 (27.6)[6]	A, F[12], P	600 (356)	0.40	5±2	N.A.	2-4 (50-100)	1-2.5 (25-65)

N.A. – Not Applicable

[1] Except for Class AA, AA(M), or F concrete, the maximum volume of water; gal. (L), shall be reduced 5 percent when a water-reducing admixture is used, and 10 percent when an air-entraining admixture, or air-entraining and water-reducing admixtures, is used. When the coarse aggregate portion of the mix is 100 percent crushed aggregate, the water may be increased by 5 percent provided the maximum water listed in Table 901-3 is not exceeded.

[2] Also slump range for other concrete placed by extrusion methods.

[3] Refer to Subsection 901.08(c).

[4] Total air content ranges when air-entrainment is allowed or specified. Air content shall be designed at midrange. See Subsection 901.08(b).

[5] Values shown represent the minimum compressive strengths allowed.

[6] Average compressive strengths for Pavement Type concrete shall be 3600 psi (25.0 MPa) when air-entrainment is used.

[7] No more than a 2 inch (50 mm) slump differential for any design pour.

[8] Grade F coarse aggregate shall be used only when specified or permitted. The minimum cement content shall be increased when this aggregate is used.

[9] For mixes including partial replacement of cement with fly ash or ground granulated blast furnace slag, the minimum cement and maximum water contents shown apply to the total cement and fly ash or ground granulated blast furnace slag content of the mix. Additional cement may be required to achieve minimum compressive strength.

[10] When a slump range is specified in other sections, that range shall govern.

[11] See Subsection 901.08(a) for allowable types of cement.

[12] For use in partial depth patching.

[13] Aggregate grading shall comply with the requirements of Subsection 1003.02(c).

[14] The minimum cement factors may be waived in writing by the District Laboratory Engineer in accordance with Subsection 901.06(a).

Table 901-4
Over-Design to Meet Compressive Strength Requirements[1]

Number[2,3,5] of Tests	Standard Deviation, psi (MPa)[4]				
	300 (2.1)	400 (2.8)	500 (3.4)	600 (4.1)	700 (4.8)
	Additional Compressive Strength, psi (MPa)				
15-19	470 (3.2)	620 (4.3)	850 (5.9)	1,120 (7.7)	1,390 (9.6)
20-29	430 (3.0)	580 (4.0)	760 (5.2)	1,010 (7.0)	1,260 (8.7)
30 or More	400 (2.8)	530 (3.7)	670 (4.6)	900 (6.2)	1,130 (7.8)

[1]When designing the mix, add the tabulated amounts to the average compressive strength at 28 days shown in Table 901-3.
[2]Number of tests of a concrete mixture used to estimate the standard deviation of a concrete production facility. Test of another mix within 1,000 psi (6.9 MPa) of the specified strength may be used.
[3]If less than 15 prior tests are available the over-design should be 1,000 psi (6.9 MPa) for specified strength less than 3,000 psi (20.7 MPa), 1,200 psi (8.3 MPa) for specified strengths from 3,000 to 5,000 psi (20.7 to 34.5 MPa) and 1,400 psi (9.7 MPa) for specified strengths greater than 5,000 psi (34.5 MPa).
[4]Interpolation between standard deviations is required.
[5]A strength test result is defined as the average strength of all specimens of the same age, fabricated from a sample taken from a single batch of concrete. A strength test cannot be based on only one cylinder; a minimum of two cylinders is required for each test.

Table 901-5E
Acceptance and Payment Schedules
Cast-In-Place Structural Concrete

Average Compressive Strength per Lot, psi (28 to 31 days)					
Class A or S	Class AA	Class A(M) or AA(M)	Class D	Class F	Percent of Contract Price[1]
3800 & above	4200 & above	4400 & above	3300 & above	3400 & above	100
3400-3799	3800-4199	4200-4399	3000-3299	---	98
3000-3399	3500-3799	4000-4199	2500-2999	---	90
below 3000	Below 3500	below 4000	below 2500	below 3400	50 or remove and replace[2]

Table 901-5M
Acceptance and Payment Schedules
Cast-In-Place Structural Concrete

Average Compressive Strength per Lot, MPa (28 to 31 days)					
Class A or S	Class AA	Class A(M) or AA(M)	Class D	Class F	Percent of Contract Price[1]
26.2 & above	29.0 & above	30.4 & above	22.8 & above	23.5 & above	100
23.5- 26.1	26.2-28.9	29,0-30.3	20.7-22.7	---	98
20.7-23.4	24.1-26.1	27.6-28.9	17.2-20.6	---	90
Below 20.7	below 24.1	below 27.6	below 17.2	below 23.5	50 or remove and replace[2]

[1]When concrete is part of an item or not a direct pay item, lot sizes, sampling and acceptance testing for the required quantities will be in accordance with Subsection 805.18. The value for each cubic yard (cu m) required will be assessed at $350 ($460) for the purpose of applying payment adjustment percentages. The amount of payment adjustment for the quantity of concrete involved will be deducted from payment.

Acceptance and payment schedules shall apply to the contract item itself for cast-in-place piling.

[2]When the average compressive strength of **any batch in a lot** is less than 4000 psi (27.6 MPa) for Class A(M) or AA(M), less than 3500 psi (24.1 MPa) for Class AA, less than 3000 psi (20.7 MPa) for Class A or S, less than 2500 psi (17.2 MPa) for Class D, or less than 3400 psi (23.5 MPa) for Class F, an investigation will be made. If concrete is allowed to remain in place, payment will be based on the average compressive strength for the lot. If concrete is not allowed to remain in place, the identifiable deficient areas shall be removed and replaced at no direct pay.

When the average compressive strength for a **lot** is less than 4000 psi (27.6 MPa) for Class A(M) or AA(M), less than 3500 psi (24.1 MPa) for Class AA, less than 3000 psi (20.7 MPa) for Class A or S, less than 2500 psi (17.2 MPa) for Class D, or less than 3400 psi (23.5 MPa) for Class F, an investigation will be made. If concrete is allowed to remain in place, payment for the lot will be based on 50 percent of the contract price.

Any cores obtained in these investigations will be used for evaluation purposes only and payment will be based on original acceptance samples.

Table 901-6E
Acceptance and Payment Schedules
Cast-In-Place Minor Structure Concrete

Average Compressive Strength, psi (28 to 31 days)		
Class M or Y	Class R	Percent of Contract Price [1]
3000 & Above Below 3000	1800 & Above Below 1800	100 50 or Remove [2]

Table 901-6M
Acceptance and Payment Schedules
Cast-In-Place Minor Structure Concrete

Average Compressive Strength, MPa (28 to 31 days)		
Class M or Y	Class R	Percent of Contract Price [1]
20.7 & Above Below 20.7	12.4 & Above Below 12.4	100 50 or Remove [2]

[1]When concrete is part of an item or not a direct pay item, sampling and acceptance testing for the required quantities shall be in accordance with this section. The value for each cubic yard (cu m) of concrete required will be assessed at $350 ($460) for the purpose of applying payment adjustment percentages. The amount of payment adjustment for the quantity of concrete involved will be deducted from payment.

[2]When the average compressive strength is less than 3,000 psi (20.7 MPa) for Class M or Y, and 1,800 psi (12.4 MPa) for Class R, an investigation will be made. If concrete is allowed to remain in place, payment will be based on 50 percent of the contract price.

Any cores obtained in these investigations will be used for evaluation purposes only. Payment will be based on original acceptance samples.